Winter 2001

Estimating the environmental costs of the hydro fuel cycle using life cycle assessment techniques and economic valuation

Benjamin Harwood Ellis
University of New Hampshire, Durham

Recommended Citation

Ellis, Benjamin Harwood, "Estimating the environmental costs of the hydro fuel cycle using life cycle assessment techniques and economic valuation" (2001). *Doctoral Dissertations*. 50.
https://scholars.unh.edu/dissertation/50

ESTIMATING THE ENVIRONMENTAL COSTS OF THE HYDRO FUEL CYCLE USING LIFE CYCLE ASSESSMENT TECHNIQUES AND ECONOMIC VALUATION

BY

BENJAMIN ELLIS
Bachelor of Science, Lewis and Clark College, 1990
Masters of Business Administration, University of New Hampshire, 1997

DISSERTATION

Submitted to the University of New Hampshire
in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy
In
Natural Resources

December, 2001

UMI Number: 3030601

UMI®

UMI Microform 3030601

Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

This dissertation has been examined and approved.

RW England

Dissertation Director, Richard W. England, Professor of Economics and Natural Resources.

John D. Aber, Professor of Natural Resources and Earth, Oceans and Space, and Complex Systems Research Center.

Michael J. Merenda

Michael J. Merenda, Professor of Strategic Management.

Gregory Norris, Adjunct Research Professor of Complex Systems Research Center.

Greg Theyel

Gregory Theyel, Assistant Professor of Strategic Management, California State University.

12/12/2001

Date

ACKNOWLEDGMENT

I am sincerely grateful to Professor Richard England for his sustained support throughout my long stay at UNH. Professor England has been a valuable source of knowledge and an important mentor ever since I took his Ecological Economics course, and his patience and direction as thesis advisor were critical to the completion of this project. Professor England is an inspirational educator, and I am fortunate to have been his student.

I am indebted to Dr. Greg Norris at Sylvatica, who developed and donated the LCNetBase software and provided ongoing technical and moral support for this thesis. I am impressed by Dr. Norris' experience modeling complex systems and I appreciate his friendship, as well as his continuous help throughout my research.

For their support and help throughout my UNH experiences, I am especially grateful to Professors Mike Merenda, Gregory Theyel and John Aber. They are excellent educators who have helped shape my world view, and I am lucky to have studied in their classrooms.

Many thanks to my wife, Shannon Shuptrine, for patience and love, to Sandy Shuptrine for good questions and help with editing, and to many other family members and friends, whose contributions to this project are less tangible, but without whom completion of this project would not have been possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

ESTIMATING THE ENVIRONMENTAL COSTS OF THE HYDRO FUEL CYCLE USING LIFE CYCLE ASSESSMENT TECHNIQUES AND ECONOMIC VALUATION

By

Benjamin Ellis

University of New Hampshire, December, 2001

A Life Cycle Assessment model, with an integrated impact assessment, is used to estimate average external economic damages from the hydro fuel cycle. Aggregated average damage assessments of the hydro fuel cycle are complementary to marginal and site specific assessments, and are useful for general energy policy planning. For the upstream inventory assessment, detailed material input data from the Morrow Point Dam is used to estimate material inputs at 174 New England, and 4 Quebec, concrete hydroelectric projects. LCNetBase input-output life cycle assessment software, developed by Dr. Gregory Norris at Sylvatica, is used to estimate upstream emissions associated with material inputs and construction activities. Operations-phase emissions assessed include methane (CH4), carbon dioxide (CO2) and methyl mercury (MeHg), which are primarily associated with microbial activity in reservoirs. In the impact assessment, economic valuation is used to estimate the environmental impact associated with emissions from the hydro fuel cycle. Estimates of average externalities are as follows: small NE dams = \$.0343/kWh, medium NE dams = \$.0202/kWh, large NE dams = \$.0193/kWh, Hydro Quebec, La Grande Complex = \$.0461/kWh. Results indicate that the average external impacts from the hydro fuel cycle are less than, but similar to, the external costs from fossil fuel cycles. However, more detailed assessment of individual projects shows that emissions from the majority of hydro projects are very small as compared to fossil fuel cycles. In contrast, site specific characteristics at a small handful of hydro projects greatly exceed emissions per unit of energy for the coal fuel cycle, and increase the average estimates for small, medium and large New England dams.

EXECUTIVE SUMMARY

ES.1 Introduction

The hydro fuel cycle is an important part of the electricity generation mix in the U.S. and throughout the world. In New England, hydroelectricity is responsible approximately 30 percent of electricity consumed, much of which is imported from Quebec. With growing environmental concerns, hydro is increasingly seen as a clean alternative to fossil fuel electricity generation.

However, the environmental burdens associated with the hydro fuel cycle, particularly those burdens that are not included in the price of power, are complex, difficult to quantify, and difficult to compare to other fuel cycles. Some of these impacts are commonly understood, even if scope of the impact is not typically quantified. For example, many New England residents are aware that dams affect Atlantic salmon migration and spawning habitat.

Other impacts from the hydro fuel cycle are not commonly recognized, such as air pollution associated with materials and construction activities of the dam, or greenhouse-gas emissions from reservoirs. These burdens can have significant environmental impacts, the costs of which are not included in the price of power.

As many states move toward deregulating the electricity industry, quantifying the full costs of energy production is an important factor in making good decisions about energy. This thesis documents a quantitative analysis of the external costs of the hydro fuel cycle, or those costs born by society that are not included in the private costs of business. Externalities are a common measure of environmental and social damages from a product or process. The purpose of this study is to provide average, baseline estimates of hydro externalities that extend previous quantitative analysis of the fuel cycle by including previous ignored emissions. To that end, we quantify the external costs of emissions from the construction and operations-phase of the fuel cycle that are generally applicable to all hydro facilities. These include air and water pollutants from construction activities and greenhouse-gas emissions from the operations-phase. We do not quantify external costs that are typically site specific, such as wildlife habitat impacts or land use changes associated with new hydro projects.

Results from this study are unique, and they provide new insights into hydro electricity's role in pollution and global warming. We find that, on average, externalities from New England projects are approximately $24 per megawatt hour, and externalities from Hydro Quebec projects are approximately $44 per megawatt hour. Of these average estimates, greenhouse-gases from the reservoir account for more than half of total emissions. However, a handful of small and large projects have very high emissions per unit of energy that increase the total average externalities, suggesting that project size has little to do with per unit of energy externalities, and that the majority of New England projects have very low externalities per unit of energy.

It is important to note that this report is intended to be used as a starting point for further research rather than an endpoint for valuing the environmental impacts of the hydro fuel cycle. Expanded scope of study to include North America, improved material input data, and quantitative estimates of error would improve the accuracy of our findings.

ES.2 Objectives

The primary objectives of this study were to:

- Use affordable modeling techniques and existing data to develop, within time and resource constraints, an assessment of the external emissions from the hydro fuel cycle, including greenhouse-gas emissions from reservoirs.
- Develop a range of estimates of average externalities associated with selected impacts.
- Explore the relationship between material inputs, reservoir emissions and hydroelectric project size for the representative projects.
- Explore the role of time in quantitative life cycle assessment models.

ES.3 Methods

The damage function approach (DFA) was chosen as the basic methodology. DFA is a methodology which combines natural science and economics to model incremental changes in baseline conditions. An economic valuation process was used to estimate the average environmental damages and average externality costs associated with the quantified emissions. Specifically, input-output life cycle assessment (IO-LCA) was used to estimate the emissions associated with construction materials and construction activities. Conventional life cycle assessment was used to estimate emissions from reservoirs, such as carbon dioxide and methane, that occur during the operation of a hydroelectric project. Economic valuation was used to interpret the impact of emissions on human and environmental systems.

This application of DFA using LCA and economic valuation has not been applied to the hydro fuel cycle and the methodology has afforded a broader scope of study. For example, input-output life cycle assessment utilizes data from economic interactions throughout the entire U.S.

economy, allowing us to estimate emissions from all upstream activities for over 1000 of the direct materials used in constructing dams. Materials assessed in this study include everything from concrete and structural steel to waterproofing materials, paints and explosives[1]. Previous assessments of the hydro fuel cycle considered only the three primary inputs, concrete, steel and copper. These studies assumed that other material inputs were inconsequential, because the volume of these materials used to construct hydro projects are typically small.

In addition, previous assessments of the hydro fuel cycle have not included emissions from the operations-phase, or those activities associated with generating power once project construction is completed. Operations-phase emissions include estimates of greenhouse-gas emissions that form in the reservoir as a result of microbial decomposition of flooded organic materials.

Another typical assumption in previous hydro fuel cycle assessments is that the technology is mature and the fuel cycle emits no emissions in the operations-phase, thus limiting the time period for assessment to the present. The nature of our modeling techniques provides a dynamic data set, where emissions in any given year of the fuel cycle's life differ from the previous year. Rather then restrict the assessment to the present, this study utilizes discounting at different rates to explore the dynamic relationship between hydro and coal externalities over time.

Our methodology is a departure from previous assessments of the hydro fuel cycle. Although DFA has been applied utilizing life cycle assessment modeling, our application, with a mix of IO-

---

[1] In this study, we refer to these activities as "upstream" as it relates to the business supply chain. Building the materials and components for a hydro project are necessary activities that take place before the operation of a dam to produce electricity. Our use of "upstream" should not be confused with "further up a river."

LCA, conventional LCA and economic valuation, has only recently been developed and has not been applied to the hydro fuel cycle.

ES.4 Scope & Data

The study utilizes data published by the Federal Energy Regulatory Commission (FERC) and the Army Corps of Engineers (Corps) for concrete hydro projects with the primary purpose of electricity generation. Our scope was limited to 174 New England dams and 4 Hydro Quebec dams that are part of the La Grande project. The FERC and the Corps publish data that characterize certain physical descriptions of existing projects, such as annual average generation, dam size, powerhouse characteristics, generator characteristics, installed power capacity, and reservoir details.

Table ES.1 summarizes structural characteristics of the projects assessed in this study. Column C shows that the structural size of the dams ranges from 12,500 cubic yards to over 6.8 million cubic yards. Likewise, average annual generation ranges from 2,000 to 6 million megawatt hours per year.

Detailed material input data, a necessary minimum for estimating emissions associated with constructing dams, is not publicly available for these projects. In order to estimate the materials used in constructing each of these dams, data was taken from one project, the Morrow Point Dam, from which a detailed list of material quantities and costs was published by the Corps. The Morrow Point Dam was completed in 1968 on the Gunnison River in Colorado and is a large, concrete, arch-type dam. We separated the material into categories (Dam, Powerhouse, Transmission Lines, and Roads) and estimated the materials needed for a cubic yard of Dam and Powerhouse, and a meter of Transmission Line and Road. We then multiplied these data by structural characteristics for the 178 dams in the study in order to estimate materials used at each of our study sites.

Table ES.1 Structural characteristics of hydro projects assessed in this study

a) Group size	b) Model Number	c) Average Dam Volume (y^3)	d) Average Annual Electricity Generation (MWh/year)	e) Average Reservoir Volume (f^3)	f) Average Reservoir Surface Area (acres)	g) Number of Dams in Each Model
Small	1	12,500	2,003	4.E+07	324	27
	2	29,186	2,355	4.E+07	198	29
	3	51,178	4,705	4.E+08	571	23
	4	67,551	8,974	2.E+07	61	15
	5	92,062	12,315	4.E+07	84	6
	6	109,818	13,606	3.E+07	99	7
	7	124,980	19,574	4.E+07	183	5
	8	150,940	19,320	6.E+07	157	5
	9	173,213	11,878	4.E+07	96	3
	10	190,796	27,445	3.E+07	93	4
Medium	11	239,445	54,558	4.E+08	710	12
	12	350,824	86,435	2.E+08	603	11
	13	444,124	34,605	4.E+09	4,545	4
	14	536,410	64,700	3.E+08	1,022	2
	15	668,321	104,984	1.E+09	1,747	5
	16	769,542	30,644	3.E+08	399	2
	17	871,704	16,850	5.E+09	4,183	2
	18	905,072	228,042	3.E+10	29,270	1
Large	19	1,335,549	51,517	2.E+09	2,518	5
	20	2,162,999	148,850	2.E+09	3,100	1
	21	3,554,953	105,200	1.E+07	300	1
	22	6,800,742	277,800	5.E+09	2,292	2
	23	8,018,947	356,064	9.E+09	3,240	1
Hydro Quebec	24	87,000,000	6,800,000	3.E+12	3,376,045	4

Estimates of the quantity of greenhouse-gas emissions at each dam were developed from recent studies of Canadian reservoirs. These studies measured greenhouse-gas emissions from experimental lakes and have demonstrated that lands flooded by dams yield high levels of carbon dioxide and methane where previously they had been neutral, or slight net sinks for carbon. Other work has measured emissions at Hydro Quebec's La Grande complex. Using this data, estimates were made for greenhouse-gas emissions for a square meter of reservoir surface area and applied to the projects in the study.

ES.5 Results

Table ES.2 summarizes the average emissions per megawatt hour quantified in this study. For most emissions categories, the largest projects, those associated with Hydro Quebec, have the lowest emissions. Notable exceptions are for methane (CH_4), carbon dioxide (CO_2) and methyl mercury (MeHg), where the Hydro Quebec projects produce approximately ten times the emissions of the New England projects.

Table ES.2 Normalized external emissions from the hydro fuel cycle (metric/MWh)

	VOCs (ST)	NOx (ST)	CO (ST)	SO2 (ST)	PM10 (ST)
Small NE	1.88E-05	6.22E-05	1.01E-04	1.23E-04	1.80E-05
Medium NE	3.11E-05	1.03E-04	1.66E-04	2.03E-04	2.98E-05
Large NE	5.17E-05	1.71E-04	2.76E-04	3.37E-04	4.94E-05
Hydro Quebec	3.04E-05	9.30E-05	1.52E-04	1.84E-04	2.69E-05
	Fossil CO2 (MT)	TRI Air (lbs)	TRI Water (lbs)	TRI UnGnd (lbs)	TRI Land (lbs)
Small NE	2.67E-02	1.26E-02	1.30E-03	4.95E-03	6.78E-03
Medium NE	4.42E-02	2.08E-02	2.14E-03	8.17E-03	1.12E-02
Large NE	7.34E-02	3.46E-02	3.56E-03	1.36E-02	1.86E-02
Hydro Quebec	4.04E-02	2.01E-02	2.04E-03	7.72E-03	1.06E-02
	TRI POTW (lbs)	TRI Off-Site(lbs)	Cost D&T ($K)	CO2 Equiv (ST)	MeHg (ST)
Small NE	2.84E-03	5.38E-02	4.09E-05	1.55E-01	4.70E-03
Medium NE	4.69E-03	8.88E-02	6.76E-05	2.66E-01	2.24E-02
Large NE	7.80E-03	1.48E-01	1.12E-04	6.67E-02	6.83E-03
Hydro Quebec	4.45E-03	8.44E-02	6.30E-05	1.82E+00	1.56E-01

Viewing the average emissions data in Table ES2 provides some information about the normalized releases from different hydro projects, but it does not allow for comparisons between emission categories or for estimates of total impacts. For example, knowing that the Hydro Quebec projects are the largest projects, but that they emit less pollutants in most emission categories is not enough information to understand what these emissions mean to those affected by the pollutants.

Table ES.3 summarizes the results from externality assessments of the emissions data, which allowed us to quantify disparate emissions data into a common measure of social and environmental damage. Column A shows the average externalities for the upstream activities assessed in this study. Hydro Quebec projects have the smallest upstream externalities of those projects considered in this study, with approximately 48 cents per megawatt hour of generation. Column B summarizes operations-phase emissions, the majority of which represent greenhouse-gas emissions from the reservoirs (refer to Table ES.2). Column B indicates that Hydro Quebec projects have the highest externalities of the projects assessed in this study, on the order of $43 per megawatt hour. In total, column C shows that New England projects have average externalities that range from $12 to $28 per megawatt hour and Hydro Quebec projects are approximately $44 per megawatt hour

Table ES.3 Normalized external emissions from the hydro fuel cycle (Dollars/MWh)

	A) Total Upstream Emissions	B) Total Operations Emissions	C) Total Impact	D) Total Impact 5% Discount	E) Total W/O 3 Outliers	F) Total W/O 10 Outliers
Small NE Dams	$5.27	$22.42	$27.70	$21.40	$9.85	$5.56
Medium NE Dams	$3.09	$13.26	$16.35	$12.62	$4.78	$5.52
Large NE Dams	$6.04	$5.75	$11.79	$9.96	$11.79	$4.47
Average NE Dams	$4.82	$19.39	$24.22	$18.76	$13.66	$5.53
HQ	$0.48	$43.14	$43.62	$31.66	$43.62	$43.62

Column C in Table ES3 suggests that large New England dams have the lowest average externalities of the projects assessed in this study. However, a more detailed look at the underlying data shows that a few outliers exaggerate the average externalities from the New England projects. For example, one small project has total externalities over $2,000 per megawatt, while the median externality for the entire New England pool is only $3.63, indicating that the average externality estimates are highly skewed by a few projects. Column D shows our results without the three highest outliers, or those that exceed $200 per megawatt. Column E shows our results without the ten highest outliers, or those that exceed $50. With the outliers removed, total externalities per megawatt hour for the New England projects range from $4.47 to $5.56.

Commonly referenced results from other externality studies of the hydro fuel cycle range from $0 to $.1 per megawatt (Pace 1990, DOE 1995). Our average estimates are significantly higher than previous hydro assessments, particularly for the Hydro Quebec projects.

Discounted results from externality studies of the coal fuel cycle range from $1.3 to $64 per megawatt. Our estimates of externalities for Hydro Quebec are generally at the higher end of the coal externality studies.

ES.6 Conclusions

Total externalities assessed in this study are driven by relationships between average annual generation and structural characteristics of the project. Upstream emissions per unit of energy are associated with the size of the dam and powerhouse, and the length of the transmission lines and access roads. Operations-phase emissions are related to the surface area of the impoundment and the total volume of water stored in the reservoir. In general, the projects with the lowest emissions have small reservoirs, short roads and transmission lines, and small dams and powerhouses relative to the average annual generation.

Previous studies of the hydro fuel cycle conclude that a major advantage of hydroelectricity over fossil fuel cycles are the negligible total externalities. In general, we find that a majority of New

England hydro projects assessed in this study have low externalities as compared to fossil fuel cycles. However, our findings suggest that a small handful of New England hydroelectric projects, and the Hydro Quebec projects assessed in this study, may have significant externalities that are of similar magnitude to coal fuel cycles.

A second key finding of previous studies is that there is essentially no risk of climate change from hydroelectricity as a result of greenhouse-gas emission. However, this study suggest that, on average, greenhouse-gas emissions from the operations-phase account for approximately half of total externalities for New England projects and the majority of externalities from the Hydro Quebec projects.

This assessment provides insight into planning and siting new hydro facilities, and it is helpful in identifying pathways from emission to impact on the environment to include in marginal externality studies. Insofar as public utilities and federal agencies are considering ways to internalize the external damages from the electricity generation mix, our findings conflict with previous understandings and suggest the need for more quantitative assessments of the hydro fuel cycle. Extending this study with improved data and with an expanded scope that covers North America would help in understanding the effects of the hydro fuel cycle and assist in planning an electric generation mix to minimize environmental impacts.

The scope of this study was limited by a set of resource and time constraints. The study findings are based on a number of assumptions that suggest the need for more research. Important assumptions in this study include:

- The materials used in the Morrow Point Dam are generally representative of the materials used in New England and Hydro Quebec concrete hydroelectric projects.
- Greenhouse-gas emissions measured at the La Grande complex in northern Quebec are reasonably transferable to temperate reservoirs.
- Reservoir greenhouse-gas emissions generally follow Fernside's (1995) emission curve decay rate model.

Error in our results is magnified because of embedded assumptions in the three primary data manipulation steps, including estimates of material inputs at study sites, input-output life cycle assessment of upstream emissions, and economic valuation of emissions data to estimate impacts on society. We qualitatively describe our assumptions and inconsistencies in the data, but we provide no quantitative estimates of uncertainty. One published study on the hydro fuel cycle utilizes Monte Carlo modeling to develop quantitative estimates of uncertainty (DOE 1995). Monte Carlo simulation would be possible with the data we collected, but we felt it was beyond the scope and charter of the project.

The study could be expanded in a number of ways to address these limitations. First, with little increased effort, the model could be expanded to include all regions of the U.S., Mexico and Canada, which would improve regional, average estimates of externalities and provide insight into marginal damages at proposed sites. Second, more detailed, site-specific infrastructure data would enhance the accuracy of the model. Third, additional site-specific environmental impacts and external benefits could be included, such as long-term impacts on anadromous fish, degraded water quality, increased recreation activity or increased real-estate value. Last, improved estimates of error utilizing sensitivity analysis or Monte Carlo modeling, would provide more accurate and useful results.

PART I

LIFE CYCLE INVENTORY OF THE EXTERNAL EMISSIONS FROM THE HYDRO FUEL CYCLE

CHAPTER I

INTRODUCTION TO THE HYDRO LIFE CYCLE

1.1 Introduction

This paper represents the first of three describing our work in valuing hydro externalities. Our primary concern in this paper is to use affordable modeling techniques to quantify some of the emissions that are often excluded from LCA models of the hydro fuel cycle. To that end, we use input-output life cycle assessment (IO-LCA) to quantify upstream and construction phase emissions, and we use conventional life cycle assessment (LCA) to model some operations-phase emissions. We introduce methods to include some of the impacts typically ignored in hydro LCA studies, specifically greenhouse-gas emissions from the impoundment and methyl-mercury mineralization associated with the flooding of new reservoirs. Our model is based on a case study of 174 concrete hydroelectric dams in New England and four Hydro Quebec projects associated with the La Grande project. The results are presented in emissions per unit of energy for a size-graduated profile of the individual hydro projects. We use the model and results presented in this paper as baseline data for valuing hydro externalities in the following paper.

A secondary purpose of this study is to explore the relationship between material inputs, emissions, and hydroelectric project size in a New England and Hydro Quebec cases study. We hypothesized that small New England hydroelectric projects emit less energy per unit than larger projects. Our hypothesis is based on the assumption that small projects require the least infrastructure and smallest impoundment for the available power potential of a given site. Additional rationale for this assumption comes from previous studies, where it is commonly held that small hydro has fewer impacts than large hydro (American Rivers 1998, Wiser & Pickle 1997, Holt 1997). To test this hypothesis we calculated baseline estimates for a set of air, water and land emissions on a per-unit of energy basis for small, medium and large projects.

The structure of the paper follows the Society of Environmental Toxicology and Chemistry (SETAC) recommendations for reporting LCA results (SETAC 1996). SETAC is a scientific association that has played a leading role in the documentation and dissemination of guidance for LCA methodology and practice. We first define the scope and boundary of the hydro fuel cycle considered in the model. Next, we review LCA studies of the hydro fuel cycle. We include a review of economic externality studies of hydro because they are among the most comprehensive studies of the fuel cycle, and they utilize methods that are similar to ours for estimating the quantity of emissions. In addition, externality studies assess the impacts emissions have on social and environmental communities, which is a primary purpose of this study and the subject of the following papers. Following the literature review, we describe the data and methods used in the modeling process. Finally, we present the results of the LCA model and a discussion of the importance of our findings.

We find that hydro power leads to direct and indirect air, water and land emissions, and that emissions per unit of energy are poorly correlated with project size. Our model suggests that certain small and certain large projects have equally high emissions per unit of energy. In testing our hypothesis, we find that three simple ratios are useful predictors of emissions. These ratios can be used to compare emissions from proposed projects with regional averages.

1.2 Study Boundary and Scope

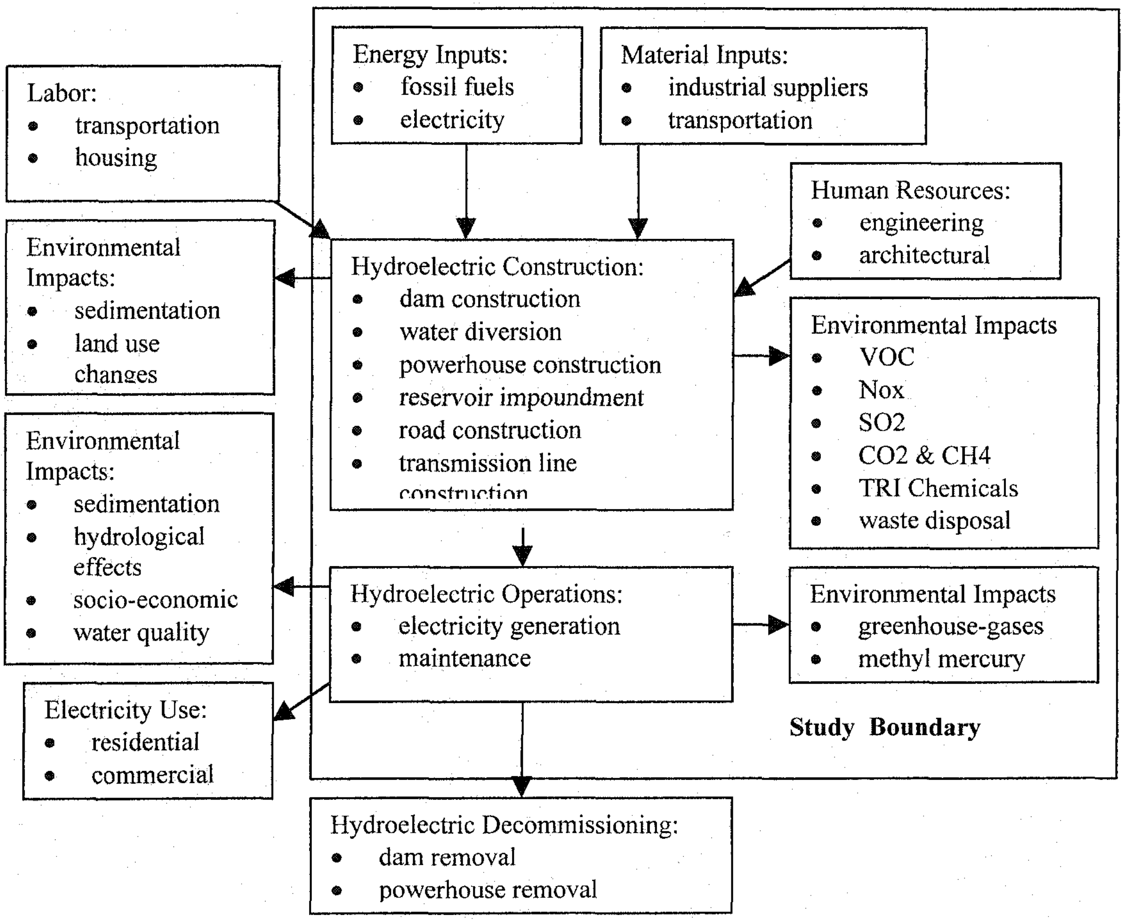
Figure 1 summarizes the scope of quantified and assessed emissions from the hydro fuel cycle. We quantify and model emissions from processes within the indicated study boundary, including upstream emissions associated with building materials and design activities, emissions from construction, and mercury and greenhouse-gas emissions from the operations-phase. Figure 1 also shows that we excluded numerous emissions and impacts from the construction and operations-phase. We find that the emissions excluded from our analysis tend to be site-specific and beyond the scope of our assessment.

1.3 Hydro Life cycle

The hydro life cycle has similarities to other electricity generation fuel cycles in that the primary product, electricity, is highly consumable, applied to disparate forms of work, and the environmental impacts tend to be site specific. Beyond these, however, comparisons become difficult. The hydro fuel cycle is relatively simple. The "fuel", which is water, is renewable and does not undergo chemical changes during electricity generation. The operation phase of the hydro life cycle does not include many of the external industrial inputs necessary for other fuel cycle, such as mining, refining and fuel processing, and fuel transportation. Many of the impacts affect the immediate surrounding environment, including local water quality, aquatic habitats and land-use changes, which are more typically associated with damages to the environment rather than damages to human health or well being (DOE 1995).

The hydro life cycle starts with architectural, engineering, planning and accounting activities. Following the planning phase, energy and products are combined with labor to divert the river, clear the impounded area, and construct the superstructures, access roads, and transmission lines. In this study, we refer to this combination of activities as the upstream and construction phase.

Figure 1 Study boundary



We define "upstream emissions" [2] as those emissions from the chain of processes necessary to produce any of the materials used in constructing the dam. For example, steel, a primary material input, requires a set of mining, manufacturing and transportation activities, each of which result in emissions and has environmental consequences. IO-LCA allows us to model the many industrial linkages necessary to produce every material used in dam construction. We can then estimate the upstream emissions embodied in the construction materials in order to develop a comprehensive profile of impacts from the fuel cycle. We further aggregate upstream emissions

---

[2] Upstream is used in a process rather than hydrologic sense.

into six supply tiers, in which the first tier represents the emissions from constructing and supplying the direct materials purchased to construct the dam, and the second tier represents the emissions produced to supply the first tier, and so on.

The operations-phase consists of those activities necessary to run and maintain the hydroelectric facility. These include facilities management, ongoing maintenance to the moving and non-moving systems, and licensing. We assume that the primary product of the facility is electricity generated during the operations-phase, although secondary internal and external benefits may exist at individual projects, such as increased flat-water recreation on the impoundment, shoreline real-estate development opportunities, or irrigation.

In this study, we assume that the working life of a hydroelectric facility is 50 years. This assumption is undoubtedly somewhat arbitrary, given that many facilities have been in operation for more than 100 years. We chose the 50-year life for four reasons. First, 50 years is the longest license issued by the Federal Energy Regulatory Commission (FERC) in the U.S. to private hydroelectric facilities. FERC is the regulatory agency with jurisdiction over private electricity generation. Fifty years was considered by the commissioners to be a reasonable time for hydroelectric facilities to recapture environmental mitigation costs assessed during the licensing process (FERC 1998).

Second, a literature review of hydroelectric fuel cycle studies indicate that the majority of studies assume a 50-year life (PACE 1990, DOE 1995, BPA 1984, Meyers et al. 1986, Rudd et al. 1993). This time-period assumption is somewhat institutionalized in academic research of the hydro fuel cycle and the use of a 50-year life cycle in this study allows direct comparison to the results of other studies.

Third, it is reasonable to assume that meaningful predictions about the role of hydroelectric facilities beyond 50 years from today are not possible. Changes in technology, improvements in conservation and efficiency, and demand for electricity products by residential and industrial users have proven difficult to predict with certainty even 10 years in advance (DOE 1995). Consider, by way of example, the long-term contracts signed in the early 1980s between New England PUCs and renewable energy generators to supply electricity at prices well beyond market values (PURPA 1999). These contracts were based on assumptions about rapid and sustained increases in electricity demand that did not materialize.

Finally, major renovations are typically required at hydroelectric facilities as they reach 50 years in age (FERC 1998, ExternE 1998). These retrofits are site specific, but may include overhaul and rewinding of the generators, reconstruction of spillways and dam superstructures, improvements for recreation access and other environmental mitigation, and major maintenance to buildings.

The decommissioning phase includes a number of possible outcomes, primarily driven by the site and politics. Outcomes include total removal of all buildings and dams, partial breaching of the project with no removal of the associated infrastructure, in-place abandonment of the project assets, and full renovation of existing facilities (FERC 1998). Because these decisions are site-specific, we do not assess emissions from the decommissioning phase.

1.4 Environmental Impacts from the Hydro Fuel Cycle

Construction and operation of hydroelectric facilities can affect ecological systems, cultural and recreation resources, safety, and economic systems through a variety of impact pathways. The primary environmental impact pathways are changes in hydrology and water quality, changes in land use, and interference with fish and wildlife movement through construction of barriers

(Rosenberg et al. 1997). Other primary impacts, which may have both positive and negative external results, include affects on recreation and commercial opportunities (Medsker 1982, PACE 1990, DOE 1995). Secondary impacts can come from emissions associated with building, transporting and installing construction materials, as well as emissions from reservoirs. Appendix I provides a qualitative summary of emissions and other impacts from the hydro fuel cycle in a table format.

Land-use changes are initiated through building of dam superstructures, cutting and maintaining transmission lines, and flooding of reservoirs (PACE 1990). Sediments and nutrients in unaltered river basins are typically flushed through the rivers during periods of high flows. In altered systems, sediments settle in the reservoirs and can contribute to eutrophication. Sediment-free waters below dams can increase shoreline erosion, reduce downstream agricultural fertility and reduce the productivity of aquatic organisms (Bodaly et al. 1984).

Water quality in reservoirs can degrade in response to thermal stratification, which takes place when dense, cool waters settle on the bottom of the impoundment and resists mixing with warmer, upper-level waters (Bodaly et al. 1984, PACE 1990). In upper-level waters, aerobic decomposition of flooded organic matter can lead to releases of CO2, which is thought to be a primary factor in global warming (Rudd 1995, Tathy et al. 1992). Flooding of new reservoirs has been demonstrated to initiate natural mercury mineralization, which leads to the highly toxic and persistent form of methyl mercury (Kelly et al. 1997). In the cold, deeper waters, dissolved oxygen content can decrease to the point where decomposition of flooded organic materials becomes anaerobic. Many of the by-products of anaerobic decomposition are toxic to aquatic life, including ammonia and hydrogen sulfide. In addition, anaerobic biological activity produces methane, which is a particularly potent greenhouse-gas (Galy-Lacauz et al. 1997). Water released from the depths of an impoundment can require many miles of travel to re-oxygenate (FERC 1995).

Biological communities, including fish, wildlife and macro invertebrates, are affected by hydro projects, although many of these impacts are poorly understood (DOE 1995, PACE 1990). At a minimum, flooding reservoirs causes changes in biological communities as natural riparian and wetland areas are covered and lake environments are created. Fish and other aquatic species are affected by changes in flow, reduced spawning grounds, reduced food, increased temperature, decreased water quality, increased mortality, and restricted mobility caused by the dam structures (FERC 1995). Hydroelectric projects are known to cause extinction in certain fish species in certain regions of the U.S. and Canada (Meyer 1986).

Safety concerns can exist with the possible, but improbable, result of dam failure and catastrophic flooding (FERC 1999). Safety concerns are typically minimal, as dam construction and licensing is subject to significant and comprehensive review by the FERC.

Damming and flooding rivers can affect recreation and commercial activities, as well as cultural resources. There are numerous examples of lost whitewater boating and fishing opportunities, as well as the flooding of important Native American cultural sites in the Southwest U.S. exist (see RIMS database maintained by FERC). Recreational and cultural impacts, though at times significant and external to project operations, are site-specific and beyond the scope of this study.

Many of these environmental impacts are internalized in the price of power. For example, new standards for minimum and flushing flows downstream of a dam may be required during the FERC relicensing process (see FERC License Application for Kennebec p-2143, Mokelumne p-137, Feather p-1963) . The goal of such an action would be to improve water quality, habitat and sediment transport. The utility may have to forego electricity generation or install special floodgates to provide such flows, which increases the price of power and internalizes the costs of the mitigation measure. However, many other environmental impacts are not captured in the price of power, including upstream and operations-phase emissions.

With the exception of upstream and operations-phase emissions, most of hydro's environmental impacts are site specific. Quantifying these site-specific impacts at all New England and Hydro Quebec projects is beyond the scope of this analysis. As indicated in Figure 1, we focused our attention on assessing upstream and operations-phase emissions that are common to the concrete hydroelectric projects assessed in this study.

CHAPTER II

REVIEW OF QUANTITATIVE ASSESSMENTS OF THE HYDRO FUEL CYCLE

2.1 Introduction

In this study, we use input-output life cycle assessment to quantify upstream emissions, which are the emissions associated with providing the construction materials for the hydro projects in question. We use conventional LCA methods to assess greenhouse-gas and methyl mercury emissions from the operations-phase. IO-LCA is distinguished from conventional LCA in both the method and scope of the study (Lave 1997). IO-LCA is a particularly affordable and powerful modeling tool in that it captures detailed upstream emissions not only for each individual material used in new dam construction, but also emissions for material extraction and construction for each part used in the dam. IO-LCA software provides a method to assess emissions from all tiers in the supply chain for each product used in new dam construction (Norris 1996). In this study, we assessed more than 1000 individual material inputs. Certain products, such as explosives, waterproofing, or paints, may be used in very small quantities as compared to other materials, such as concrete and steel, but their damages to the environment and human health may be disproportionately large to the volume of the material used. Ignoring upstream material inputs, or focusing on only a few materials used in construction, could obfuscate the overall impacts from the hydro fuel cycle.

In this section, we compare our study methods and scope to hydro LCA studies and other quantitative assessments of the hydro fuel cycle. We find that no other studies utilize the IO-LCA methodology for assessing upstream emissions and no other studies assess the greenhouse-gas or methyl mercury emissions for individual projects from the operations-phase of the hydro fuel cycle. We conclude that our methods are unique and that we capture broader range of emissions as compared to other quantitative assessments of the hydro fuel cycle.

2.2 Hydro LCA Studies and Databases

We reviewed fuel cycle LCA studies to identify methods used, inventory results, and valuation outcomes. In general, previous LCA studies of the hydro fuel cycle defined a narrow scope around operations-phase emissions, and typically conclude that the hydro fuel cycle has zero emissions. LCA has been extensively developed in Europe and there are at least two publicly available LCA studies of hydroelectricity, but they are not published in English (ETH 1994, Norsk Hydro 1998). In addition, the product and process focus of LCA has led to many privately commissioned studies, the results of which are not generally available. Finally, many private firms and quasi-public organizations have established proprietary databases that are available for a fee. The user manuals, often available in marketing materials, do not provide sufficient information on the sources, scope and quality of the background data to reconstruct detailed LCA methodology of the hydro fuel cycle (SimaPro 4.0, Umberto)

Nonetheless, a number of LCA studies have been conducted on hydroelectricity, and most databases available for use in conventional LCA modeling assess the environmental impacts of hydro to some level. In 1995, the Society for the Promotion of LCA Development (SPOLD) published a directory of life cycle inventory data (SPOLD 1995). The directory was published in an attempt to overcome the limitations of data location and formatting, and the report lists details of the sources, geographic boundary, data quality and price of the majority of conventional LCA databases. All of the data listed in the SPOLD directory follows the SETAC, or an adapted SETAC methodology. Many of the data sources are not independent assessments. For example, the "Ecobalance of Packaging Materials" (BUWAL 250 1995) study uses ETH energy data for hydroelectricity.

Many other databases utilize BUWAL as a primary source of data. Table 1 summarizes the material inputs from which emissions were quantified in this and other LCA studies. Detailed descriptions of our methods are located in Section 4, and detailed descriptions of our results are located in Section 5.

Table 1 Summary of inputs assessed in hydro LCA studies

	Ellis	ETH	Franklin	EcoBalance
Upstream Emissions				
Cement	√	√		
Concrete	√	√		√
Steel	√	√		√
Copper	√	√		√
Aluminum	√	√		
Explosives	√	√		
Paints & Waterproofing	√			
Other metals	√			
Construction Fuel	√			
All other material inputs	√			
Operations Emissions				
CO2	√			√
CH4	√			

The SPOLD report lists four sources of independently constructed hydroelectric LCA data: ETH-ESU (Switzerland), Franklin Associates, Ltd. (USA), EcoBalance (USA), and IVAM Environmental Research (Netherlands). Of this data, the ETH-ESU is general recognized at the most comprehensive source of LCA fuel cycle data, (Personal discussion with Greg Norris, Sylvatica; Keith Weitz, RTI; Jim Wasla, SCS; Bob Hunt, Franklin Associates) . The database, developed from existing infrastructure in European countries, is publicly available, but the supporting materials describing study methods and scope are only available in German. Part of this literature review is an effort to translate the hydropower section into English in order to compare the results, methodology and scope of the study to the results of this paper. We used German to English translation software with 90 percent accuracy. Our translated text, however, did not preserve any of the formatting, so it is inadequate to ascertain the true intent, scope or results of the study. The translated text from the ETH study is located in Appendix J.

From what we can understand from the translated text, the ETH study appears to be extremely comprehensive. It estimated first-tier air, water, and toxic chemical emissions from explosives, cement, aluminum, copper and steel, the primary materials by volume used in hydro projects. ETH considered the operational life of various facility components, including turbines, powerhouses and dam structures. It identified large and small projects based on hydraulic head and estimated annual energy production. ETH concluded that hydro has low emissions per unit of energy, primarily because there are no greenhouse-gases emitted from the operations-phase. In its summary tables, ETH allocated emissions to units of energy, although we have been unable to translate the tables into English.

Franklin Associates, Ltd. (FAL) has a long history of conducting LCA studies in the U.S. for private firms (Hunt 1996). FAL sells and supports its their database directly to customers and through their LCA software package EcoManager. FAL quantified the environmental impacts of other fuel cycles, but did not quantify the impacts of hydro. FAL assumed that the emissions from operations were negligible or not quantifiable, and it followed SETAC guidelines by ignoring capital goods and equipment. As a result, the database has "zero" values in all emission categories for the hydro fuel cycle (FAL 1998).

EcoBalance, a consulting firm based in Rockville, Maryland, developed the DEAM inventory database with independent assessments of the environmental impacts of hydroelectricity. Its operations emissions data comes from Chamberland's (1996) article on hydroelectricity.

EcoBalance estimated average reservoir size and depth and average annual electricity generation from data published by the FERC for all US hydroelectric projects. Its model includes first-tier assessments of four construction materials. EcoBalance further assessed the greenhouse-gas emissions released during operations. Details of how these assessments were made, the life cycle of the facility, and the construction materials assessed are not publicly available, and have not been made available by the staff at EcoBalance. The results of this model: 1 MJ of hydroelectricity results in .0042 g of CO2 & .00057 g of CH4 (personal correspondence with Vince Camobreco).

IVAM, a private research, consulting and software development firm in the Netherlands, has developed an independent, peer-reviewed database for 700 processes that lead to more than 250 materials (IVAM 1999). Its database has been constructed from internal LCA studies in combination with BUWAL, ETH and other publicly available data. Hydroelectric data appears to have come from a Dutch fuel cycle study, which was a subsidiary study of the ETH study (van Heijningen 1992).

We conclude that our methodology, which considers upstream as well as operations emissions using IO-LCA techniques, is more comprehensive than the methods described above. Our results, as described in following sections, consider many additional impact pathways and result in a substantially higher inventory of emissions.

2.3 Hydro Externality Cost Studies

Methods used in externality cost studies are similar to conventional LCA studies in their calculation of upstream and operations emissions data, and their assessment of human and environmental impacts from these emissions. We reviewed the methods, scope and results of three commonly cited and comprehensive hydro externality studies, including "Estimating

Externalities of the Hydro Fuel Cycle" conducted by the DOE Oak Ridge Laboratory (DOE 1995), the "The Environmental Costs of Electricity" conducted by Pace University (PACE 1990), and the "Sultan River Study" conducted by the Bonneville Power Authority (BPA 1984).

Some of the data underlying the final results is similar to the inventory data used in LCA studies, however we conclude that the IO-LCA methodology provides a more comprehensive assessment of upstream emissions than the externality cost method. Of the externality studies reviewed, only the DOE study includes any upstream emissions from construction materials.

As with the LCA studies reviewed above, the externality cost studies devote little attention to operations-phase emissions. All of the externality cost studies identify the avoidance of greenhouse-gases and heavy metals in the operations-phase as a significant external benefit of the hydro fuel cycle. In contrast, we found that greenhouse-gas emissions from reservoirs are a quantifiable and significant environmental impact pathway.

2.3.1 Estimating externalities of the hydro fuel cycle - Department of Energy, 1995.

The DOE sponsored a comprehensive study of fuel cycles with the primary goal of estimating environmental externalities through application of cost-benefit methodology. The DOE reviewed the externality cost literature in order to construct a range of estimates of the marginal damages from certain impacts of new hydro projects. The study considers two U.S. reference sites with a total of 12 hydroelectric projects. The two sites are a hydroelectric retrofit of an existing water diversion project in the Southeast, and a proposed new construction of a diversion project in the Northwest.

For upstream damages, the DOE assessed the indirect emissions resulting from the use of four primary construction materials: concrete, steel, copper and aluminum. The scope of the upstream assessment was limited to the first tier in the supply chain. No assessment was made of raw material extraction or transport of building materials to the manufacturer.

Estimated quantities of construction materials per cubic yard of dam construction were provided by the Army Corps of Engineers. Steel in the dam and diversion structures was estimated to be 120 lbs/cubic yard of concrete, which is the value used by the DOE for estimating steel in all concrete-reinforced structures. The DOE assumed that all of the turbine, and all but 8 percent of the generators' gross weight, is steel. It assumed that remaining 8 percent of the generator weight is copper. By treating the generator and turbine as raw material, the study disregarded emissions associated with energy and material inputs that result from manufacturing these complex products. The study assumed that powerhouse structures would a.ll be 30x60 feet, and explicitly excluded other building materials, such as waterproofing, roofing, paints and explosives, arguing that they are negligible as compared to concrete and steel.

DOE estimates of aluminum input requirements are based exclusively on transmission line cable at the weight of 1/3 pound per linear foot. The study ignored steel, rubber and other circuitry necessary for transmission lines. No effort was made to assess the emissions from access road construction or transportation of construction materials to the site.

In order to convert the inventory of steel, concrete, copper and aluminum into estimates of atmospheric emissions, the DOE utilized data from the TEMIS database. TEMIS was developed by Meridian Corporation from LCA emissions data for Germany and Western Europe. The DOE utilized this data in place of data developed in the U.S. because TEMIS was comprehensively collected and the U.S. and European manufacturing practices are similar. Table 2 summarizes the emission factors from the TEMIS database.

Table 2 Emission factors for materials manufacture (lb/ton)

	Steel	Concrete	Aluminum	Copper
CO_2	6,000	1,800	50,000	17,600
SO_2	6	10	50	8
NO_x	10	30	40	10
PM	1	2	10	2

The DOE study was unable to quantify impacts and emissions from changes in water quality, flow alterations, air quality, or land-use changes initiated during the construction or operations-phase.

Two operations-related impacts were quantified: loss of fish from suspended sediment load and loss of fish spawning habitat as a result of altered hydrology. Data for the estimate of impacts to fish from suspended sediments was collected from site-specific details in the FERC license application, including estimated annual sediment load associated with each project, risk factors for catastrophic collapse of the diversion structures, and the number of anadromous fish downstream of each project.

Data for the assessed losses to fish and fish habitat from altered flows was taken from the FERC license application and was highly site-specific. At each of the reference sites, in-stream flow studies were conducted as part of the license application, indicating the percent of fish habitat available before and after project development. These percentages were multiplied by the estimated number of spawning fish in each reach.

Despite the fact that numerous impacts were not quantified, the DOE study concludes that the hydro fuel cycle has smaller environmental impacts than other fuel cycles because it does not produce greenhouse-gas emissions and impacts to road from transporting heavy fuels are not present. The final results calculated for the diversion project were .1 mill/kWh for reduced fishing benefits.

2.3.2 Environmental Costs of Electricity – Pace University, 1990.

The primary purpose of the Pace study was to conduct a comprehensive review of the environmental externalities literature as it relates to electricity generation, and to present best estimates of externalities per unit of energy. A secondary purpose of the Pace study was to use the literature reviewed to prepare damage estimates for typical pollutants released during the generation of the fuel cycle.

Pace reviewed two studies on the environmental impacts and costs of hydroelectricity, including "Methods for Valuation of the Environmental Costs and Benefits of Hydroelectric Facilities: A Case Study for the Sultan River Project," and "Calculation of Environmental Costs and Benefits Associated with Hydropower Development in the Pacific Northwest." Both studies were prepared for the Bonneville Power Authority (BPA) in the late 1980s in an attempt to quantify external impacts of BPA operations.

Pace prepared an overview of small hydroelectric facilities, as defined as less then 80 MW capacity. Pace concluded that the potential impacts from small hydropower are generally the same as large hydropower on a kilowatt-hour basis, and that the magnitude of impacts per unit of energy can be smaller or larger than large hydropower. On a project-by–project basis, the impacts from small hydro tend to be less than large hydro. However, the stacking effects of numerous small hydro projects built in succession along a river tend to increase the impacts of these facilities on a unit of energy basis. Pace found no environmental cost studies of small hydropower, so the study provides only a qualitative description of the possible impacts of project size.

Pace was unable to estimate the externality value of hydroelectricity. However, it pointed to a number of factors that make hydropower attractive as compared to energy generated from fossil fuel. Pace argues that there are many important positive externalities, including avoided greenhouse-gas emissions, avoided acid rain precursor emissions, avoided trace metal emissions, and no cooling water impacts. Pace reprints a table from a DOE white paper that indicates that on a kilowatt-hour basis hydro CO2 emissions are 10 times higher than fossil fuel CO2 emissions during the construction phase (A-12). During the operations-phase, the table indicates that hydro CO2 emissions are zero and coal plant CO2 emissions are over 1000 tons per GWH. In total, the study claims that CO2 emissions from hydropower are 100 times less than those from coal plants.

Two shortcomings in the Pace study make the results somewhat controversial (DOE 1995, BPA 1991). First, the scope of the Pace study included operations emissions only. Those direct and indirect emissions associated with construction and maintenance activities were ignored. Second, Pace assumed that electricity generation is the primary social purpose for hydroelectric projects. Pace assigned all external impacts to electricity production, ignoring for simplicity purposes the parts responsible for flood management, irrigation and recreation. Despite problems with the hydro fuel cycle analysis, the Pace study is often cited in the literature and is considered a seminal study on the environmental costs of electricity (DOE 1995).

2.3.3 Sultan River Study- Bonniville Power Administration, 1984.

The Sultan River Study (BPA 1984) was developed to test the merit of applying cost valuation methodologies to site-specific environmental attributes. The study argues that environmental costs of hydropower are unique to each site and that calculating generic costs per unit of energy for the hydro fuel cycle may not be possible. The study also suggests that economic valuation methods may not be necessary or sufficient for quantifying the environmental externalities of hydropower.

The Sultan River study used three methods to quantify numerous, site-specific estimates of impacts, including hedonic pricing, willingness to pay, and willingness to be compensated. Impact areas quantified include: old growth, deer, whitewater, extreme kayaking, commercial timber, and general recreation. The study used a 3 percent discount rate and presented the results in mills/ kWh. The final results are 10.87 to 12.31 mills/kWh for total external costs. These results are considerably higher than other externalities estimates, which range from zero (Pace 1990) to .01 mills/kWh (DOE 1995).

The study has been criticized for using methodologies that overestimate certain impacts (DOE 1995, PACE 1990). The study, for example, calculated that 30 deer are valued at $6200, class V kayaking at $1886 per day, and commercial timber at $32,628 per acre. The Pace reviewers criticized the study on three accounts. First, they noted the study's dependence on willingness to be compensated methodologies that Pace asserts are "seriously biased." Second, Pace noted flaws in the survey instrument that could have led to biased answers. Third, the method used for calculating loss of old-growth forest is misleading because old growth "confounds equity and efficiency considerations." The DOE points out that the study does not develop and document uncertainty surrounding the value estimates.

2.3.4 Other externality studies.

Numerous valuation studies have been conducted that quantify the value of recreation, fisheries and other biological attributes of river ecosystems. Andrews and Dolcine (1990) contains a bibliography of 117 valuation studies. These studies, though useful in the economic valuation of the inventory assessment, provide little insight into assessing the life cycle impacts from the hydro fuel cycle.

2.4 Lessons from the Literature Review

We emphasize three points from our review of the literature. First, each study utilized a unique methodology, with a unique scope and disparate results. Our approach, using IO-LCA for assessing upstream emissions and conventional LCA for assessing operations emissions, considerably extends the scope of previously conducted studies. We were able to include all upstream material inputs, and some of the operations emissions, such as greenhouse-gas and methyl mercury emissions from reservoirs, that have not been included in previous assessments. New science indicates that greenhouse-gas emissions from hydroelectric reservoirs may be significant, and we were able to model these emissions at all 178 case study sites.

Second, our methodology, relying primarily on publicly available data and IO-LCA techniques, is an affordable and transferable approach to assessing upstream emissions. In addition, our model allowed us to utilize data from all hydroelectric projects in our study region, a total of 178, rather than a handful of representative projects. This allows us to consider both marginal damages from a proposed project against regional averages, and average damages for small and large projects.

Third, we concur with the position taken, or implied, in all of the reviewed studies that current scientific understanding of most of the hydro impacts is inadequate to assist in quantitative modeling of the fuel cycle. Impacts, such as degraded water quality and reduced fish habitat, must be modeled for each site and requires assessment of other projects in a given watershed, as well as other land uses within the watershed. Such an assessment was beyond the scope of this study. Quantitative analysis in our study, as with other studies reviewed, is limited to emissions associated with construction and, in our case, a few operations-related emissions.

CHAPTER III

METHODS AND DATA

3.1 Introduction

Data necessary for running the model was compiled, aggregated and adjusted in a number of steps. Each data set required considerable adjustment for use in the model. Table 3 summarizes our modeling activities and Appendix G describes our assumptions and adjustments for each data set. In this section we summarize our modeling steps, the data used, and the data conversions necessary for use in our model.

3.2 Step 1: Model Material Inputs

First, we calculated material inputs in dollars per cubic yard of concrete hydroelectric dam from detailed construction data for the Morrow Point Dam (BOR 1983). The Morrow Point Dam is the only project in the U.S. for which extensive construction details are available to the public. The Army Corps of Engineers finished construction of the dam in 1968 and published an extensive report on every detail of dam construction. The report lists all material and labor purchase orders in dollars, and the quantity of materials used in various units. The line-item data was reported as the aggregated cost of direct material, labor, profit and service inputs into the project. Approximately 1000 product line items were entered into a spreadsheet (Appendix A).

Next, the total reported value of each line item was reduced by the percentage of contractor profit, labor, and on-site transportation costs in order to derive actual costs of materials used in the dam. Percentage adjustments were developed using RS Means construction cost data (RS Means 1998). RS Means develops an annual detailed average construction cost database for concrete construction, heavy construction, site-work and landscaping, and building construction.

Table 3 Summary of modeling activities

Step	Modeling Activity	Hours
Step 1: Calculate material inputs to new dam construction	Hydro LCA literature review	200
	Hydro cost benefit literature review	200
	Input quantities and dollar value for all materials used at Morrow Point Dam from the Army Corps of Engineers (CORPS) data	160
	Assign commodity code for each material line item using BEA descriptions	25
	Create construction category for excavation, transportation and road construction using RS Means percentages	10
	Allocate materials to Dam, Powerhouse, Switchyards, Transmission lines, Roads using CORPS data	7
	Remove profit & labor using RS Means	8
	Convert dollar value to 1992 using CPI	5
Step 2: Model emissions for cubic yard of new dam	IO-LCA literature review	100
	Input dollar value per commodity into LCNetBase	1
	Model emissions using LCNetBase per cubic yard of dam.	15
Step 3: Model New England & Hydro Quebec profile of concrete hydroelectric projects	Input average annual generation, and operation regime for 174 NE dams from FERC data	25
	Input structural information for 174 dams from CORPS data: year of construction, height, length, number & type of generators, nameplate rating, impoundment surface area, impounded area volume,	25
	Estimate structural volume of dam, length of roads, length of transmission lines	10
	Convert CORPS identifying numbers to FERC	1
	Hydro Quebec Literature review	30
	Convert disparate Hydro Quebec literature descriptions into structural and average generation for the La Grande	10
Step 4: Model emissions for all NE and HQ projects	Apply emissions from LCNetBase output to structural aspects of all assessed dams	35
Step 5: Model greenhouse-gas & methyl mercury emissions	Literature review	75
	Estimate greenhouse-gas (GHG) residence time and turnover rate from Fernside	10
	Estimate GHG emissions per square meter of impoundment surface areas from empirical Hydro Quebec data	30
	Estimate methyl mercury residence time and turnover rate	8
	Estimate methyl mercury emissions per cubic meter of impounded water	10
	Frivolous time that can't be allocated to a real task, but was somehow necessary for completing this project	≈ •
	Total Hours	1025

The database lists more than 40,000 component installation line-items with unit costs, labor, installation materials, and profit estimates for an average installation. Labor and profit were removed entirely from the calculus. For products where RS Means percentages were not available, the average of all percentages used for labor, profit and transportation were used to reduce those products and materials by labor, profit and transportation. A new category, "on-site transportation," was created and the residual fuel costs from activities such as excavation and landscaping were summed and placed in the new category cell.

Each line item was assigned a product sector code number that corresponds to the Bureau of Economic Analysis (BEA) input-output tables. LCNetBase software publishes a search table of 485 industries and close to 12,000 products produced by those industries (Norris 1998). We matched the Corps descriptions with product descriptions (Appendix A). The data was then subtotaled under each BEA product sector code. Using annual changes in the Consumer Price Index (CPI), subtotaled dollars were converted to 1992 dollars in order to correspond with the 1992 input-output tables.

Morrow Point Dam data was not reported in discrete segments, such as transmission line costs, road construction costs, or powerhouse costs. We separated the data into four material input categories: powerhouse and switchyard, dam, transmission lines, and roads. We used data from the Morrow Point Dam to estimate the dollar of inputs from each industry sector for a generic, cubic yard of dam construction, cubic yard of powerhouse and switchyard construction, meter of road construction, and meter of transmission line construction. We assumed that material inputs scale linearly within these categories.

3.3 Step 2: Model Upstream Emissions Using LCNetBase IO-LCA Software

In step 2, we used LCNetBase^{TM} software developed by Greg Norris at Sylvatica (1997) to run the input-output LCA model and calculate emissions for new dam construction. Wassily Leontief developed input-output analysis to capture economy-wide economic interdependencies based on the assumptions that complicated interactions between industries can be simulated with proportionality relationships (Leontief 1996, Miller et al. 1995). For example, if 3 tons of copper is required to build one industrial electric generator, then 6 tons would be required to build two generators. In addition, an increase in demand for industrial electric generators would require increased output by hundreds of other industry sectors, including electricity, steel, petroleum, plastics, and engineering services, to name a few. Based on a change in final demand, the input-output analysis models the change in output for all of the direct and indirect supplies to an industry.

Figure 2 Steps in Input-Output LCA (adapted from Joshi 1998)

Step 1) Estimate direct output for changes in sector (f)

Step 2) Estimate direct and indirect economic change (x) with input output matrix (a)

Step 3) Estimate environmental discharges from industry sector output (e)

Step 4) Add all industry sector discharges to find total emissions

Recent work in life cycle assessment has combined pollution discharge data for industry sectors with input-output estimated change in final demand for each sector, producing an input-output life cycle assessment model for the entire economy (Lave et al. 1996, Horvath 1997, Joshi 1998). Figure 2 shows the IO-LCA modeling process in which change in final demand (f) for a product leads to an assessment of direct and indirect economic change (x) for all industry sectors within the I/O matrix (a) necessary to produce the product. Equations 1) shows that final demand (f) plus intermediate demand (ax) equals the change in total output of a given sector[3]:

---

[3] More detailed descriptions of input-output analysis, including underlying assumptions about the economy and detailed mathematical descriptions, can be found in Miller 1985.

(1) $x - ax = f$.

However, equation 1 does not calculate sectoral input requirements because it does not include the actual indirect inputs from other sectors in the supply chain. The industry sector output to meet final demand is calculated by pre-multiplying equation (1) by $[I\text{-}a]^{-1}$:

(2) $x = (I - a)^{-1} f$

where x= total output of a vector, a= the matrix of direct requirements, f= the vector of final demand, and I= is the identity matrix for sectoral interactions. Equation (2) can be expanded to represent the infinite transactions between industry sectors:

(3) $x = (I + a + a^2 + a^3 + a^4 + ...)f$

In step 3, we expand the input-output model to assess the pollution discharges to the environment associated with changes in final demand. If (r) represents a matrix of emission coefficients associated with a dollar change of output from each industrial sector, and if (e) represents the vector of total direct and indirect emissions, then the total environmental effects associated with a change in the demand vector (f) is:

- $e_{total} = rx = r(I - a)^{-1} f$,

and the direct discharges are:

(5) $e_{direct} = r(I + a)f$

Input-output tables are developed and used by many countries for economic planning (Miller et al. 1985), and comprehensive input-output tables are maintained by the Department of

Commerce. U.S. economy input-output data used in LCNetBase is from the Bureau of Economic Analysis (BEA 1997). The economic tables are compiled from survey and Economic Census data and are reported on the national level by the commodity and industry sectors. Data for more than 500 commodities and nearly 500 industries are catalogued and used in developing the input-output tables. When we ran the model, the most recent set of input-output data available was from 1992.

The environmental emissions matrix (r) can include vectors for any pollutant with sufficient data to be included in the model. Environmental emissions data, such as raw material consumption, energy use, and emission releases, is reported annually to various federal agencies. When combined with the input-output matrices in the LCNetBase software, we can model the emissions profile for a product, process, service, or the entire economy. Environmental matrixes used in LCNetBase are from the EPA's Toxic Release Inventory (TRI), Emission Trends Inventory, Aerometric Information Retrieval System (AIRS), and Resource Conservation and Recovery Act (RCRA) (Norris 1997). These matrices provide sufficient data to estimate toxic chemical releases to air, water and land, the emissions of conventional air pollutants, and greenhouse-gas emissions from fuel and electricity consumption.

3.4 Step 3: Material Inputs and Emissions at NE and HQ Projects

In this study, we assume that concrete hydroelectric projects utilize similar materials in similar proportions. In order to model emissions for individual hydro projects, we combined emissions data from LCNetBase for a cubic yard of construction material for the four categories previously described to detailed structural data for the individual projects. Data for the size, structure and average annual generation for the New England hydroelectric projects was calculated from data published by the Army Corps of Engineers (CORPS 1996) and from the Federal Energy

Regulatory Commission (FERC 1999). Structural data for the Hydro Quebec La Grande project was compiled from the literature.

Army Corps data, as reported in the National Inventory of Dams (NID) (CORPS 1996), provides structural information for every U.S. dam, including structural height and length, reservoir size, hydraulic head, year of construction, and materials used (Appendix C). Appendix K summarizes categories in the NID database. Column 13 includes the primary purpose of the facility, including: Irrigation; Hydroelectric; Flood Control; Navigation; Water Supply; Recreation; Fire/Farm Pond; Fish andWildlife; Debris Control; Tailings; Other. Column 23 indicates which federal agency has regulatory oversight of the project. Column 27 identifies the NID code for the type of dam construction for each project, including: RE = Earth; ER = Rockfill; PG =Gravity; CB = Buttress; VA = Arch; MV = Multi-Arch; CN = Concrete; MS = Masonry; ST = Stone; TC= Timber Crib; OT = Other. We sorted the database for New England, hydroelectric projects overseen by the FERC, and further sorted for those dams constructed of concrete in a similar manner to the Morrow Point Dam project FERC project numbers were assigned to the hydro facilities and subtotals of structural details were calculated. Of more than 400 New England dams, we were left with 174 individual projects that fit our criteria.

Army Corps data included structural length and height of dams, but did not report the dam width or the volume of materials in FERC-licensed projects. Although “volume” appears in the NID data fields, no data was entered in any of the concrete hydroelectric projects in New England. In order to estimate volume for the New England projects, we developed a multiplier from Morrow Point Dam data that scaled with the height of the dam. The structural height of Morrow Point Dam is 469 feet, ranging in width from 10 feet at the top of the impoundment structure, to 52 feet at the bottom of the structure. We assumed a linear decrease in dam width from the foot to the top of the structure. This multiplier was used to estimate dam width for the New England projects.

The FERC database (FERC 1999) presented kilowatt output in both capacity and annual average generation for each project as organized under FERC licensing and project ownership. FERC and Army Corps data sets were combined in a metafile to reflect average annual generation in kilowatt hours relative to volume of structural materials used, surface area of the impoundment, average head for each development, and year of damming for all New England hydroelectric projects that were constructed primarily of concrete (Appendix D).

A similar methodology was used for estimating the material inputs for the Hydro Quebec La Grande complex. Data on the size of the impoundment, volume of superstructure development, length of new roads constructed, length of high-tension transmission lines, and average annual generation are from Ludwig et al., (1980), Amyot et al., (1976), and Duchemin et al. (1995). Structural profile data was combined with the detailed material inputs for the Morrow Point dam project in order to estimate total upstream emissions for the La Grande complex.

3.5 Step 4: Calculate Emissions per MWh at NE and HQ Projects

In order to calculate upstream emissions at the 174 dams, we allocated upstream emissions per cubic yard of material to the total structural materials used in each project. Emissions for each project were then divided by the annual average generation for the assumed 50-year project life. We used one megawatt hour as the functional unit (the basis for comparison) for the study.

3.6 Step 5: Estimate Greenhouse-gas and Methyl Mercury Emissions

We derived our estimates of greenhouse-gas emissions and methyl mercury mineralization from a literature review of empirical studies conducted in Canada and at the Hydro Quebec La Grande complex. Details of this review, and further discussion of the strengths and weaknesses of the studies, as well as a discussion of how we derived greenhouse-gas estimates are in Appendix G.

3.6.1 Greenhouse-gas emissions.

Over the last decade, research has led to the conclusion that artificial reservoirs are sources of greenhouse-gases (Rudd et al, 1993, Chamberland 1993, Kelly et al. 1994, Duchemin et al. 1995, Fernside 1995, Galy-Laxaux et al. 1997). Decomposition of flooded vegetation leads to the release of carbon stored in the biomass. Where decomposition tends toward aerobic conditions, CO2 is typically released to both the water column and the atmosphere. Where anoxic conditions dominate, methane and hydrogen sulfide are released.

We used Duchemin's estimates of CO2 and CH4 releases for deep and shallow waters (Duchemin et al. 1995 & 1997). We used Chamberland's (1993) estimates of the ratio of deep and shallow waters at the La Grande complex: 10% of the La Grande project lands is shallow (less than 10 meters), and 90 percent is deep. We used Fernside's (1995) estimate of decay rates and release curves for the flooded carbon stock based over a 50-year life. We chose Duchemin's estimates because they are based on direct measurements from the La Grande complex. Other studies of greenhouse-gases, including those of the Freshwater Institute, are also based on direct measurement, but are conducted at other boreal reservoirs. In addition, the Freshwater Institute studies are primarily concerned with flooded peatland, which is thought to release more greenhouse-gasses than other forest soils.

Duchemin (1995 & 1997) measured CO2 and CH4 emissions in the La Grande reservoirs at the air-water interface in both shallow and deep regions of the lake. The studies are limited in a number of ways. They assume that there are only 120 days of ice-out conditions and that no greenhouse-gasses will be accumulated or released when the reservoir is frozen. They did not account for the increased contribution of flooded peatland. They did not account for the possible increased biological activity along the riparian borders where lake levels inundate and retreat with seasonally. In addition, the Duchemin studies did not conduct a mass-balance of carbon emissions from the lands before and after flooding in order to establish an estimate of net greenhouse-gas flux. For these reasons, we conclude that Duchemin's measurements are likely to be conservative underestimates of the total greenhouse-gas emissions from the La Grande project.

All of the studies of boreal reservoirs measure greenhouse-gas emissions at a certain point in time (Rudd,1993, Duchemin, 1995, Chamberland, 1993). However, these studies made few quantitative estimates of the total flooded carbon stock that would be released as CH4 and CO2, and no estimates of the magnitude of greenhouse-gas flows over time. In contrast, Fearnside (1995) estimated the total carbon stocks associated with three zones in the reservoir: anoxic or fully submerged material, partially aerobic within 3 meters of the surface area, and aerobic organic material flooded by the reservoir but periodically exposed to the air. The zones included deeply submerged organic materials that were assumed to decay very slowly (over 500 years) and produce primarily methane. Fearnside assigned biological decay rates and percent releases of CH4 and CO2 for all the carbon stored in the studied reservoirs and developed release curves associated with different points in time. In order to estimate the greenhouse-gas releases from Canadian and New England reservoirs, we used the measured emissions data at the water-air interface from reservoir studies at theLa Grande complex in years 17 to 22 after flooding. We placed the empirical data from the La Grande complex on the Fearnside emission rate curve in order to assign a total value for greenhouse-gas emissions for each reservoir studied for 50 years following flooding, and to assign relative impacts to each year in the hydro life cycle.

The estimates of greenhouse-gas releases were converted to grams per square meter per year at the water-air interface. Using the same ratio of 10 percent shallow and 90 percent deep, we developed profiles of greenhouse-gas releases for the New England reservoirs. It is likely that these estimates exaggerate actual emissions from New England reservoirs. In contrast to boreal reservoirs, when temperate reservoirs were constructed the timber was typically first harvested and sold, removing considerable amounts of the carbon stock before flooding lands. In addition, most of these reservoirs were flooded in the late 1800s and early 1900s. Assuming that Fernside's greenhouse-gas release curve is valid, then the CO2 releases are currently reduced to background levels. Also, all of the New England reservoirs are many times smaller than the Hydro Quebec La Grande complex. The profile of the lake tends to have a higher ratio of shallow to deep water than those found at La Grande. As can be seen in Table 4, emissions of both CH4 and CO2 are lower in shallow waters, and the proportion of methane to carbon dioxide is smaller. Both of these factors would lead to lower total greenhouse-gas emissions per unit of energy.

Table 4 Estimated greenhouse-gas emissions from reservoirs (metric tons/m^2/180 days)

	shallow		deep	
	ch4	co2	ch4	co2
Estimated release	0.00000220	0.00579306	0.00000092	0.00695168
CH4 as CO2 equivalent		0.00004615		0.00001923
Total		0.00583922		0.00697091

Figure 3 shows the CO2 and CH4 curves for the La Grande complex. We assumed that ice-in conditions stop greenhouse-gas production. We assumed ice-out conditions of 120 days for the La Grande complex and 180 days for the New England dams.

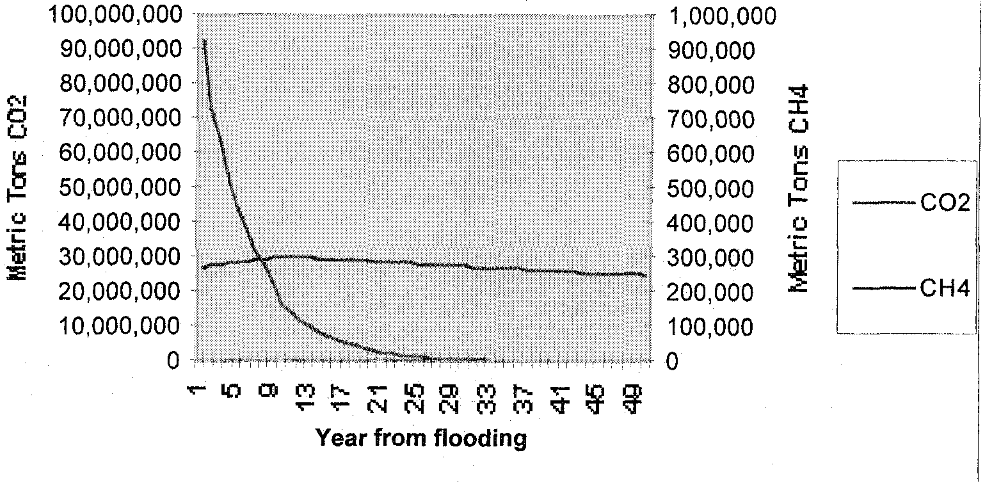


Figure 3 Hydro Quebec Operations Emissions

We adjusted the CH4 impacts into CO2 equivalents by utilizing a multiplier of 21 for the following reasons. The Intergovernmental Panel for Climate Change (IPCC) preferred method for calculating direct impacts from CH4 releases is to consider a 100-year timeframe without discounting (Isaksen et al. 1992). When considering direct impacts only, the IPCC recommends utilizing a CO2 equivalent multiplier of 11. When considering the indirect impacts, the IPCC recommends a CO2 equivalent multiplier of 21. Methane's direct effects are directly related to atmospheric warming, and its indirect effects are due to the production of tropospheric ozone and stratospheric water vapor. CO2 emissions include no indirect effects (IPCC 1996). Because this study is concerned with the cumulative impacts of hydroelectricity, and because many of the methane-related impacts to global warming are indirect, we chose the higher multiplier

3.6.2 Methyl mercury emissions.

Mercury is a known mutagen, tetragen, and carcinogen (FS 1984). At comparatively low levels, mercury absorbed by animals behaves as a neurological toxin, affecting behavior, reproduction and other basic biological functions. At sufficient levels, mercury ingestion is fatal. Mercury has no known metabolic function, and bio accumulates at higher trophic levels. Many documented examples of mercury poisoning follow its rapid path through the environment, from toxic release, to accumulation at higher levels of the food chain, to toxic impacts on human populations (Eisler 1987).

Ample evidence supports the claim that mercury levels increase significantly in recently flooded reservoirs (Potter et al. 1974, Abernathy & Crumbie 1977). Extensive research in Quebec, Ontario, Manitoba (Bodaly et al. 1983 & 1991), Finland, Sweden (Lodenius et al. 1983) and the Southeast US (Abernathy et al. 1977) indicate that mercury levels in reservoir fish are between two and five times higher than that of fish in unpolluted, natural lakes.

The increase of mercury in newly flooded reservoirs is thought to result from the release of natural and deposited inorganic mercury in the soil (Abernaty & Crumbie 1977, Bodaly 1991). Flooded reservoirs tend to support increased microorganism activity as the flooded biomass becomes an available food source. Chemical speciation of mercury is complex, especially in reservoir environments. However, in newly flooded areas, the toxic characteristics of mercury tends to increase by following path from inorganic forms of Hg, which are most common in soils, to organic methylated forms of mercury, which are more common in water (Trembaly & Lucotte 1997). Anaerobic and aerobic microbial activity converts the various species of inorganic mercury (Hg^0) to the highly toxic and mobile methyl mercury (CH^3Hg^+).

Methyl mercury is a particularly toxic species of Hg because of its stability and solubility in fats, and its ionic potential tends to move the molecule across cell membranes. Once ingested, it accumulates in fatty tissues. Organisms higher up the food chain, such as predatory fish and fish feeding birds and mammals, tend to have the highest concentrations of methyl mercury. Data collected from the La Grande complex indicates that mercury levels in predatory fish 20 years after flooding remain on average five times higher than marketable levels established by the

Canadian government (Tremblay & Lucotte 1997). Mercury levels in predatory fish from natural lakes in the region are within marketable thresholds.

Most of the published literature concerning methyl mercury in reservoirs has been conducted in Canada in response to mercury poisoning of the Cree Indians and other indigenous peoples living around the large Canadian reservoirs[4]. The Freshwater Institute at the University of Manitoba created an artificial reservoir and tested the total mercury and methyl mercury content of the natural pond and flooded reservoir before and after flooding in 1992 (Kelly et al. 1997, Rosenberg et al. 1997). Their ongoing studies indicate that northern peat landmasses are small net annual sources of total mercury and methyl mercury. Following flooding, total mercury increases marginally, but the percentage of methyl mercury increased from 4 percent to 79 percent, with a long-term average increase of 37 percent.

Table 5 Measurement of percent change in methyl mercury (Kelly et al. 1997)

(ng/L-1)	Before	After Flooding	Net Change
Total Hg	2.5	2.65	0.15
Methyl mercury	0.1	0.98	0.88

Other findings indicate that methyl mercury concentration in fish and in the water column are more dependent on upstream factors than reservoir factors (Johnston et al. 1991). Two variable models of fish mercury levels from physical characteristics of the flooded reservoirs, utilizing within-lake measures and upstream measures, were able to account for more than 70 percent of the variation in mercury levels. Upstream characteristics accounted for the majority of impacts.

In the US and other sub-arctic temperate countries there has been little empirical work concerning methyl mercury in reservoirs. Elevated mercury levels in natural and artificial lakes have been

---

[4] The Cree Regional Authority's successfully 1986 suit against Hydro Quebec and the Quebec government brought international attention to the environmental impacts of Quebec's hydroelectric projects. This suit, along with others, has been a catalyst for scientific research into these impacts.

recorded throughout the US, but it is assumed that these high levels of mercury are related to atmospheric deposition and point-source pollution instead of methyl mercury mobilization from flooding new lands (USFWS 1987). This theory is supported by the fact that most reservoirs in the U.S. are older than 50 years, suggesting that initial impacts from flooding would be mitigated.

Empirical data on the residence time and turnover rate of methyl mercury in reservoirs has yet to be established. Actual methyl mercury loads in reservoirs depend on numerous site-specific factors, including inflow and outflow of the impoundment, acidity, soil substrates, atmospheric deposition, dissolved oxygen content, and the quantity of flooded biomass (Lodenius et al. 1982). Empirical evidence from the Experimental Lake project indicates that methyl mercury in the water column returns to background levels after 10 years (Kelly et al. 1997). Mass balance models of methyl mercury in reservoirs are currently under development by private consulting firms (Manitoba Hydro 1997). These models depend on data collected by the Freshwater Institute and are calibrated to predict mercury levels in fish in specific regions. No estimates of residence time or turnover rate used in the model are publicly available (Literature search and personal correspondence with Dr. Reed Harris). Best-guess estimates of mercury residence time in fish from newly flooded reservoirs vary from five years (Abernathy & Cumbie 1977) to more than 30 years (Maxwell et al. 1997).

Extensive measurements of mercury accumulation in fish do not provide adequate information for assessing the annual production of mercury per liter, residence time, or turnover rate. However, given the persistence of methyl mercury in fish tissue, and the fact that elevated levels tend to peak, stabilize and slowly decline over time, it is hypothesized that methyl mercury formation in newly flooded reservoirs will bloom in the first years of the flooded system. Future impacts and biological accumulation in the biota result from an initial bloom of methyl mercury (personal correspondence with Dr. Drew Bodaly, Freshwater Institute; Dr. Reed Harris). The Freshwater institute is currently using 10 years for average residence time in the water column.

Table 6 summarizes the estimates of methyl mercury contamination used in this study. The net change in methyl mercury in nanograms per liter$^{-(1)}$, as measured by Kelly (1997), was multiplied by the total volume of water in each reservoir. We assumed the average turnover time to be one year, and that the measured quantity of methyl mercury declined to background levels over 10 years following a linear curve. We estimated the total methylation of mercury in each reservoir for each year and divided the annual emission by average annual generation. The table includes conversion into total pounds of methyl mercury generated in the entire reservoir each year.

Table 6 Methyl mercury mobilization from flooding at the La Grande Complex

year	1	2	3	4	5	6	7	8	9	10
Total MeHg	0.980	0.882	0.784	0.687	0.589	0.491	0.393	0.296	0.198	0.100
Net MeHg (ng L^{-1})	0.880	0.792	0.704	0.616	0.528	0.440	0.352	0.264	0.176	0.088
Total Reservoir (g/year)	83,877	75,489	67,101	58,714	50,326	41,938	33,551	25,163	16,775	8,388
Total Reservoir (kg/year)	84	75	67	59	50	42	34	25	17	8
Total Reservoir (lbs/year)	185	166	148	129	111	92	74	55	37	18

3.7 Comparison of Our Methods to Other Quantitative Hydro Studies

Our methodology appears to be unique. LCA and externality cost studies of fuel cycles more typically define the major direct materials as the average of a set of "representative" products (ETH 1994, PACE 1990). For hydro projects this typically means the average direct material inputs for, say, zero to 30-megawatts of installed capacity, and 30-100 MW projects. The model would then aggregate impacts to a kilowatt-hour functional output, so that within the tested range impacts would be linearly related.

The problem with this approach is that the quantity of the material inputs into a hydro facility is assumed to be linearly correlated to the megawatt-hour output of the facility. However, we have found that megawatt-hour output is not a good predictor of the size of the impoundment, the size of the dam, the length of the transmission lines or other necessary infrastructure which lead to life cycle emissions. In constructing our model, we assumed that most hydroelectric facilities have similar direct materials inputs in similar proportions to the Morrow Point Dam project. But, rather than directly apply impacts to energy output, we assume that the total volume of material inputs to hydro projects is site-specific rather than linearly related to average annual generation. For example, a large dam in a small drainage may have small annual generation, a large reservoir, and a proportionally large upstream burden.

Table 7 Average annual generation dependence on dam volume

Multiple R	0.7636912					
R Square	0.58322425					
Adjusted R Square	0.57969225					
Standard Error	6613808.67					
Observations	120					
	Coefficients	**Standard Error**	**t -Statistic**	**p-value**	**Lower 95%**	**Upper 95%**
Intercept	-2169188.5	680243.271	-3.1888423	0.00182943	-3516253.9	-822123.12
Dam Volume	79.7969464	6.2098156	12.8501314	3.5798E-24	67.4998343	92.0940585

In order to assess the variability of material inputs to annual kilowatt output, we regressed the volume of dam materials (dependant variable) into the average annual kilowatt hour output (the independent variable) of all New England concrete hydroelectric facilities. Table 7 summarizes the results of the simple regression model. The model indicated that material inputs explain approximately 58 percent of average annual generation. This suggests that traditional methods of assigning environmental impacts directly to kilowatt-hour output would falsely allocate more than 40 percent of impacts to certain projects.

3.8 Assumptions and Weakness in the Data and Model

We consider our model to provide baseline information about the pool of New England hydroelectric projects. We find that our methods could be useful in assessing baseline information at other hydroelectric sites, or for other fuel cycles, in an efficient and affordable manner.

There are a number of weaknesses in our methods and the data used to model hydroelectric emissions. The scope of our model, though beyond other published assessments of the hydro fuel cycle, is limited to upstream emissions plus two pollutant emissions from the operations-phase. We were unable to model other environmental impacts external to the hydro fuel cycle, such as water-quality effects, or changes in biodiversity. Our research suggests that these impacts are site-specific and often internalized in the cost of operations. Modeling these impacts would require detailed knowledge about the individual projects and other land uses in the watershed. In addition, the scope of our project did not include end-of-life assessments, such as decommission, breaching or retrofitting.

We assume similar material inputs for all concrete dams and associated infrastructure. Many of the dams included in this assessment were constructed more than 100 years ago. The construction methods and materials used are somewhat different than those of today. In addition, we depend on only one set of input data from the Morrow Dam, and we assume that other hydroelectric facilities use materials in similar proportions. Further, we estimated dam volume at our reference sites based on height and width characteristics of the Morrow Point Dam. A more complete methodology would utilize detailed input data from each hydro facility assessed. However, at this time such data is not publicly available in sufficient detail to support such an analysis.

Finally, we qualitatively describe our assumptions and inconsistencies in the data, but we provide no quantitative estimates of uncertainty. One published study on the hydro fuel cycle utilizes Monte Carlo modeling to develop quantitative estimates of uncertainty (DOE 1995). This would be possible with the data we collected, but we felt it was beyond the scope and charter of this project.

In summary, we have taken a new approach to quantifying emissions from the hydro fuel cycle on a regional basis. Because we assessed every hydroelectric project in New England, our results are necessarily generalized. The number of projects in our assessment reduced our ability to study many of the fuel cycle impacts for which generalized data was not available. Nonetheless, our results provide insight into the environmental impacts of the fuel cycle and provide baseline information from which further site-specific modeling can be done.

CHAPTER IV

INVENTORY OF EMISSIONS FROM THE HYDRO FUEL CYCLE

4.1 Introduction

We theorized that larger projects would have larger impacts when normalized to annual generation. We assumed that smaller projects, as assessed by the volume of the dam superstructure, would be built first in areas with proportionally high head, thus minimizing the materials used and associated environmental impacts when considered on a per unit of energy metric. We find that both small and large projects have profiles that cannot be easily generalized by the small, medium and large criteria. Rather, we have developed three sets of ratios, including dam volume, reservoir size, and reservoir surface area to annual generation, to more easily generalize impacts from individual projects.

The primary purpose of this section is to profile the inventory of emissions released during the upstream, construction and operations-phases. We first look at the emissions from construction of a generic 10,000 cubic yards of new hydroelectric dam. We used LCNetBase to model upstream and construction-phase emissions. LCNetBase output allowed us to consider emissions by chemical, supply chain tier and industry. This assessment is important in identifying emissions from the hydro fuel cycle that are similar by chemical type, rather than quantity or environmental impact, for all hydroelectric projects.

In section 5.2 we present the results of our assessment of upstream emissions from the New England and the La Grande complex hydroelectric projects. The results are normalized by the average annual megawatt hour output of each project over 50 years in order to compare the impacts in a common metric. In section 5.3 we present the results of our assessment of emissions from the operations-phase. In section 5.4 we combine upstream and operations emissions and present the results for small, medium and large dams.

4.2 Upstream Emissions to the Environment from the Hydro Fuel Cycle

In order to assess the upstream and construction-phase emissions of hydroelectric projects we calculated the materials and energy used to create a hypothetical 10,000 cubic yards of hydroelectric dam and associated superstructure. In the New England context, 10,000 cubic yards would represent the smallest hydro projects, with the largest projects extending well over a million cubic yards.

Eight emission categories were used to assess the total upstream environmental impacts of hydro projects. Table 8 summarizes the impact indicators.

Table 8 Upstream emissions from the hydro fuel cycle assessed in this study

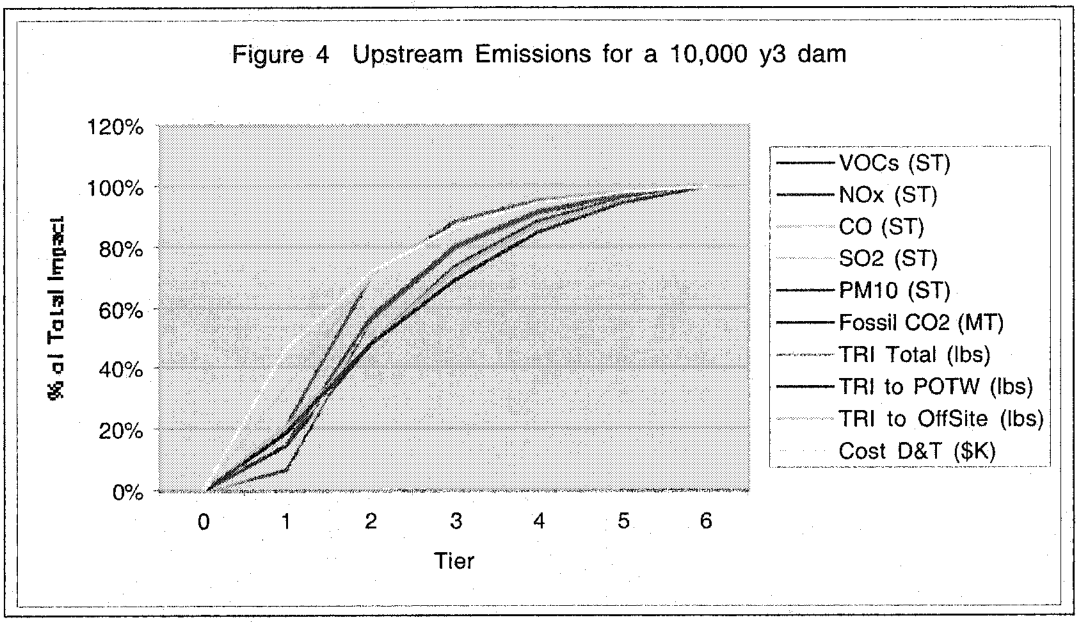
Symbol	Description (total upstream)	Measurement
VOCs	Volatile organic compounds to air	Short Tons (ST)
NOx	Nitrogen oxides to air	Short Tons (ST)
CO	Carbon monoxides to air	Short Tons (ST)
SO2	Sulfur dioxides to air	Short Tons (ST)
PM10	Particulate matter < 10 microns to air	Short Tons (ST)
Fossil CO2	Carbon dioxide from fossil fuel combustion to air	Metric Tons (MT)
TRI	Toxic releases to air, water, underground, land, public waste treatment, other off-site processes	Pounds (lbs)
D&T	Expenditures on treatment and disposal of all wastes	2000 dollars ($K)

Table 9 summarizes the total upstream and construction-phase emissions associated with the eight indicators for 10,000 cubic yards of new dam construction. In this table, the toxic release inventory is further divided to highlight the direction of the pollutant flows.

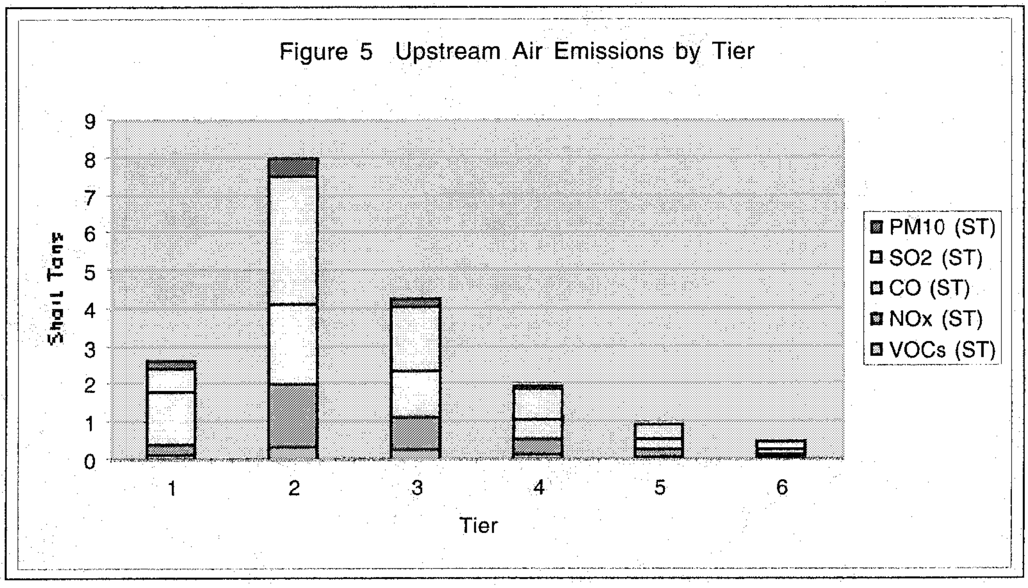
Table 9 Upstream inventory results	**Total**
VOCs to air (ST)	1.06566
NOx to air (ST)	3.52334
CO to air (ST)	5.6916
SO2 to air (ST)	6.9435
PM10 to air (ST)	1.01954
Fossil CO2 (MT)	1514.17
TRI to Air (lbs)	713.64
TRI to Water (lbs)	73.397
TRI to UnGnd (lbs)	280.02
TRI to Land (lbs)	383.831
TRI to Total Environment (lbs)	1450.97
TRI to POTW (lbs)	160.841
TRI to OffSite (lbs)	3043.04
Cost D&T ($K)	2.31648

For our hypothetical dam project, upstream emissions range from 1 to 7 short tons of air pollutants. Approximately 1500 metric tons of CO2 would be released at other, off-site facilities along the supply chain and from fossil-fuel combustion during construction.

Figure 4 shows the emissions associated with upstream production tiers. The figure shows that the bulk of emissions, close to 80 percent, are associated with the first three tiers of production.



Figures 5 through 7 highlight the upstream emissions for conventional air pollutants and CO2 releases for six of the upstream tiers. For all of the environmental impact categories, the majority of impacts occur in the second production tier. For air pollutants, SO_2, CO and NOx comprise the majority of releases and account for more than 7 short tons of emissions.



The second production tier accounts for the majority of upstream CO2 emissions. Figure 6 indicates that more than 550 metric tons of CO2 were released in the second production tier and that approximately 400 metric tons of CO2 were releases in the first production tier.

Figure 6 Upstream CO2 Emissions by Tier

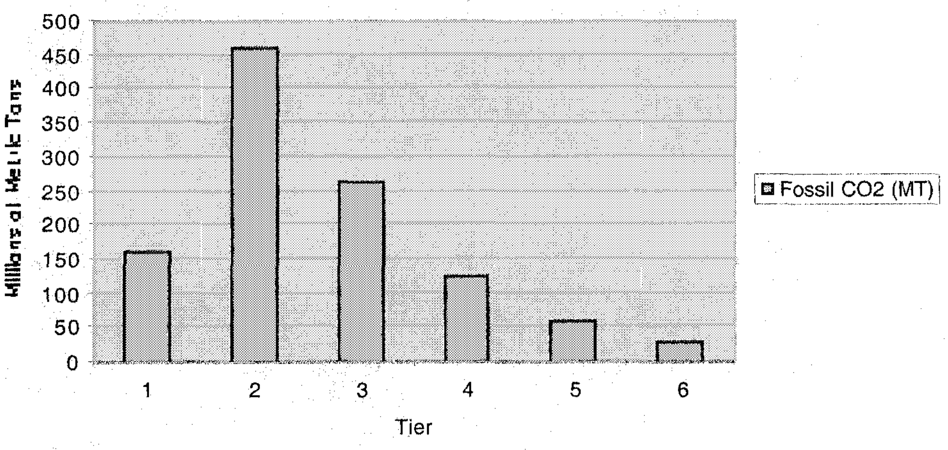
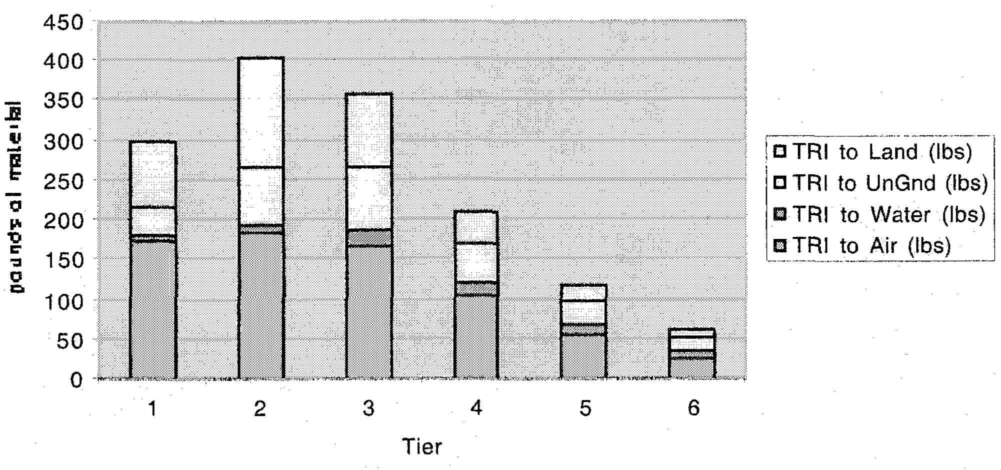


Figure 7 shows the upstream emission of toxic chemicals by tier. As with the other upstream emissions, the second production tier accounts for the majority of TRI releases with a cumulative total of approximately 1500 lbs. For all tiers, toxic emissions to air and land account for the majority of TRI emissions.

4.2.1 Upstream emissions by industry.

We reviewed the upstream impacts from various industries in order to understand which industrial inputs to hydroelectric dam construction contribute the largest environmental emissions. As with other factors assessed in the upstream analysis, the data is modeled in LCNetBase from the BEA "make and use" tables at the 500-commodity/industry level. The figures are presented in Appendix F. We considered the upstream emissions of pollutants associated with the 15 largest industrial producers of the emissions in the supply chain. No industry dominates all emission categories , however a number of industries are in the top five producers of many of the pollutants, including blast furnaces, industrial inorganic and organic chemicals, and concrete and cement products.

Figure 7 Upstream Toxic Emissions by Tier



For volatile organic compounds (VOCs) to the air, the top 15 industries account for approximately 75 percent of all VOCs produced from upstream material assembly and facility construction. The four largest emitters of VOCs are industrial inorganic and organic chemicals, petroleum refining, blast furnaces and steel mills, plastics materials and resins. These industries account for approximately 45 percent of all VOC emissions.

For upstream emissions of Nitrogen Oxides (NOx) to the air, the top 15 industries account for more than 95 percent of all NOx produced. The two largest industrial polluters of NOx, electrical services and hydraulic cement, are responsible for more than 65 percent of all upstream NOx releases.

For carbon monoxide (CO) releases to the air, the top 15 industries are responsible for more than 95 percent of upstream CO emissions. Blast furnaces alone accounts for more than 55 percent of these emissions, which is the single highest industrial producer of any of the emissions studied.

For upstream emissions of sulfur dioxide (SO2) to the air, the top 15 industries account for more than 95 percent of all SO2 produced in the cradle-to-gate scenario. The two largest industrial polluters of SO2, electrical services and hydraulic cement, are responsible for more than 65 percent of all upstream SO2 releases.

For upstream emissions of Toxic Release Inventory (TRI) chemicals to the environment, the top 15 industries account for more than 80 percent of all upstream TRI chemicals released. The two largest industrial polluters of TRI chemicals, blast furnaces and petroleum refineries, are responsible for approximately 85 percent of all upstream TRI releases.

For upstream emissions of particulate matter (PM10) to the air, the top 15 industries account for approximately 90 percent of all PM10 produced in the cradle-to-gate scenario. The two largest industrial polluters of PM10, hydraulic cement and blast furnaces, are responsible for more than 40 percent of all upstream PM10 releases.

For upstream emissions of carbon dioxide (CO2) to the air, the top 15 industries account for approximately 90 percent of all CO2 produced in the cradle-to-gate scenario, with two largest industrial polluters of PM10, motor freight and electrical services, responsible for approximately 36 percent of all upstream CO2 releases.

4.2.2 Other upstream inventory questions that could be explored with IO-LCA

Output from LCNetBase allows for a considerably more detailed study of upstream emissions data and results. For example, we could identify industries responsible for each release, to the chemical level, for each tier. We could graph material, product and service inputs for each type of emissions. And, we could categorize the largest emission contributors. However, such a detailed analysis is not pertinent to our research question and is, therefore, beyond the scope of this study.

Table 10 Structural characteristics of hydro projects included in this study

	Model #	#of Dams in Group	Average Dam Volume (y3)	Average Annual MWh	Increase in Cubic Yards of Material (1000y3)
Small Dams	1	27	12,500	2,003	0-19
	2	29	29,186	2,355	20-39
	3	23	51,178	4,705	40-59
	4	15	67,551	8,974	60-79
	5	6	92,062	12,315	80-99
	6	7	109,818	13,606	100-120
	7	5	124,980	19,574	120-139
	8	5	150,940	19,320	140-159
	9	3	173,213	11,878	160-179
	10	4	190,796	27,445	180-199
Medium Dams	11	12	239,445	54,558	200-299
	12	11	350,824	86,435	300-399
	13	4	444,124	34,605	400-499
	14	2	536,410	64,700	500-599
	15	5	668,321	104,984	600-699
	16	2	769,542	30,644	700-799
	17	2	871,704	16,850	800-899
	18	1	905,072	228,042	900-999
Large Dams	19	5	1,335,549	51,517	1m
	20	1	2,162,999	148,850	2m
	21	1	3,554,953	105,200	4m
	22	2	6,800,742	277,800	5m
	23	1	8,018,947	356,064	6m
Hydro Quebec	24	4	87,000,000	6,800,000	
	Total	178			

4.3 Upstream Emissions from New England & Hydro Quebec Projects

It is difficult to understand the results of life cycle models outside of a direct comparison between similar products. In this study, we compare upstream emissions between small, medium and large hydroelectric projects in New England normalized to a unit of energy output for each group.

Table 11 Upstream conventional air emissions (metric/MWh)

	VOCs to air (ST)	NOx to air (ST)	CO to air (ST)	SO2 to air (ST)	PM10 to air (ST)	Fossil CO2 (MT)	TRI OffSite (lbs)	Cost D&T ($K)
1	1.11E-04	3.68E-04	5.95E-04	7.26E-04	1.07E-04	1.58E-01	3.18E-01	2.42E-04
2	5.71E-05	1.89E-04	3.05E-04	3.72E-04	5.46E-05	8.11E-02	1.63E-01	1.24E-04
3	7.62E-05	2.52E-04	4.07E-04	4.97E-04	7.29E-05	1.08E-01	2.18E-01	1.66E-04
4	5.52E-05	1.83E-04	2.95E-04	3.60E-04	5.28E-05	7.85E-02	1.58E-01	1.20E-04
5	1.35E-04	4.47E-04	7.22E-04	8.81E-04	1.29E-04	1.92E-01	3.86E-01	2.94E-04
6	4.19E-05	1.39E-04	2.24E-04	2.73E-04	4.01E-05	5.96E-02	1.20E-01	9.11E-05
7	5.91E-05	1.95E-04	3.16E-04	3.85E-04	5.65E-05	8.40E-02	1.69E-01	1.28E-04
8	3.00E-05	9.91E-05	1.60E-04	1.95E-04	2.87E-05	4.26E-02	8.56E-02	6.51E-05
9	3.56E-05	1.18E-04	1.90E-04	2.32E-04	3.40E-05	5.05E-02	1.02E-01	7.73E-05
10	1.97E-05	6.52E-05	1.05E-04	1.28E-04	1.89E-05	2.80E-02	5.63E-02	4.29E-05
11	6.13E-05	2.03E-04	3.27E-04	3.99E-04	5.86E-05	8.71E-02	1.75E-01	1.33E-04
12	1.70E-05	5.64E-05	9.10E-05	1.11E-04	1.63E-05	2.42E-02	4.87E-02	3.71E-05
13	3.79E-05	1.25E-04	2.03E-04	2.47E-04	3.63E-05	5.39E-02	1.08E-01	8.24E-05
14	1.88E-05	6.22E-05	1.00E-04	1.23E-04	1.80E-05	2.67E-02	5.37E-02	4.09E-05
15	1.73E-05	5.73E-05	9.25E-05	1.13E-04	1.66E-05	2.46E-02	4.95E-02	3.77E-05
16	6.71E-05	2.22E-04	3.59E-04	4.37E-04	6.42E-05	9.54E-02	1.92E-01	1.46E-04
17	1.57E-04	5.18E-04	8.37E-04	1.02E-03	1.50E-04	2.23E-01	4.48E-01	3.41E-04
18	8.46E-06	2.80E-05	4.52E-05	5.51E-05	8.09E-06	1.20E-02	2.42E-02	1.84E-05
19	1.15E-04	3.79E-04	6.13E-04	7.47E-04	1.10E-04	1.63E-01	3.28E-01	2.49E-04
20	3.10E-05	1.02E-04	1.65E-04	2.02E-04	2.96E-05	4.40E-02	8.84E-02	6.73E-05
21	7.20E-05	2.38E-04	3.85E-04	4.69E-04	6.89E-05	1.02E-01	2.06E-01	1.57E-04
22	5.25E-05	1.74E-04	2.80E-04	3.42E-04	5.02E-05	7.46E-02	1.50E-01	1.14E-04
23	4.80E-05	1.59E-04	2.56E-04	3.13E-04	4.59E-05	6.82E-02	1.37E-01	1.04E-04
HQ	3.04E-05	9.30E-05	1.52E-04	1.84E-04	2.69E-05	4.04E-02	8.44E-02	6.30E-05

As described in the methods section, New England dams selected for this study were averaged together to represent small, medium and large dams. Within each category, models were developed to capture the gradual increase in superstructure volume, and the associated average annual generation for appropriate increases in dam size. Table 10 summarizes the models used throughout this analysis, including the number of dams averaged together in each model, the average volume of superstructure materials, average annual megawatt-hour output, and our trigger points for project size. The volume of superstructure materials and the average annual energy production for the Hydro Quebec model exceeds by an order of magnitude the largest New England projects assessed.

Upstream and construction emissions from New England and Hydro Quebec projects were assessed by multiplying structural material emissions with the structural characteristics of all individual project assessed. The results were normalized by dividing emissions into the average annual kilowatt output for the each project. Table 11 summarizes the upstream conventional air pollutants per megawatt hour. The model numbers listed in Column A correspond to the model numbers in Table 4.4. For each group of small, medium and large, we highlighted the project with the largest upstream emissions in yellow, and the smallest upstream emissions in green.

We found no pattern of emissions per unit of energy based on the size of the project. Some small projects, such as model 5, have large upstream emissions per MWh, while the La Grande project, model 24, has proportionally small upstream emissions.

Table 12 Average upstream emissions for small, medium and large dams (metric/MWh)

Project Size	VOCs to air (ST)	NOx to air (ST)	CO to air (ST)	SO2 to air (ST)	PM10 to air (ST)	Fossil CO2 (MT)	TRI OffSite (lbs)	Cost D&T ($K)
small	6.21E-05	2.05E-04	3.32E-04	4.05E-04	5.94E-05	8.83E-02	1.77E-01	1.35E-04
medium	4.81E-05	1.59E-04	2.57E-04	3.13E-04	4.60E-05	6.83E-02	1.37E-01	1.05E-04
large	6.36E-05	2.10E-04	3.40E-04	4.15E-04	6.09E-05	9.04E-02	1.82E-01	1.38E-04
HQ	3.04E-05	9.30E-05	1.52E-04	1.84E-04	2.69E-05	4.04E-02	8.44E-02	6.30E-05

Table 12 shows that with further averaging of the data, large New England dams tend to have slightly higher normalized upstream emissions per megawatt-hour output than smaller dams.

Hydro Quebec's La Grande complex, though extremely large in scope, has an upstream environmental burden that is less than the New England average.

4.4 Operations Emissions from New England and Hydro Quebec Projects

As indicated in the introduction, numerous operations impacts were not included in this analysis. The limited available data and uncertain methods for quantifying the impacts made assessment of impacts such as bio-diversity losses, changes in sedimentation patterns, or impacts to anadromous fish, both site-specific and difficult to quantify. However, recent discovery of greenhouse-gas emissions and methyl mercury releases from reservoirs provided adequate data to estimate these operations-related impacts for New England and Hydro Quebec. Table 13 summarizes the operations emissions per unit of energy for the assessed projects.

The methyl mercury cycle in new reservoirs is considered to be short (Kelly 1997). The initial bloom of organic mercury is thought to decline to background levels over 10 years following flooding. When amortized over 50 years of electricity generation, the impact of the initial bloom is small compared to other flows assessed in this study. On a per megawatt-hour basis, we found that short tons of methyl mercury emissions from New England dams range from $1*10^{-6}$ to $1*10^{-9}$ per megawatt hour. Methyl mercury per megawatt hour released from New England projects during operations is many times smaller than the toxic chemical emissions that result from construction activities. This is due in part to the small total active and passive volume of water in reservoirs as compared to the lifetime generation of the hydro project.

The mobilization of methyl mercury at the Hydro Quebec La Grande complex is considerably higher on a per megawatt-hour basis than that of the New England projects. We assessed the emissions to be on the order of $1*10^{-1}$ short tons per megawatt hour, approximately 10 times higher than the worst – case New England example. In addition, methyl mercury at the La

Grande complex represents a higher portion of toxic chemical emissions than those released during the construction phase. This can be explained by the relatively large volume of reservoirs to the power generated.

Table 13 Total operations-phase emissions of CO2 and MeHg+ (ST/MWh)

	Model #	CO2 Equivalent Emissions (ST/ MWH)	Methyl Mercury (STMWH)
Small	1	0.599039	0.007001
	2	0.312365	0.005575
	3	0.450178	0.028905
	4	0.025183	0.000613
	5	0.025323	0.001139
	6	0.026986	0.000790
	7	0.034714	0.000581
	8	0.030140	0.001001
	9	0.030081	0.000959
	10	0.012619	0.000396
Medium	11	0.048233	0.002543
	12	0.025875	0.000908
	13	0.487170	0.034605
	14	0.058558	0.001332
	15	0.061705	0.003563
	16	0.048232	0.002884
	17	0.920742	0.090743
	18	0.476056	0.042660
Large	19	0.181312	0.014916
	20	0.077244	0.005063
	21	0.010577	0.000033
	22	0.030594	0.006086
	23	0.033749	0.008039
	Hydro Quebec	1.822602	0.155703

Releases of CO_2 equivalent greenhouse-gases during the operation phase of the hydro life cycle represent a large portion of the total emissions from New England and Hydro Quebec projects. In New England, operations-phase greenhouse-gas emissions range from .01 to .92 tons per megawatt hour. In all cases, greenhouse-gas emissions are many orders of magnitude larger than the greenhouse-gas equivalents released during the construction phase.

Emissions of CO2 equivalent greenhouse-gases from the Hydro Quebec projects assessed in this study represent the largest flow of emissions during the operations-phase of the life cycle. We calculated just under 2 tons of greenhouse-gas emissions per megawatt hour. As with methyl mercury releases during the operations-phase, the large contribution of greenhouse-gas emissions from the Hydro Quebec model can be explained by the large volume of impounded water as compared to annual average generation.

CHAPTER V

DISCUSSION OF RESULTS

5.1 Introduction

In this section we look at methods for assessing individual projects against regional averages using simple ratios. Total emissions from the construction and operations-phases of hydroelectric facilities vary according to certain characteristics described in the previous section. We have found that simple descriptive ratios can provide substantial information about the environmental burdens of individual projects against the regional averages.

Hydroelectric projects with a large volume of construction materials embodied in superstructures and with relatively low electricity generation will produce larger upstream emissions per unit of energy generated from the facility. This suggests that, relative to baseline averages, a low ratio of dam volume to energy produced would be indicative of low upstream environmental emissions.

5.2 Energy Output as a Function of Dam Size

Table 13 appears to suggest that the annual megawatt-hour output of hydroelectric facilities increases with the volume of construction materials used in the superstructures. As discussed in the methods section, this is a common assumption embedded in other quantitative assessments of the hydro fuel cycle. However, generation and total volume of inputs do not appear to be tightly correlated. In Figure 8, we graph the volume of materials in the superstructure against the average annual kilowatt-hour output for each of the New England hydro projects. The graph shows that average annual energy production increases as dam size increases. However, there is considerable variation in average annual generation for all of the facilities assessed. Some large projects generate small amounts of electricity.

Figure 8 Dam volume to annual electricity production

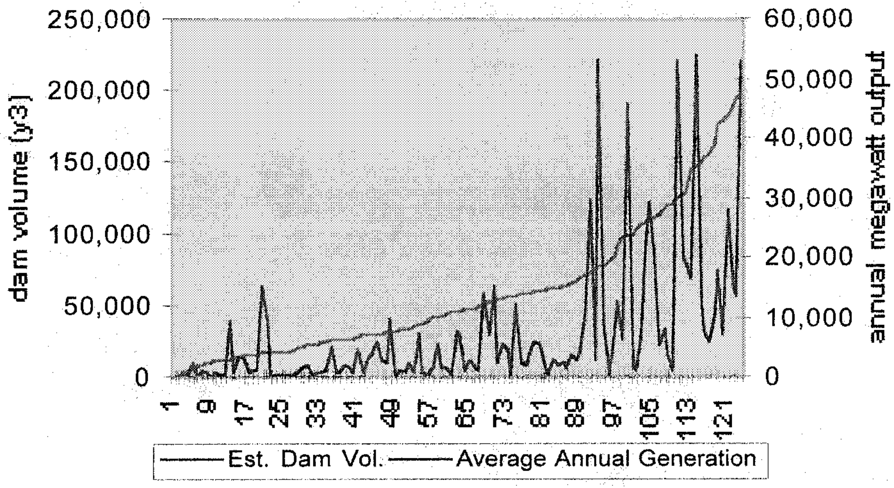


Figure 9 provides another view of the same data. Plotting the ratio of total dam volume to average annual energy production shows that there is little relationship between project size and energy output.

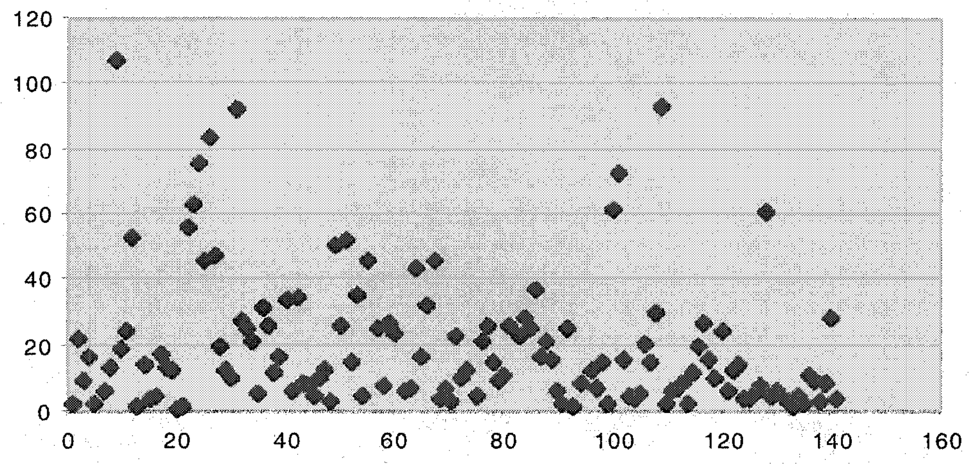


Figure 9 Ratio of Dam Volume to MWh

For demonstration purposes, we consider the Wyman Hydroelectric project (FERC # 2329.0101) located on the upper Kennebec River in northern Maine. The Wyman project has the largest dam volume and generates the most electricity of those New England projects assessed in this study. However, the project has a proportionally small reservoir and active generation volume. Ratio analysis, as summarized in Figure 10, indicates that the Wyman project has smaller upstream emissions per unit of energy when compared with other large New England projects. However, the upstream burdens from the Wyman project are marginally larger than small and medium-sized New England projects, and considerably larger than those of the Hydro Quebec projects.

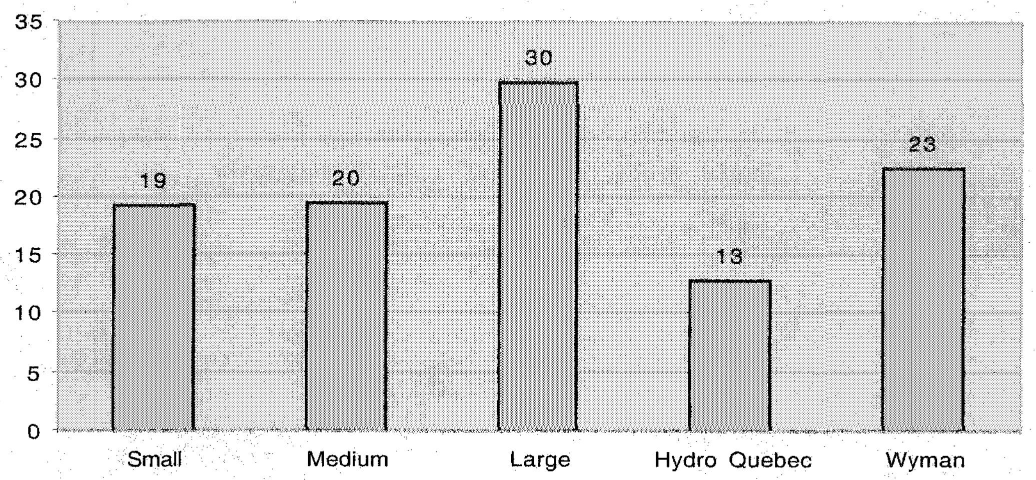
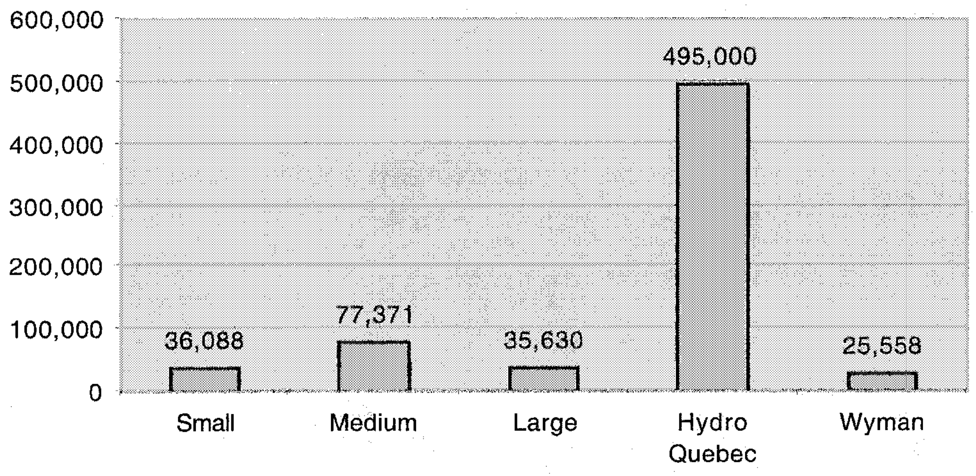


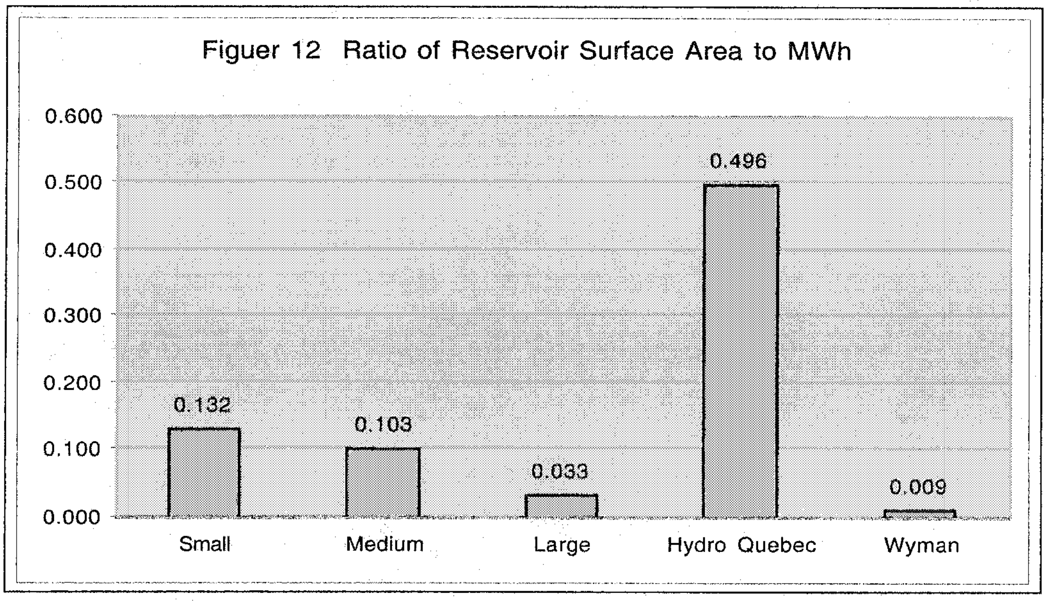
Figure 10 Ratio of Reservoir Volume to MWh

Similar descriptive ratios can be constructed for methyl mercury and greenhouse-gas emissions during the operations-phase. For methyl mercury, the descriptive ratio is the volume of impounded waters per unit of energy for a given project. Figure 11 summarizes mercury emission ratios. The Wyman project has proportionally small operations emissions of methyl mercury as compared to any of the New England baseline averages. Methyl mercury emissions from Wyman are many times smaller than emissions from the La Grande complex, as is the case with all of the New England projects.

Figure 11 Ratio of Reservoir Volume to MWh



For operations-phase greenhouse-gas emissions, the descriptive ratio is the final flooded surface area per unit of energy. The Wyman impoundment is characterized by a long, thin reservoir that follows the natural channel of the Kennebec River. Steep canyon walls reduced flooded surface area in proportion to the electricity generated. Figure 12 shows that greenhouse-gas emissions from the Wyman project are 10 times less that those associated with large New England projects and more than 100 times less than those of the Hydro Quebec La Grande complex.


Figuer 12 Ratio of Reservoir Surface Area to MWh
0.600
0.500
0.400
0.300
0.200
0.100
0.000
0.132
0.103
0.033
0.496
0.009
Small
Medium
Large
Hydro Quebec
Wyman

CHAPTER IV

CONCLUSIONS

The primary purpose of this paper was to construct a quantitative profile of external upstream and operations emissions from the hydro fuel cycle. The results of this study provide baseline data for further research in the valuation of the external impacts of the hydro fuel cycle. We hypothesized that external emissions are not zero and that small dams would have smaller emissions per unit of energy.

Using IO-LCA methods and LCNetBase software, we were able to profile upstream and construction-phase emissions. Using conventional LCA methods, we included two operations-phase emissions. We included 174 New England concrete hydroelectric dams and the four concrete dams associated with the Hydro Quebec La Grande project. Our model allowed us to consider emissions at both individual facilities as well as averages for the entire collection of hydroelectric facilities within the region.

We were unable to quantify many site-specific environmental impacts from the hydro fuel cycle, including impacts to water quality, fisheries and changes in land use. We determined that these impacts could be considered in site-specific analysis, but insufficient data was available for inclusion in our general profile of regional hydro assets.

We confirmed the first part of our hypothesis: that the emissions from the hydro fuel cycle are not zero. Both upstream and operations-phase activities generate direct and indirect emissions to air, water and land. Table 14 summarizes the emissions from the hydro fuel cycle during upstream and operations-phase activities. This data, and the associated model, provides sufficient detail to estimate societal values of hydro fuel cycle emissions.

Table 14 Normalized external emissions for small, medium, large and Hydro Quebec projects (metric/MWh)

	VOCs (ST)	NOx (ST)	CO (ST)	SO2 (ST)	PM10 (ST)
Small NE	1.88E-05	6.22E-05	1.01E-04	1.23E-04	1.80E-05
Medium NE	3.11E-05	1.03E-04	1.66E-04	2.03E-04	2.98E-05
Large NE	5.17E-05	1.71E-04	2.76E-04	3.37E-04	4.94E-05
Hydro Quebec	3.04E-05	9.30E-05	1.52E-04	1.84E-04	2.69E-05

	Fossil CO2 (MT)	TRI Air (lbs)	TRI Water (lbs)	TRI UnGnd (lbs)	TRI Land (lbs)
Small NE	2.67E-02	1.26E-02	1.30E-03	4.95E-03	6.78E-03
Medium NE	4.42E-02	2.08E-02	2.14E-03	8.17E-03	1.12E-02
Large NE	7.34E-02	3.46E-02	3.56E-03	1.36E-02	1.86E-02
Hydro Quebec	4.04E-02	2.01E-02	2.04E-03	7.72E-03	1.06E-02

	TRI POTW (lbs)	TRI Off-Site(lbs)	Cost D&T ($K)	CO2 Equiv (ST)	MeHg (ST)
Small NE	2.84E-03	5.38E-02	4.09E-05	1.55E-01	4.70E-03
Medium NE	4.69E-03	8.88E-02	6.76E-05	2.66E-01	2.24E-02
Large NE	7.80E-03	1.48E-01	1.12E-04	6.67E-02	6.83E-03
Hydro Quebec	4.45E-03	8.44E-02	6.30E-05	1.82E+00	1.56E-01

We incorrectly hypothesized that small New England hydroelectric facilities would emit a smaller quantity of emissions per unit of energy than larger projects. We assumed that sites with smallest infrastructure requirements relative to annual inflow and hydraulic head would have been developed first and would have proportionally low emissions compared to annual generation. However, when considered individually, the size and the age of the project have little bearing on the quantity of emissions per unit of energy. Certain small projects and certain large projects have very small emissions per megawatt hour, while other small and large projects have very high emissions per megawatt hour. The unique characteristics of the Hydro Quebec projects assessed in this study suggest that the life-cycle emissions per megawatt hour greatly exceed those of the New England pool. The Hydro Quebec operations-phase emissions are on an order of magnitude larger than the New England average.

In testing the second part of our hypothesis, we found that three simple ratios, dam size, reservoir size and reservoir surface area to annual generation, provide quick and simple estimates of the upstream and operations emissions assessed in this study. These ratios can be used to compare individual projects to regional averages, allowing for simple marginal assessments of proposed projects that are similar in size and annual average generation to existing projects.

PART II

LIFE CYCLE IMPACT ASSESSMENT OF THE HYDRO FUEL CYCLE

CHAPTER I

INTRODUCTION

This paper is the second in a series of three describing our Life Cycle Assessment (LCA) model of hydro emissions and externalities. In this paper, we conduct an LCA impact assessment of the hydro fuel cycle using economic valuation.

We have two main objectives. The first objective is to identify assumptions and problems in the application of economic valuation to LCA inventory data that can lead to erroneous results. To address this objective, we review the Craighill and Powell (1996) LCA impact assessment methodology, which borrows per unit economic damages from past studies, in order to understand how assumptions in economic studies are recognized, adjusted, or hidden when combined with LCA. We then consider the appropriate conditions for combining the Damage Function Approach (DFA), which is often used in economic valuation studies, with LCA in order to present more comprehensive impact assessment results. We develop heuristic tests to inform the level of detail needed in combining per unit economic damage values with the quantity of emissions estimated in LCA models. We suggest that the Craighill and Powell methodology is appropriate for average assessments of external impacts, particularly when assumptions embedded in the per unit economic valuation data are made explicit, or adjusted to dovetail with the assumptions in the LCA model. We anticipate that LCA impact assessments conducted using

DFA will provide additional detail and be appropriate for marginal, site-specific assessments of externalities.

Our second objective is to develop baseline, average externality estimates for the hydro fuel cycle in order to incorporate recent scientific understanding of hydro impacts into estimates of net external damages. In the first paper in this series, we developed an inventory assessment of upstream and operations-phase emissions for 174 New England concrete hydroelectric projects and four projects associated with the La Grande complex in Quebec. In this paper, we develop an impact assessment by combining the results of the inventory assessment with economic valuation. We follow the Craighill and Powell methodology and provide additional detail about our economic valuation step.

We find that the construction and operations-phase emissions assessed in this study are significant and measurable, and that the size of the hydro project is not useful in predicting normalized average emissions. We estimate the following average externality values for the hydro fuel cycle: small NE dams = \$.0343/kWh, medium NE dams = \$.0202/kWh, large NE dams = \$.0193/kWh, Hydro Quebec, La Grande Complex = \$.0461/kWh[5].

Our results indicate that the average external impacts from the hydro fuel cycle are less than, but similar to, the external costs of fossil fuel cycles. However, more detailed assessment of individual projects shows that emissions from the majority of hydro projects are very small compared to fossil fuel cycles. In contrast, site-specific characteristics, and a handful hydro projects greatly exceed emissions per unit of energy for the coal fuel cycle, and significantly increase our average estimates for small, medium and large New England dams.

---

[5] In this paper, all dollar units are reported for the year 2000 cost basis unless otherwise noted.

We conclude that life cycle assessment and economic valuation provide a useful and affordable methodology for assessing some of the external impacts of the hydro fuel cycle. The methodology allows for direct comparison of impact pathways in common units, as well as comparison of individual, site-specific projects against regional baseline estimates.

This paper is divided into six sections. In section 2 we discuss common LCA impact assessment methods with a focus on economic valuation. We present the Craighill and Powell methodology for combining LCA inventory output with economic valuation. We also consider the Damage Function Approach (DFA) used in economics for estimating net externalities at the margin. We identify important assumptions embedded in LCA with economic assessments and discuss the ability to transfer damage values between studies. In section 3 and 4 we present our methods and results for hydro impact assessment with economic valuation. Section 5 we consider our average externality estimates in the context of previous hydro externality studies, and we recommend steps for improving the transparency and validity of IO-LCA with economic valuation. Our conclusions are in section 6.

CHAPTER II

ECONOMIC VALUATION IN THE IMPACT ASSESSMENT

2.1 Introduction

One of the primary purposes of LCA modeling is to provide information for public decisions and policies about the environmental consequences of future actions (Fava 1991). Of concern to decision makers may be the impacts and costs of alternative technologies, the development of methods for designing new technologies that minimize total environmental burdens, or the identification of components within existing technologies that have the greatest external impacts. In LCA modeling, quantifying the emissions from material and energy use in a product or process is known as the inventory assessment. Translating the emissions into social, economic and ecological impacts is referred to as the impact assessment.

The majority of LCA studies conducted in the U.S. do not extend beyond the inventory assessment (Hunt & Franklin 1995). However, as it relates to public decisions and policy, problems arise when LCA studies are restricted to the inventory stage (Powell et al. 1997). Quantifying emissions in the inventory stage of LCA modeling does not inform society about the effect emissions have on the environment, human health, buildings, equipment, and other social factors. As Craighill and Powell (1996) state, “it is not the emissions themselves, but their resulting impact upon the environment with which we are concerned.”

LCA impact assessment allows for direct comparison of the impacts from emissions by placing value on emission parameters. The parameters are typically in common metrics such that the associated impacts can be compared between emissions categories, and summed for an assessment of cumulative impacts. When conducted, the impact assessment is often considered a controversial step in LCA methodology, in part because it requires the analyst to weight the relative impacts of unrelated emission flows on society. While the impact assessment allows us to compare emissions in a common metric, analysts must make assumptions about which emission has greater impacts on society and weight the impacts accordingly. The associated controversy has limited the use of LCA modeling in public policy (Shankle and Humphreys 1998).

Another factor that has limited the use of LCA in public policy is its focus on emissions from existing products or processes (see Rafenberg and Mayer 1998, Legarth et al., 2000). From a local, regional and state public policy perspective, emissions and impacts from the life cycle of existing products are only useful in so far as they inform strategies to minimized marginal impacts from future decision within a set of constraints (Mitchell and Carson 1989). LCA models concerned with past emissions are less helpful in making future decisions than assessments focused on the impacts of a proposed action. For example, quantification of the impacts from an existing recycling scheme is less useful to a municipality or a county in deciding what system to adopt than a study that considers the costs and impacts from a number of proposed waste disposal actions.

Also, from a public policy perspective, total impacts from a product or process are of less concern than those impacts that are external to the private costs of operations (Kahneman and Knetch

1992). Many impacts from a product or process may be incorporated in the costs of operations. For example, a hydro facility may reduce access to fishing and other recreation opportunities along a river. Regulation, however, may require the owners to build fishing access facilities. These costs would be included in the costs of operations. In contrast, the facility may reduce populations of anadromous fish, such as salmon, which could have impacts on commercial fisheries and reduce bio-diversity in the watershed. If regulation does not require the owners to mitigate for these costs, then these costs are external to the costs of doing business and are borne by society. From a policy perspective, it is the private costs, plus these costs which are external to private costs, that are of concern. Private costs plus external costs are referred to in this study as the total social costs.

In this section (2), we briefly review LCA impact assessment methodology, with a focus on economic valuation methods currently used. Then we consider problems in the impact assessment step when using economic valuation. Finally, we recommend heuristic measures for choosing the level of detail needed in the economic valuation impact assessment in order to fit within the scope of the LCA study and the type of public policy decisions to be made. We make three primary points in this section. First, of the LCA methods currently used for impact assessment, economic valuation is the most appropriate for policy decisions as it is focused on measures of total social costs, can provide estimates of marginal and average damages, and allows for consideration of externalities. Second, the methods currently used to combine LCA with economic valuation have deeply embedded assumptions, including assumptions about time-value, intergenerational equity and the value of human life. Third, the accuracy and applicability of LCA impact assessment with economic valuation could be improved if studies focus primarily on future decisions and assessments of change at the margin.

2.2 Impact Assessment Using Distance-to-target, Cost Control, and Scoring

Four methods are commonly used in LCA to choose weights for the emissions identified in inventory assessment: distance-to-target, environmental control costs, scoring, and economic valuation[6] (Powell, et al. 1997). The distance-to-target approach calculates weights for emissions by measuring the extent to which environmental performance exceeds desired standards (SETAC 1996) For example, if the actual level of PCBs in a water body is 11/ppm and the target level is 10/ppm, then a weight of 10 percent would be assigned to the impact. This method works on the assumption that the social and political processes for developing environmental standards represent the best possible action for maximizing social welfare.

The environmental control costs method determines weights for emissions by comparing the expenditures necessary to control the environmental damages for each impact (Powel et al. 1997). If controlling environmental damage requires 100 dollars per unit for one impact and 200 dollars per unit for a second impact, then the second impact would be assigned a weight that is two times larger than first impact.

The scoring method relies on expert testimony, or, in some cases, stakeholders to determine weights for the environmental impacts (Powel et al. 1997). Two stages are required to determine the appropriate weights. First, the panel ranks the extent to which emission flows initiate further damages to the environment. Second, the panel ranks each pollutant relative to all the other pollutants analyzed.

---

[6] Economic valuation is not considered part of the SETAC or ISO 14000 methods for calculating environmental impacts in LCA studies. However, the methodology has been established in economic cost-benefit studies, and it is being applied by LCA practitioners.

A number of problems with these three methods have been recognized (Shankle & Humphreys 1998, Powel et al. 1997). Because environmental standards are set through political processes, they do not necessarily represent a scientifically "optimum" solution that utilizes natural and human resources, including ecosystem benefits, to maximize social welfare.

Another problem with these methods is the fact that not all material and energy flows identified in LCA models will have associated standards (Powel et al. 1997). The Society of Environmental Toxicology and Chemistry (SETAC), recommends ignoring impacts from flows with no associated standard, on the assumption that no standard is a statement that society does not value the flows (Fava 1991).

Finally, results from the impact assessment using these methods tend to be irreproducible within or between countries (Powel et al. 1997). In addition, relatively few studies have been conducted, so established ranges for impact assessment weights are not available in peer-reviewed literature.

2.3 Impact Assessment Using Economic Valuation

The guiding principal behind economic valuation is to calculate changes in well-being of those affected by the emissions identified in the inventory assessment (Pearce 1995, Bockstael et al. 2000) . LCA models estimate the emissions from a product or process and economists estimate the economic costs of impacts through assessments of willingness-to-pay (WTP) for a change in well being before the change has occurred. Assessing this change is performed through the use of a set of indirect methods, such as travel-cost and hedonic measures, or direct questioning studies, known as contingent valuation. Both direct and indirect methods estimate the amount of money people would be willing to pay, or willing to accept, to avoid the changes in their personal experience caused by the emissions. The resulting estimate in dollars is used as a proxy for the social and environmental damages caused by the emissions.

One of the first LCA impact assessments with economic valuation was developed as part of a LCA of curbside recycling (Craighill and Powell 1996). The arguments for LCA with economic valuation were further refined in a review of impact assessment methodology conducted for SETAC (Powell, Pearce and Craighill 1997). Extensive research has been conducted using WTP to identify the externality value for numerous impacts. Low, medium and high estimates for numerous emissions categories are available in peer-reviewed literature. New studies verifying past estimates and estimating impacts from previously untested emissions are regularly undertaken (Aldred 1994; EPA 1998, Bockstael et al. 2000).

The methodology for establishing WTP estimates, though controversial, is well established in public policy domains and continues to be refined through academic dialogue. WTP models have been used in these fields for more than 40 years with increasing acceptance. A database maintained by Environment Canadian lists more than 2000 published WTP studies, and more than 50 countries utilizing these methodologies for public policy purposes (Carson 2000). In 1993, Robert Solow and Kenneth Arrow hosted a panel of economists at the National Oceanic and Atmospheric Administration (NOAA) in order to determine the validity of WTP analysis in public policy. The panel recommended guidelines for use in natural resource damage assessments to help ensure the reliability of WTP survey instruments, including the use of in-person interviews, a binary discrete choice question, a careful description of the good and its substitutes, and several different statistical and subjective tests of the survey results. Since the panel issued its report, many empirical tests have been conducted, and many key theoretical issues have been clarified (Carson 1999). Though more work needs to be done in developing economic valuation methodology, economists continue to refine the methodology, improve the quality of the results, and reduce the level of error.

Of the methods used to assign value in the LCA impact assessment, economic valuation tends to be the most transparent. Brent (1996) points out that one cannot avoid making value judgements when making social decisions. Rather than avoiding subjectivity and value judgements, modeling social impacts involves a question of whether assumptions are implicit or explicit in the model. Assumptions about social values are deeply embedded in any of the methods previously discussed (Powell et al. 1997). Political positions used in crafting policy, or in the personal opinions of experts, make reproducing results from other impact assessment methods difficult to impossible. Understanding what assumptions are at work when an agency or legislative body sets target emissions is, to say the least, difficult. In contrast, the assumptions made in estimating economic parameters are typically identified in the background studies. If assumptions are appropriately presented, analysts can test previous results with similar methods, and explore the relationship between assumptions and the estimated parameters (DOE 1995, Shankle et al. 1998, Frankhauser 1994, EPA 1998).

Finally, economic valuation results, based on willingness-to-pay estimates of damages, are consistent with the general goals of maximizing social welfare, a fundamental tenet of economic thought (Brent 1996). A principal goal of welfare economics is to ensure that society as a whole benefits from policy and regulatory actions, even if some individuals are negatively impacted. Economists argue that external costs affect all members of society and that market prices are not a good substitute for individuals' willingness to pay to avoid the impacts. Economic valuation reflects a social price, or a price that is adjusted to reflect the effects market prices do not capture.

The results of economic valuation impact assessment are tailored for use in actions that maximize social welfare.

In addition to these four benefits of economic valuation over other LCA impact assessment methods, Craighill (1996), Powell (1997) and Pearce (1995) argue that economic valuation is technically easy to apply to inventory assessment output. Results from the inventory assessment are in heterogeneous units for each emissions category, such as SO2 in metric tons, and toxic chemicals in standard pounds. Results for economic valuation studies are typically in dollars per unit. For example, economic valuation results for SO2 are reported in dollars per metric ton. Calculating social and environmental impacts for SO2 is as simple as multiplying the quantity of emissions by the estimated per unit value.

2.4 Uncertainty and Embedded Assumptions

Four types of uncertainty exist with the economic valuation methodology. First, the methodology for combining LCA inventory output with economic valuation is still evolving, and the array of externality estimates available does not cover all impact flows that may be calculated in LCA models. In addition, externality estimates are typically developed as marginal estimates for one location. Transferability of per-unit externality values, without significant adjustment to the local conditions of the LCA study site, is limited (Krewitt 1999).

Second, the combination of externality estimates with LCA output following the Craighill and Powell methodology assumes that each unit of pollutant has the exact same impact as subsequent units. This leads to average assessments of damages (DOE 1995, ExternE 1995&1997). In reality, the impacts are site-specific and can be larger or smaller depending on regional characteristics, such as population density, critical habitat, and other biological systems that might mitigate, or magnify, the damages caused by the flow of pollutants.

Third, though increasingly rare, some academicians argue that the use of existence values, or value that extend beyond market values, has no place in economic analysis (Aldred 1994). Existence values are not consumed and do not, therefore, fit the economic definition of a preference. However, Krutilla (1967) observed that people do place value on natural resources, and excluding existence values from economic analysis would place a zero, or very low, value on any public good or environmental damage.

Fourth, there are still outstanding technical issues involved in quantifying individuals and societies' willingness-to-pay. Some argue that irreproducibility of results from WTP models is symptomatic of anomalies associated with individual studies (Aldred 1994, Carson 2000). The debate tends to focus on the shortcomings of the various WTP methods and whether they result from the problems of particular methods or reflect deeper problems in WTP models.

Uncertainty with the results requires that the final output of LCA economic valuation should be considered order-of-magnitude estimates of damages (Powell et al. 1997, Krewitt 2001). WTP models are highly simplified pictures of real-world processes. The errors associated with each step in the externality modeling process, as well as those associated with the LCA modeling process, are combined in the final output. In addition, the WTP methodology is still evolving, along with the scientific understanding of the effects emissions have on society. It is probable that certain flows and impacts are left out of the assessment.

2.5 Example of Embedded Assumptions with Economic Valuation

In order to demonstrate how uncertainty is magnified in LCA impact assessment with economic valuation, we take a closer look at the valuation step in the Craighill and Powell (1996) curbside recycling versus waste disposal study. We focus on their valuation of greenhouse-gas emissions in order to identify some of the assumptions that are deeply embedded in their results. Though we focus on greenhouse-gas valuation estimates used in their study, the analysis is applicable to their method of applying other per unit estimates of damages.

Craighill and Powell quantified the greenhouse-gas emissions for each stage of the life cycle and multiplied these total emissions by the cost per unit of emissions estimated in Frankhauser's (1994) externality study in Great Britain. Their report provides no assessment of Frankhauser's externality results and assumptions, or the transferability of his per-unit estimates to the local conditions in rural England. However, to run Frankhauser's model of the marginal costs of greenhouse-gases requires a set of assumptions which are relevant to the question of external impacts calculated in the Craighill and Powell model.

Table 15 summarized the assumptions and sources of data used in Frankhauser's greenhouse-gas study. Each of these micro questions requires a set of assumptions. Frankhauser is explicit in his assumptions, and identifies the source from which his positions are derived. However, there is no way to dismantle and reconstruct Frankhauser's model with different assumptions. If, for example, we assume that the GNP will remain steady or actually decline over the next 200 years, or that the appropriate discount rate is zero for intergenerational projects, then we must reject Frankhauser's results. Frankhauser's assumptions about the structure of populations and economic systems, as well as the behavior of biochemical and ecological systems, are deeply embedded in the Craighill and Powell study.

Table 15 Assumptions in Frankhauser (1994) that are implicit in Craighill (1996) and Powell (1997)

Micro Question	Assumptions	Source
Ambient Stock of Pollutant	Size of stock based on pre-industrial atmospheric concentrations Non linear decay rates to carbon sinks	Schmalensee (1993)
Source & quantity of future Emissions	Populations growth at 1990 rate Gross national product growth rate 1-2% No policy to reduce GHG emissions Fossil fuel use at 1990 rates Deforestation at 1990 rates	IPCC (1992)
Accumulation of emissions	Nonlinear decay rate Absorption to other stocks	Hasselmann (1987)
Radiative forcing of per unit increases in stock concentrations	Relationship between ozone, total stock and forcing Excludes overall cooling effects of other emissions	IPCC (1990)
Rate of global temperature rise	Temperature rise in atmosphere, upper oceans, deep oceans.	Nordhaus (1992)
Annual damages	Accept optimum gas emissions curve as baseline. Damages increase as populations grow and economies change. Threshold conditions exist where ecosystem is unable to adapt Include market & non market damages	Frankhauser
Discounting	Social time preference rate	Frankhauser

Assumptions for other emissions and environmental damages are equally important to the results of both the per-unit values and the resulting LCA impact assessment conclusions. For example, the assumed value of human mortality, which is necessary data for assessing health effects from emissions or traffic accidents, ranges from \$500,000 to more than \$4,000,000 (Lee 1995). These differences can result in fundamentally different estimates of per-unit value. It is unclear in Craighill and Powell what assumptions are included in their unit values and how these assumptions dovetail with the authors' position.

In economics, a significant issue is the transferability of WTP estimates from one location to another (DOE 1995). The three studies used for per-unit damage estimates were conducted as marginal estimates. The location of populations, environmental attributes and economic activities relative to the site assessed are important in marginal externality studies, to the point that damage estimates are rarely transferable from one study to the next. For example, the value external damages associated from SO2 releases as assessed in the Ohio Valley may not be transferable to rural Quebec locations In general, economists recommend adjusting WTP estimates to site-specific marginal impacts.

Although Craighill and Powell's method of multiplying of per-unit damages estimates with the quantity of emissions released is technically easy, their methods embed implicit assumptions and off-site specific attributes in their results.

2.6 Average versus Marginal Assessment

Craighill and Powell use estimates of existing damages from one curbside recycling scheme and one waste disposal scheme to consider which method has the least overall environmental burden. However, from an economic perspective, comparing the impact of existing methods is of less concern than comparing the impacts associated with a proposed project. Economists consider past impacts, including those associated with past capital expenses and emissions, to be sunk. The emissions are released, and the product or process cannot recapture past actions.

What Craighill and Powell have provided is a first cut assessment of average damages from the two systems such that it generally informs communities about future waste versus recycling-related decisions. Estimates of average damages consider the impacts from, ideally, a pool of representative products or processes normalized on an appropriate per-unit metric (PACE 1990).

In contrast, marginal damages are the impact of a one-unit change in the output of a product or process as compared to baseline conditions. Marginal damages are of central concern in economic and policy analysis of the environmental consequences of a product or process. From an economic efficiency perspective, regulators would raise compliance standards for a new project if the new standards would reduce damages more than they would raise the costs of compliance. Stated in economic terms, regulatory standards should be adopted if the marginal damages avoided exceed the marginal costs.

As it relates to our study, assessments of average damages provide insight into certain characteristics of the hydro fuel cycle, such as facility siting and emissions profiles, that are necessary to understand the impacts from more site-specific assessments related to future decisions. For example, the size of local populations, aesthetic considerations, size and depth of the reservoirs, structure of the dams and materials used may be significant determinants of external costs.

However, average costs are not appropriate for considering the external damages from an individual product or process, because average costs can significantly under or over estimate the environmental costs at the margin. In situations where all components of the environmental impact pathway are linearly related, then marginal damages would equal average damages. But this condition is not supported by scientific understanding of how emissions disperse from a source, which suggests that distance, atmospheric conditions and other factors create nonlinear relationships between emissions and damages (DOE 1995). Under nonlinear conditions, valuation based on average physical damages and average costs will underestimate damages at high pollution levels and overestimate damages at low levels. Ideally, damages from each incremental unit of ambient pollution would be estimated and linked to changes in pollutant emissions, such that marginal damages per unit of emissions could be estimated.

From a state perspective, where externality "adders" are often used to adjust market prices to reflect social damages, marginal assessments of the fuel cycle are of primary concern. State public utility commissions (PUCs), with a charter of maximizing social welfare, typically focus on delivering power at its least social cost. Before deregulation of electricity markets was initiated in California and Pennsylvania, a majority state-level regulatory efforts included accounting for external damages in all new investment decisions (Lee and Drummer 1994). To achieve this regulatory objective, state PUCs must take the existing pool of generation assets and existing policy controls as an existing condition, such that they are forced to ignore measures of the optimal generation mix and focus instead on choosing technologies with the lowest social costs to meet new electricity demand. Often described as "least costs planning," regulations based on social costs require utilities to accept projects with the lowest social costs, even if the market prices are higher than other choices, but they do not require the utility or rate payers to actually pay the difference between market and social prices.

From a Federal perspective, marginal assessments are also of primary concern. Incentive-based regulation, such as tradable permits, require a detailed understanding of the social costs of pollution so as to quantify the economically efficient level of emissions control and the associated number of permits to be issued. However, technical issues interfere with accurate federal-level estimates of marginal damages (Lazzari 2000). For example, practical federal-level estimates demand ignoring a central tenet of marginal damage analysis: damages are site-specific. In addition, federal policy is typically concerned with larger regions where numerous types of economic activity take place. It is difficult to imagine a social cost study that explicitly estimates damages and benefits at all sites across the continent. The most common method for estimating social costs at the federal level is to ignore the dynamic effects of emission impacts on local economies and generalize with average estimates of damages for some representative or average site (DOE 1995). Simplicity requires accepting the assumption that impacts from pollutants follow linear increases and decreases. Stated another way, average assessments of social costs are the most practical means for assessing external damages on the federal level.

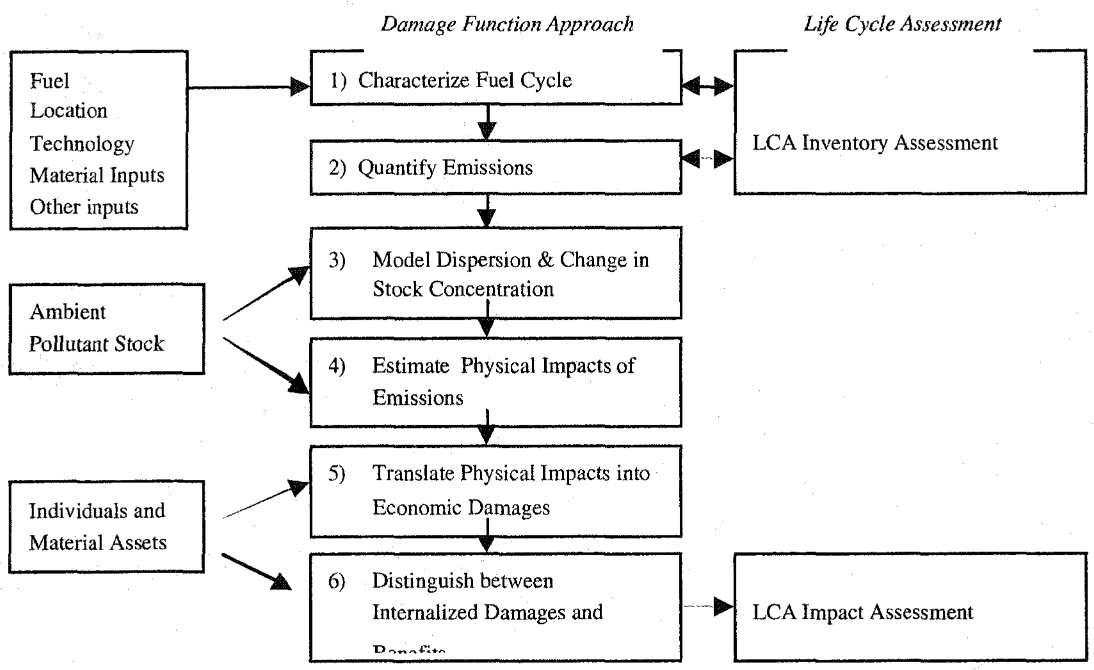
2.7 Economic Damage Function Approach

The economic damage-function approach (EDFA), summarized in Figure 13, was designed for estimating environmental damages at the margin. EDFA was born from the externality valuation literature and applied to fuel cycle analysis in a joint study by the US Department of Energy and the Commission of the European Communities (DOE 1995, ExternE 1997). LCA has traditionally skipped steps 3 through 5, moving from the inventory of pollutants to a single index of damages (Goedkoop 1995). However, more recently, aspects of the EDFA methodology has been applied in LCA modeling, making explicit the impact categories, such as human health, or crop production, that are considered in the analysis (Krewitt 1998, Goedkoop 1999, Hayashi et al. 2000, Itsubo 2000).

EDFA was primarily developed to capture the spatial and temporal marginal impacts of a proposed project. As such, EDFA requires detailed information about engineering, natural and physical sciences, and economics associated with constructing, operating and decommissioning the proposed project. The first two steps of the EDFA method are similar to the LCA inventory assessment, and include a quantification of emissions and other impacts associated with each life cycle state of the project.

In step 3, EDFA requires detailed modeling of emissions transport and deposition. These natural science models are then adjusted to site-specific characteristics, such that a footprint for each chemical emission is developed for the proposed project's local and regional characteristics.

Figure 2.1 Damage Function Approach versus LCA



Step 4 estimates the physical response by human and ecological resources to the marginal change in emission concentration. Dose-response models are typically used to capture changes in the local and regional populations, such as increased health-related incidents and increased mortality from emissions exposure.

Step 5 applies willingness-to-pay models to estimate damages and benefits, either specifically developed for the regional characteristics, or borrowed from other studies and adapted to the regional characteristics.

The final step of the EDFA process estimates the portion of marginal damages and benefits that are external to cost of operations. For example, the federal Clean Air Act and some state regulations require a tradable permit system in which power plants wishing to increase emissions of a particular pollutant are required to purchase that right from a plant wishing to reduce emissions. If such a transaction is regionally contained, then the net marginal increase in social costs is zero.

EDFA greatly increases the level of detail and data requirements beyond the Craighill and Powell approach. For marginal assessments used to develop an appropriate level of taxation, or other policy-related activities with significant financial costs, the increased scope of work can often be justified by the accuracy of the results. However, in practice, the increased scope of the EDFA approach, even with the best-funded studies, has led to ignoring many impact pathways that may be significant.

We reviewed a number of economic valuation studies of the external impacts from the hydro fuel cycle, including Pace University (PACE 1990), Department of Energy Externality of Fuel Cycles (DOE 1995), Bonneville Power Authority's Sultan River Case Study (BPA 1984), the Generic Hydro Study (Meyers et al. 1986), Extern E National Implementation (ExternE 1997), and Environmental Impacts of Alternative Energy Resources (Thayer et al. 1991). Of these studies, the best funded and most comprehensive in demonstrating and applying EDFA methodology are the DOE and Extern E studies. In their final assessment, the DOE included only the external benefits of jobs, the external costs of lost fish habitat, and reduced recreation access at their representative sites. The ExternE project rejects the damage function approach for hydro and resorts to willingness-to-pay estimates for avoiding the construction of a proposed dam. In all of these studies, upstream emissions were assumed to be inconsequential as compared to operations-phase emissions, and all of these studies concluded that hydro is an environmentally benign source of energy, primarily because it emits no greenhouse-gases.

2.8 Damage Function and LCA

LCA is moving toward a more generalized application of EDFA with the development of databases that approximate impacts for regions within continents. Such databases significantly reduce the level of original data collection necessary for site-specific analysis, while simultaneously decreasing the accuracy of the marginal assessments. Rather than initiating steps 5 and 6 of the EDFA methodology, LCA with DFA estimates the human and ecological impacts for a set of standard emissions by country, or within grid cells overlaid on a country or region. This simplification of the EDFA methodology allows for first-cut approximations of marginal externalities, but does not capture all of the spatial and temporal impacts from a proposed project (Krewitt 2001). We have come to think of LCA with DFA as an intermediate step between the affordable Craighill and Powell approach and the data-intensive, site-specific EDFA approach.

All of the recent LCA application of DFA includes Steps 1-4 of the EDFA method (Krewitt 1998, Krewitt 2001, Goedkoop 1999, Hayashi et al. 2000). For example, the Eco-indicator 99 methodology includes detailed damage function analysis of category endpoints, such as cancer or decreased biodiversity, in DFA step 4 (Goedkoop 1999). However, the Eco-indicator 99 methodology is not designed to capture the spatial and temporal aspects necessary for marginal analysis. Rather, Eco-indicator 99 estimates impacts for Europe as a whole.

Krewitt (1998) developed LCA methodology to include DFA steps 5 and 6, leading to marginal economic externality estimates. His recent work develops an integrated model for Europe, South America and Asia that assesses the externalities associated with incremental changes in certain pollutants for each cell in a county-wide, 50x50 km grid (Krewitt 2001). Krewitt's work captures many of the spatial and temporal aspects associated with a handful of emissions consider in his study. However, many of the site-specific impacts and benefits, such as changes in recreation patterns, cannot be assessed with the LCA-DFA methodology.

Krewitt's recent work suggests the future state of LCA with DFA, where more accurate average assessments, and more affordable and rapid, first-cut marginal assessments of externalities, can be made. Such databases have yet to be developed for the U.S., and the complex task of applying the EDFA approach to the hydro fuel cycle can restrict the scope of assessment to the detriment of the analysis. Where those impact pathways that are considered a priority receive comprehensive impact analysis, those impact pathways that are rejected can have untold significance.

2.9 Implications of DFA and Simple Economic Valuation on Hydro Study Methods

IO-LCA with simple economic valuation, as developed by Craighill and Powell, represents an affordable approach to assessing average, or baseline, conditions. Average assessments are useful in considering generalized characteristics of the hydro fuel cycle. In addition, the results are useful in designing and siting new plants such that gross external impacts from new facilities can be minimized in the design phase. Where average externality estimates and baseline conditions for fuel cycle analysis are the primary focus of the study, then the Craighill and Powell methodology appears to represent the most affordable and timely type of assessment.

We find that when economic valuation is used in the Craighill and Powell approach, a certain minimum review of the per-unit valuation data is necessary in order to summarize assumptions that would otherwise be deeply embedded in the impact assessment results. At a minimum, major controlling parameters that are controversial, and for which slight changes could significantly alter per-unit estimates, should be revealed, including discount rates, assumptions about the value of human life, as well as certain characteristics about the populations and locations for which the per-unit values were estimated.

In a situation with some budget and time constraints, the best case scenario for estimating the external impacts of fuel cycles appears to be the LCA with DFA methodology. As this methodology and the associated data sources develop, LCA will be able to model spatial and temporal marginal externality estimates, as well as provide improved average externality estimates, for some emissions and impacts.

Where the results of a marginal assessment have significant social implications, such as a new tax, and the value non-emissions related damages and benefits are important to the estimates of externalities, then the increased scope of work associated with EDFA methodology may be necessary.

Table 16 summarizes a heuristic test for including economic valuation in LCA impact assessment. Average assessments are appropriate for regional and larger assessments when marginal estimates are impractical. Average assessments are also useful in identifying key parameters and impact pathways to be assessed in marginal studies, as well as design and operations characteristics to be included in future projects.

Table 16 Heuristic test for level of detail needed in economic valuation step

Decision / Policy Level	Type of Assessment	Scope	Method
Local	Marginal	Proposed Project	EDFA
State	Marginal or Average	Proposed Project	LCA with DFA
Regional / Federal	Average	Numerous Representative Projects	LCA with Explicit Craighill & Powell

LCA with economic valuation is a useful methodology for capturing external impacts from a product or process. The methodology is currently being improved from the existing state through rigorous application of the DFA approach, explicative characterization of embedded assumptions, and focus on marginal assessments.

CHAPTER III

METHODS

3.1 Introduction

We augment the Craighill and Powell methodology described in Section 2.0 with more detailed assessment of the damage estimates, which we borrowed from the literature. Our primary concern is to establish average, baseline estimates of external damages from the hydro fuel cycle for the New England and Quebec regions. Rather than perform site-specific assessments for each site, we combined steps four through six of the EDFA approach (Figure 13), and borrowed externality estimates for three general geographical areas: rural, suburban and urban. Based on regional population characteristics, we label the La Grande projects in northern Quebec rural and the New England sites as suburban.

In this section, we briefly review the results from our inventory assessment in order to present the quantity of emissions per megawatt hour used in our impact assessment. Next, we present the valuation model used in this study. Then we review the damage estimates used in this study. Finally, we describe the parts of the damage estimates used in our assessment of externalities.

3.2 Life Cycle Inventory

Table 17, reproduced from the first paper in this series, summarizes the emissions from the hydro fuel cycle assessed in our model. In the first paper, we summarized emissions data from three perspectives, including all 178 individual projects, 24 models grouped into graduated size categories, and groupings of small, medium and large projects. We assumed a 50-year project life and developed all underlying data for individual projects.

Table 17 Summary of inventory results from Part I (unit/ MWh)

Project Size	VOCs to air (ST)	NOx to air (ST)	CO to air (ST)	SO2 to air (ST)	PM10 to air (ST)
Small N.E.	6.21E-05	2.05E-04	3.32E-04	4.05E-04	5.94E-05
Medium N.E.	4.81E-05	1.59E-04	2.57E-04	3.13E-04	4.60E-05
Large N.E.	6.36E-05	2.10E-04	3.40E-04	4.15E-04	6.09E-05
Hydro Quebec	3.04E-05	9.30E-05	1.52E-04	1.84E-04	2.69E-05

Project Size	Fossil CO2 (MMT)	TRI Rel Air (lbs)	TRI Rel Water (lbs)	TRI Rel UnGnd (lbs)	TRI Rel Land (lbs)
Small N.E.	8.83E-02	4.16E-02	4.28E-03	1.63E-02	2.24E-02
Medium N.E.	6.83E-02	3.22E-02	3.31E-03	1.26E-02	1.73E-02
Large N.E.	9.04E-02	4.26E-02	4.38E-03	1.67E-02	2.29E-02
Hydro Quebec	4.04E-02	2.01E-02	2.04E-03	7.72E-03	1.06E-02

Project Size	TRI Tf POTW (lbs)	TRI Tf OffSite (lbs)	Cost D&T ($K)	CO2 Equiv. (ST)	Methyl Mercury (ST)
Small N.E.	9.38E-03	1.77E-01	1.35E-04	1.55E-01	4.70E-03
Medium N.E.	7.26E-03	1.37E-01	1.05E-04	2.66E-01	2.24E-02
Large N.E.	9.60E-03	1.82E-01	1.38E-04	6.67E-02	6.83E-03
Hydro Quebec	4.45E-03	8.44E-02	6.30E-05	1.82E+00	1.56E-01

In deference to our goal of developing average damage estimates for hydro emissions, many site-specific emissions and impacts were excluded from the inventory assessment. The scope of our study included upstream emissions for all materials used in constructing hydro projects, as well as energy used for transporting materials to the construction site, and energy needed for building the dams. In addition, we included estimates of greenhouse gasses and methyl mercury released from the impoundment during project operations. We did not include impacts unique to each site, such as effects on anadromous fish, impacts on water quality, or changes in fluvial processes. Our assumptions, the data sources used in our model, the scope and boundary of the study, and the uncertainty of the underlying data can be reviewed in the inventory assessment paper (Part I of this thesis).

3.3 Damage Calculation

Emissions from the inventory assessment were derived annually for each site. We estimated the annual costs for each emission category at each site by multiplying annual emissions with damage costs for the associated year. When dealing with stock pollutants, such as greenhouse-gases or methyl mercury, the damages in any particular year depend on both the current level of emissions and the size of the accumulated stock already in the environment. Our damage estimates are based on 10-year increments, such that they are adjusted to account for changes in ambient conditions as populations and economies grow.

Equation 3.1:

$$DamageEstimate_{(year_y,\, site_x)} = Emission_{(year_y,\, site_x)} * AnnualDamage_{(year_y,\, site_x)}$$

Annual damages for individual projects in dollars per unit of energy were derived by summing the damage estimates for each emission, and dividing by average annual electricity generation for a 50-year life. Equations3.2 summarizes this relationship:

Equation 3.2:

$$AnnualDamages_{(year_y,\, site_x)} = \frac{(GHG + CAP + CWP + TOX + DIS)}{(AnnualGeneration)}$$

where GHG= greenhouse-gas costs; CAP= conventional air pollutant costs; CWP = conventional water pollutant costs; TOX = costs of toxic releases to air and water; DIS = disposal costs.

Total damage costs per unit of energy for each site are the sum of annual damages and adjusted to reflect cost per megawatt hour. All data is adjusted to the year 2000 basis with changes in the Consumer Price Index (CPI).

Equation 3.3:

$$TotalDamages_{(site_x)} = \sum_{0}^{50} AnnualDamages_{(site_x)}$$

Although we allocated external costs to each year in the hydro life cycle, we do not discount the results. SETAC, the primary authority responsible for developing LCA standards, holds that valuation results should be reported without discounting (SETAC 1996). Further discounting can be conducted after non-discounted results are reported. Discounting is controversial in LCA modeling. We consider these issues in the third paper in this series (Part III of this thesis).

Externality cost results were calculated for each emissions category for individual projects. In order to present the results for all 178 dams assessed in this study, we averaged individual projects into 24 models. Table 18 summarizes the structural characteristics of each model leading to our distinction of small, medium and large projects. The models are graduated by the volume of materials used in the dam superstructures, and the model numbers in Column B correspond to the model numbers in all of the results figures. In our conclusions, we further averaged the New England projects into small, medium and large models as summarized in Column A.

3.4 Damage Estimates

Damage estimates used in this study were derived from a review of the literature for each emission category quantified in the inventory assessment. In general, damage estimates are calculated by estimating the value to society of a one-unit increase in the underlying stock of pollutants. For example, economists ask what is society willing to pay to avoid an additional ton of greenhouse-gas emissions. In this section, we briefly review the damage estimate studies for conventional and toxic air pollutants, greenhouse-gases, conventional and toxic water pollutants, and external costs of solid waste disposal and incineration.

Table 18 Structural characteristics of hydro projects assessed in this study

a) Group size	b) Model Number	c) Average Dam Volume (y^3)	d) Average Annual Electricity Generation (MWh/year)	e) Average Reservoir Volume (f^3)	f) Average Reservoir Surface Area (acres)	g) Number of ns in Each del
Small	1	12,500	2,003	4.E+07	324	27
	2	29,186	2,355	4.E+07	198	29
	3	51,178	4,705	4.E+08	571	23
	4	67,551	8,974	2.E+07	61	15
	5	92,062	12,315	4.E+07	84	6
	6	109,818	13,606	3.E+07	99	7
	7	124,980	19,574	4.E+07	183	5
	8	150,940	19,320	6.E+07	157	5
	9	173,213	11,878	4.E+07	96	3
	10	190,796	27,445	3.E+07	93	4
Medium	11	239,445	54,558	4.E+08	710	12
	12	350,824	86,435	2.E+08	603	11
	13	444,124	34,605	4.E+09	4,545	4
	14	536,410	64,700	3.E+08	1,022	2
	15	668,321	104,984	1.E+09	1,747	5
	16	769,542	30,644	3.E+08	399	2
	17	871,704	16,850	5.E+09	4,183	2
	18	905,072	228,042	3.E+10	29,270	1
Large	19	1,335,549	51,517	2.E+09	2,518	5
	20	2,162,999	148,850	2.E+09	3,100	1
	21	3,554,953	105,200	1.E+07	300	1
	22	6,800,742	277,800	5.E+09	2,292	2
	23	8,018,947	356,064	9.E+09	3,240	1
Hydro Quebec	24	87,000,000	6,800,000	3.E+12	3,376,045	4

3.4.1 Conventional air pollutants.

The Clean Air Act designates six emissions as conventional air pollutants. These include Ozone (O3), particulate matter (PM), nitrogen oxide (NOx), sulfur dioxide (SO2), carbon monoxide

(CO), lead (Pb), and volatile organic compounds (VOCs). We reviewed six peer-reviewed studies to construct damage estimates for conventional air pollutants. These studies include the DOE Fuel Cycles Study (DOE 1995), EPA Clean Air Act Study (EPA 1998a), the PACE Externality Costing Study (PACE 1990), New England Externality Costing Study, [NE 89], California Externality Study, (CA 1993), and the Minnesota Externality Costing Study, (MN 1994). We reviewed the New England and California externality studies through a recent EPA literature review of economic valuation studies (EPA 1998b).

All of these studies estimate the marginal benefits of per-unit reductions in the emission categories. In order to do so, the studies estimate the direct external costs to human health, including mortality and morbidity. Some of these studies include indirect damages to humans through impacts to the environment, including changes to ecosystem and cropland productivity, and damages to recreation. Some studies include indirect damages to capital equipment, such as buildings, caused by pollution.

In each of the studies reviewed, the underlying data and assumptions are borrowed from other studies on morbidity and mortality. None of these studies conducted independent assessments of local populations' willingness to pay to avoid the external damages. The underlying assumptions in each of these studies greatly affect the estimates of damages for the conventional air emission categories. For example, the EPA Clean Air Act Study estimates the value of human mortality at \$1,000,000 for particulate, lead, and SO_2 emissions. The Pace University study estimates the value of a human life at \$4,000,000. In his seminal work, Hohmeyer (1988) estimates the value of life in Germany to be \$500,000. The DOE used \$3.5 million as the value for a statistical life and conducted sensitivity analysis for a range of \$1.6 million to \$8.5 million. Taken on their own, variation in estimates of mortality can change estimates of net damages by an order of two or more, especially for marginal estimates in densely populated areas.

Morbidity damages in these studies have an even broader range of cost estimates and quantified categories. For example, the DOE estimates the affects of SO_2 on children's coughs and adult chest discomfort, building and material impacts, on visibility, and on the net benefits from increased cropland fertilization. The DOE concluded that net SO_2 damages are zero. In contrast, the EPA estimated the value of productivity losses from health damages, cleaning, and premature mortality for SO_2, but did not estimate any benefits of SO_2 emissions.

Table 19 External damage estimates (1997$/MT)

		VOC	PM	NOx	SO2	CO	Lead
EPA	Low	$619			$6,144		
	Medium	$1,708	$13,683		$9,876		
	High	$2,797			$13,608		
PACE			$3,389	$2,335	$5,781		
NE				$4,431	$2,594		
Minnesota	Low		$648	$21	$11	$0.24	$463
	Medium		$816	$69	$20	$0.36	$489
	High		$985	$117	$29	$0.48	$516
CA	South Coast	$8,946	$61,637	$18,746	$9,611	$4	
	South East	$204	$880	$568	$1,942	$0	
	North Coast	$605	$713	$1,024	$1,942	$0	

Table 19 summarized the damage estimates in the reviewed studies. The DOE study and some of the results from the California study are not included in this table because their results are expressed as marginal damages for specific sites in dollars per kilowatt. Despite the various assumptions, methods of assessment and scope, the results provide adequate data for identifying low, medium and high estimates for emission categories.

The EPA recently developed a summary table for conventional air pollutants, with low, midpoint and high damage estimates, based on seven studies, six of which are included in our review (EPA 1998b). Table 20 summarized these results and we use this table for our estimates of external damages in this study. The methodology used to distill the independent studies into Table 20 is not fully developed in the EPA's report. However, the results suggest an assumption of normal distribution and Monte Carlo simulation to define low and high boundaries. The report points out that midpoint estimates for PM, SO2 and NOx are generally equivalent to those estimated in the Pace University study. Midpoint estimates for VOCs are from EPA (1998a) and midpoint estimates for CO are based on the California and Minnesota studies. Estimates for lead are based solely on the CAA study. The EPA suggests considering the low estimates for situations where pollutants impact predominately rural areas and the high estimates where pollutants impact predominately high density, urban areas.

Table 20 Conventional air emission damage estimates (1992 $ /MT) (EPA 98)

	Low	Midpoint	High
VOC	$87	$1,485	$7,862
PMK	$699	$2,970	$11,794
NOx	$175	$2,009	$5,242
SO2	$1,747	$5,067	$5,242
CO	$0	$2	$3
Lead	$174,720	$742,560	$1,397,760

In this study we used the midpoint estimates for all New England hydroelectric projects on the assumption that hydro projects are located at a mix of rural and urban sites, and the pollutants would have an average damage effect across the region. For the Hydro Quebec La Grande project, we used the low damage estimates because the site is located in northern Quebec and has a rural character with low populations.

3.4.2 Greenhouse gases.

The suspected impacts of greenhouse gases on global warming have been well established in the literature (IPCC 1990, IPCC 1995, EPA 1995). Secondary impacts of warming include reduced agricultural production, decreased biological diversity, increased sea levels, and increased destructive weather events and human health impacts. However, quantifying damages from global warming is particularly complex. In their review of the literature, the DOE (1995) identified three problems areas that lead to inconsistent and controversial estimates damage costs. First, there are scientific uncertainties about the behavior of greenhouse gases in the atmosphere, including the size and behavior of carbon sinks, reactive chemistry of methane, regional climatic effects, and the effects of stratospheric ozone on warming. Second, the impact pathways of greenhouse-gases on warming tend to be nonlinear. For example, heat trapped in the atmosphere by a unit of gas is a nonlinear function of the stock of that gas, and other gases, which trap the same wavelength. Other nonlinear elements of warming include the physical consequences, such as changes in crop growth, and social consequences, such as rising sea levels. Third, the relationship between emissions and damages are time-dependent, leading to an intergenerational relationship between those who pay for greenhouse-gas reductions and those who benefit. In addition, there appears to be a complex relationship between accumulating stocks and decay rates, such that decay may be a function of the underlying stock levels.

We reviewed three studies to estimate the external costs of greenhouse-gas emissions (Cline 1992, Nordhaus 1994, Frankhauser 1994) The primary methodology used in the three studies include assuming that a specified increase in CO2 concentrations will lead to corresponding temperature increases. The studies model a nonlinear, socially optimal greenhouse-gas emissions curve and estimate the external costs of additional greenhouse-gas emissions. Cline assumes that a doubling of CO2 will lead to 2.5^0 C increase in global temperatures, and that without significant policy action, temperatures will rise 10^0 C in 300 years. Other methods used for extrapolating warming into the future include sensitivity assessments based on functional forms such as linear, quadratic, and logarithmic curves (Reilly and Richards 1993). All three studies estimate effects of greenhouse-gas damages on agriculture, electricity demand, and real estate. Cline and Frankhauser also include some non-market damages, such as changes in biodiversity and other effects of warming.

Table 21 summarized the results of these studies. Estimates of damages range from $5.3/Mg (Nordhaus 1994) to $124/Mg (Cline 1992). Variability of the results depend on underlying assumptions about population growth and income, as well as the application of discount rates. The upper values of Cline's results reflect the "no policy" action with a corresponding 10^0 C increase in global warming.

Table 21 Damage estimates for greenhouse-gas emissions (1990$/ MT)

		1991-2000	2001-2010	2011-2020	2021-2030
Nordhaus (1994)	CO2	$5.3	$6.8	$8.6	$10.0
Cline (1992)	CO2	$5.8-$124	$7.6-$154	$9.8-$186	$11.8 -$221
Frankhauser (1994)	CO2	$20.3	$22.8	$25.3	$27.8
	CH4	$108	$129	$152	$176
	N2O	$2,895	$3,379	$3,901	$4,489

In a recent report on cost-benefit analysis, the EPA (1998b) uses Frankhauser's estimates of GHG externalities (Frankhauser, 1994), and compares these results and methodologies to other studies (Nordhaus 1991 & 1994, Ayers and Walter 1991, Cline 1992, Madison 1994). Frankhauser's results include more explicit estimates of uncertainty and specify probability distributions for key parameters. The outcome is that Frankhauser's results are somewhat higher than other similar studies, but considerably lower than the highest estimates.

In this study, we use Frankhauser's damage estimates in Table 21 for greenhouse-gas emissions because of the comprehensive nature of their study and general convergence in externality studies to used the Frankhauser estimates. We quantify upstream and operations-phase greenhouse-gas emissions, but because of their size and uncertainty, we do not include our upstream greenhouse-gas emissions in our average estimates.

3.4.3 Disposal and incineration.

Table 22 summarizes external cost estimates for disposal and incineration of solid waste from a Center for Social and Economic Research on the Global Environment study conducted in Great Britain (CSREGE 1993) as cited in EPA 1998. The CSREGE study estimated landfill emissions of CO2 and CH4, as well as traffic accidents and air pollution from the transportation of waste to the facility. The transportation externalities were assessed at an urban and rural landfills, with an average travel distance of 12 and 50 miles respectively. In this study, we assume that disposal activities are primarily at on-site landfill. The Army Corps of Engineers provides little information about how waste materials are typically handled during dam construction. We assume that most waste from the hydro fuel cycle is generated during dam construction and that these materials are disposed in project-owned landfills.

3.4.4 Toxic air and water emissions.

We use damage cost data for toxic air and water emissions as estimated by the EPA (1998b). We report our findings for toxic impacts separately from other emissions. In our final analysis, we reject our estimates of toxic impacts as too uncertain. The EPA based its damage estimates for hundreds of toxic chemicals on detailed analysis of three chemicals. The results have not been tested in other peer-reviewed studies and estimates of uncertainty have not been calculated. In addition, our results of the toxic externalities suggest that these emissions account for 90 percent of total emissions considered in this study. All recent studies of the Hydro fuel cycle find a level of toxic emissions that is not measurable (DOE 1995, ExternE 1997). Because of this uncertainty, we present our impact results for toxic emissions, but we do not include toxic emissions in our final calculation of impacts per unit of energy.

Table 22 Damage estimates for disposal and incineration (1992$/MT)

Landfill			
Urban	Rural	Onsite	
4	4	3	
Incinerator			
Urban	Regional	Onsite-urban	Onsite-rural
6	6	6	4

The EPA methodology for estimating external impacts from toxic chemicals is based on estimates of the carcinogenic effects of each chemical on human health and mortality. The EPA analysis does not include other damages associated with toxic chemical emissions, such as losses of biodiversity and other ecosystem damages. Nonetheless, the results have a very high degree of uncertainty.

To calculate damage costs for toxic chemicals, the EPA estimated the carcinogenic effects of three chemicals: chromium, arsenic and cadmium. The study calculated the total emissions of these chemicals from 684 oil- and coal-burning plants in the U.S. and estimated the number of associated cancer cases. The EPA assumed that each cancer case resulted in premature death, and valued each premature death at $5 million. The study then calculated the cost of emissions for the three chemicals on a per-unit basis.

Using the per-unit estimates of the three chemicals, the EPA derived estimates of the per-unit cost of other carcinogenic chemicals. The study separated the remaining chemicals into two groups:

those for which the EPA had established estimates of the unit cancer risk from inhalation, and those for which reference concentrations (RfC) for non-carcinogenic effects have been established. Sixty-three chemicals have established carcinogenic risk factors for inhalation of the chemical. For these chemicals, the EPA derived an equivalent unit value from the ratio of the chemical's unit risk value to the unit risk value of arsenic, cadmium and chromium. Damage costs estimates were derived for the 64 chemicals by multiplying the ratio value by the unit dollar value for the three equivalent chemicals. The EPA derived final damage estimates by averaging the unit value for the three equivalent chemicals into an average unit value for each chemical.

For non-carcinogenic chemicals with RfC values, the EPA first calculated an arsenic, cadmium and chromium RfC equivalent that estimated the chemical in air that would lead to a lifetime cancer risk of one in 100,000. It calculated equivalent scores for arsenic, chromium and cadmium, applied these equivalents to non-carcinogenic chemicals, and averaged per-unit scores into damage costs. Appendix A summarizes the EPA damage results for each toxic chemical analyzed.

The uncertainty of these estimates is likely to represent order of magnitude calculations of the value of human health damages associated with emissions of each chemical. The EPA suggests that the error is smallest with the estimates for arsenic, chromium and cadmium, but points to a number of factors that increase the uncertainty of these estimates. First, the $5 million used to approximate the value of human life is within a range of plus or minus $3 million. Second, uncertainty is compounded by applying the estimates for arsenic, cadmium and chromium to other carcinogens by assuming that the per-unit cancer risk is proportionally the same for each chemical. In addition, the methodology does not account for the environmental path and exposure each chemical follows in the environment. Finally, uncertainty is increased even further by the assumption that concentrations the non-carcinogenic chemicals, which are three times greater than the RfC, have risks that are equivalent to three out of 100,000 for the carcinogenic chemicals. The EPA states that this relationship is somewhat arbitrary.

3.4.5 Land use and change in hydrology.

Hydroelectric projects can have significant impacts on water resources through impounding water and releasing water through spillways. In addition, flooding at certain projects and development of transmission lines have significant land impacts through inundation of valuable lands used for agriculture, forestry and recreation. Reservoirs often create some mitigating factors, particularly with recreation. Numerous biological studies have identified these impacts to be large and the costs are typically site-specific. We identified no estimates that generically value the land uses and water impacts associated with hydroelectric facilities.

3.5 Externalities

Externalities represent the net damages and benefits that are external to private investment decisions about power plants. Regulatory factors lead utilities to internalize many of the damages caused by hydro projects. For example, licensing through the Federal Energy Regulatory Commission (FERC) requires equal consideration and mitigation for non-power attributes disturbed by a project. Non-power attributes include the effects of hydro development on anadromous fish, reduced gravel recruitment needed for resident fish spawning, shoreline erosion, and recreation access. In licensing, the applicant is required to mitigate for these impacts at the firm's expense.

Technology can also act to internalize external costs. For example, in this study, we assume that the methods for new hydro project construction are similar to those practiced in the recent past.

However, improvements in transportation efficiency, reductions in the strength to weight ratio of concrete and cement products, or the employment of non-toxic paints and waterproofing materials could significantly reduce the emissions from a new project.

In this study, we assume that all emissions quantified in our inventory assessment are external to the price of power. Regulatory efforts by the FERC and the Army Corps of Engineers do not require any extra measures to mitigate for emissions from new construction (BOR 1980). In fact, because operations-phase emissions are commonly assumed zero, the FERC is currently pursuing means to consider the greenhouse-gas emissions avoided by hydro. Additionally, we do not assess external recreation- or employment-related benefits that would have the effect of reducing net externalities.

CHAPTER IV

RESULTS

4.1 Introduction

It is possible to develop a simple impact assessment from the inventory results by comparing total emissions for each type of pollutant in LCA modeling. This is known as characterization of inventory results. In Table 17, the highlighted box in each emissions column represents the hydro project size with the largest emissions per unit of energy. Emissions from large New England hydroelectric projects exceed all other models, including Hydro Quebec, for all emissions categories except CO2 and methyl mercury from the impoundment. Hydro Quebec projects have the highest per unit of energy emissions for these two emissions categories.

Characterization of inventory results may lead to the conclusion that large New England hydroelectric projects exceed other examples in New England and Hydro Quebec. If toxic emissions are the analyst's primary concern, then certain factors associated with New England projects, such as large dam structures, could be the target for mitigation. If global warming is the pathway of primary concern, then the large projects associated with Hydro Quebec may become a target for greenhouse-gas mitigation.

For individual emission pathways, characterization of the inventory provides some basis for decision making. However, characterization provides no basis for comparing unrelated impacts, or common impacts that occur at different phases of production for unique products or processes. For example, while we can compare the quantity of VOC emissions between small, medium and large hydro facilities, we cannot compare VOCs to CO2, or assess the impact these emissions have on society. Some methods for weighting the impact categories is necessary before decisions can be made based on the total external impacts of hydroelectricity. Economic valuation provides such a system.

4.2 Economic Valuation Results

We calculated the external economic costs for each of the emission categories in dollars per megawatt hour with the formula described in section 3.0. Figure 14 summarizes the costs of upstream emissions. For the models assessed, the upstream burden ranges from \$1 to \$13 per megawatt hour. SO2 emissions represent the majority of the upstream external costs.

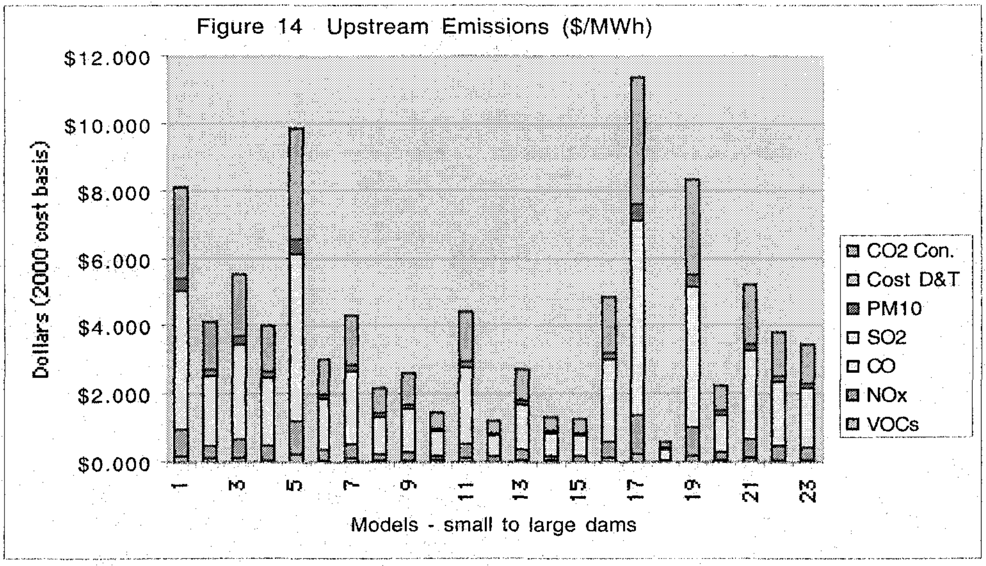


Figure 14 Upstream Emissions (\$/MWh)

Figure 14 shows an obvious disconnect between project size and normalized upstream and construction-phase emissions. As Table 17 indicates, the volume of materials used in each model increases from approximately 12,500 cubic yards for the smallest New England dams to more than 85 million cubic yards. Some of the small New England models, such as Model 1 and Model 5, have some of the highest emissions per unit of energy. Hydro Quebec, model 24, has by far the largest dam superstructure, and nearly the lowest upstream external costs of all the projects assessed.

Figure 15 summarized our externality estimates for upstream toxic emissions.

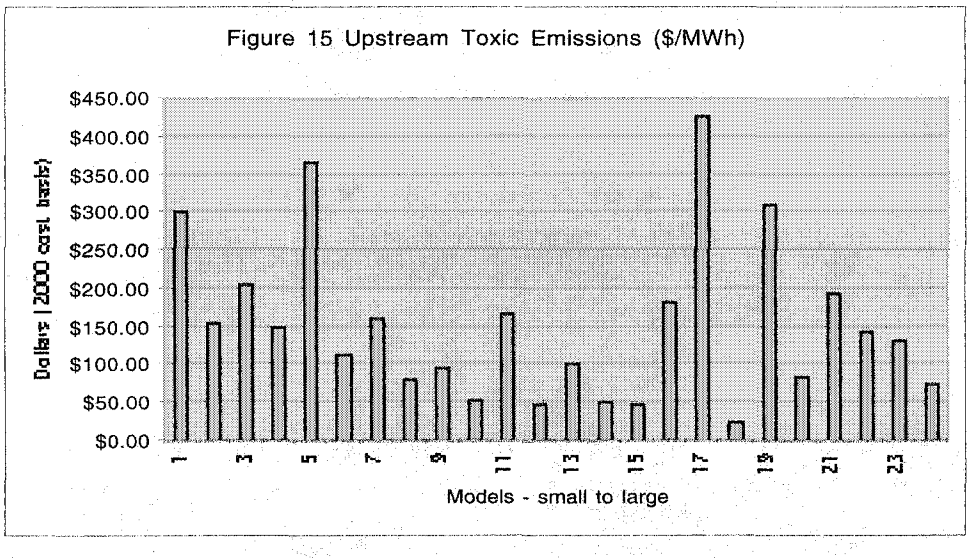
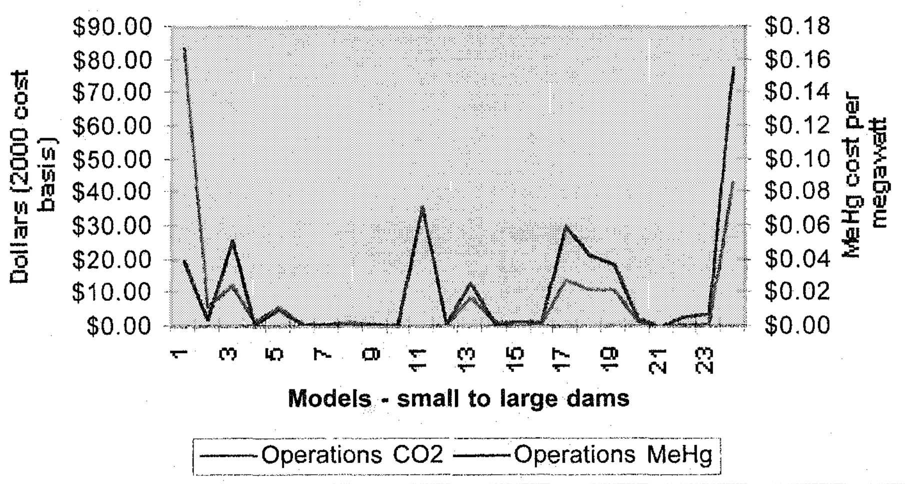


Figure 15 Upstream Toxic Emissions ($/MWh)

Figure 16 summarizes operations-phase external costs. Operations-phase emissions represent a significant portion of life cycle impacts for some models, and an insignificant portion for other models. For all projects, the cost of methyl mercury mineralization is small, between zero and $.16 per megawatt hour. Greenhouse-gas emissions range from zero to $85 per megawatt hour. Mineralization, driven in part by the volume of impounded water, tends to cycle with greenhouse-gas emissions that are related to the surface area of the impoundment and the ratio of deep to shallow waters.

Figure 16 Operations Phase External Costs ($/MWh)



As with upstream emissions, the size of the project, in terms of the volume of materials used in construction and average annual generation, has no bearing on the expected operations-phase emissions per unit of energy. By any metric, Model #1 represents the smallest hydroelectric project in New England and has the highest per unit of energy emissions of any grouping assessed in this study. Appendix B presents detailed externality costs data for the individual projects. Hydro project FERC # 5274 is one of the smallest projects assessed in the study, but represents the largest operations-phase CO2 emissions per unit of energy of the dams. Though the dam and average annual generation values are small, the impoundment, the primary source of CO2, is proportionally large and shallow.

Figure 17 summarizes total emissions from the hydro fuel cycle. Many of the models, as well as the underlying data, have very low external impacts per unit of energy. However, models 1 and

11 have anomalous data that significantly increases average impacts for those models, as well as the entire data set.

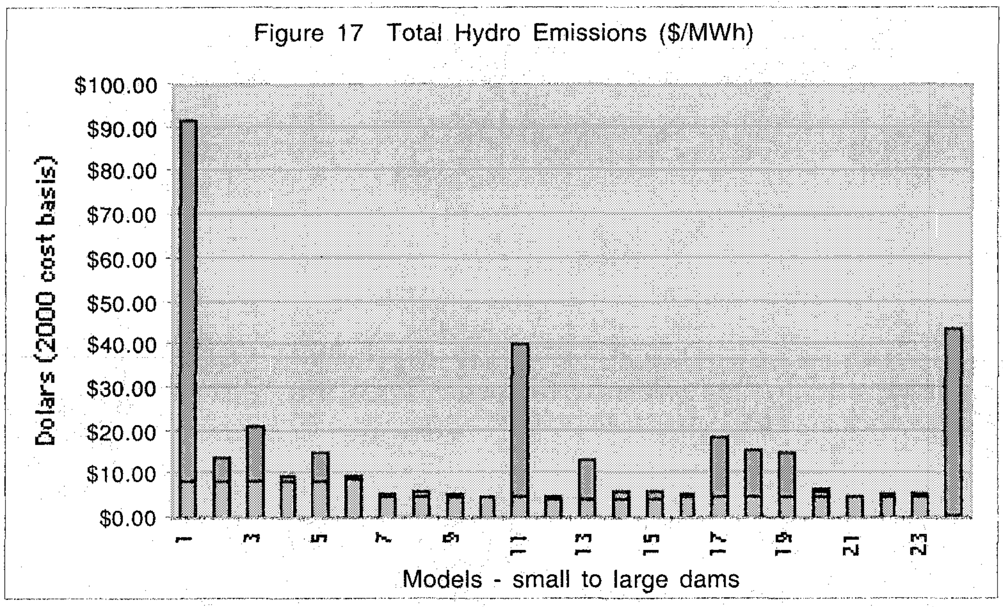


Table 23 summarized descriptive statistics for the entire New England and Hydro Quebec data set. Total emissions average $23 per megawatt hour and range from $.16 per megawatt hour to more than $2000 per megawatt hour for the individual projects. For the New England dams, the median cost per megawatt hour of $2.66 suggests a significantly skewed data set. The two outliers in models 1 and 11 increase the apparent and average operations-phase emissions per unit of energy for New England averages. For example, one project in model 1 has total external costs more than $2000 per megawatt hour. With these three anomalies removed, the median external cost estimate is $2.36, and the mean cost per megawatt hour is $7.29.

Figure 18 further aggregates total external costs for the hydro fuel cycle to reflect regional averages for small, medium and large New England projects. For these models, upstream impacts range from half to three-quarters of the total external costs. Because of the anomaly in model 1, small projects appear to have the largest total external costs of approximately $27 per megawatt hour. Average costs for all New England dams are approximately $24 per megawatt hour. When we remove the three outliers from the analysis, average costs for all dams are approximately $9 per megawatt hour.

Table 23 Total upstream and operations external costs for the hydro fuel cycle ($/MWh)

		Upstream	Upstream (no outliers)	Operations CO2	Operations MeHg	Total Operations Emissions	Operations (no outliers)	Total Emissions	Total Emissions (no outliers)
All New England Projects	Average	$3.21	$3.08	$19.45	$0.02	$19.40	$4.21	$22.61	$7.29
	Median	$1.50	$1.45	$0.82	$0.00	$0.81	$0.80	$2.66	$2.63
	Lowest Value	$0.11	$0.11	$0.01	$0.00	$0.01	$0.01	$0.16	$0.16
	Highest Value	$71.64	$71.64	$2,010.35	$1.07	$2,002.26	$168.65	$2,008.05	$173.53
Hydro Quebec		$0.48		$42.99	$0.16	$43		$43.63	

In contrast, the burdens from Hydro Quebec are concentrated in the operations-phase as CO2 releases to the atmosphere from the reservoirs. We estimate external costs to be $44 per megawatt hour. On a per unit of energy basis, the Hydro Quebec La Grande complex has the largest average life cycle burden of the projects assessed in this study.

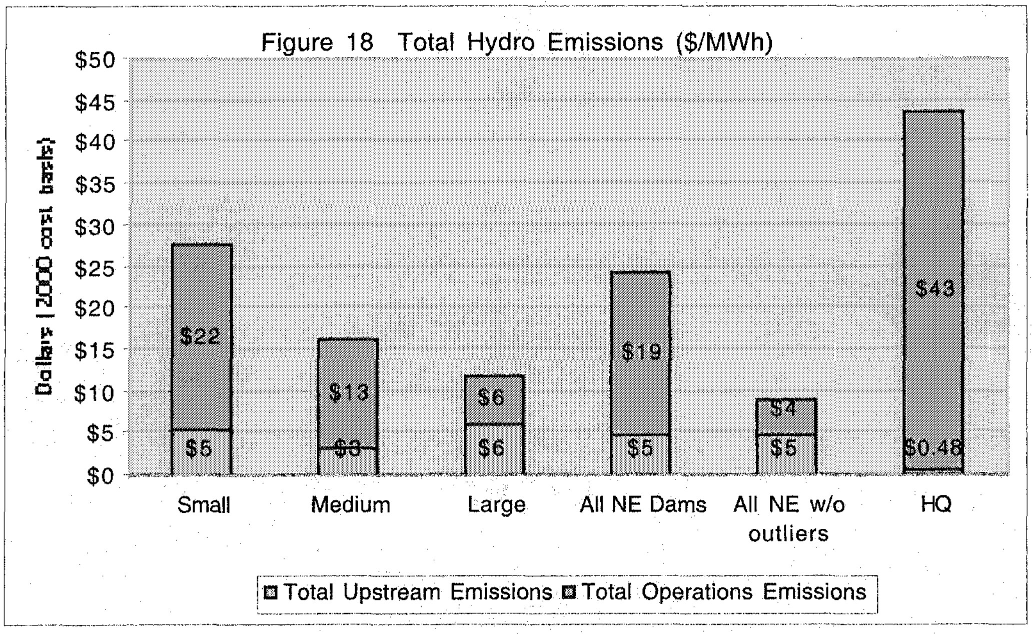


Figure 18 Total Hydro Emissions ($/MWh)

4.4 Comparison of Our Results with Other Assessments

Externality studies of the hydro cycle, summarized in Table 24, indicate that our results are high, but within the range of other findings. When comparing these results, it is important to keep in mind that we used a different methodology to assess externalities and assessed different emissions at 174 dams. The three studies listed in Table 24 considered a small handful of projects, different stages of the hydro life cycle and different emissions. For example, no peer-reviewed study included comprehensive evaluations of upstream emissions, or operations-phase greenhouse-gas or methyl mercury emissions. In addition, the PACE study and the BEA study were average assessments, whereas the DOE study was for a marginal increase new hydro. The DOE estimated their results at a Southwest retrofit of an existing dam, and a Northwest, best technology diversion project. Our higher estimates are partly explained by the extended scope of our analysis.

Our results are also comparable to peer-reviewed externality estimates for the coal fuel cycle. Table 25 summarizes the results of some peer-reviewed coal externality studies. Study estimates range from $1.3 to $64 per megawatt hour and they were discounted at a rate between 3 and 5 percent. Most of these studies concentrate their assessment on operations-phase emissions, suggesting that comprehensive upstream analysis, using IO-LCA would increase estimates. The low estimate (DOE 1995) was developed for marginal increases in 1995 for the best-available clean-coal technology.

Table 24 Study results in the context of other externality studies of the hydro fuel cycle ($/MWh)

Ellis, 2000		[PACE 90]	[DOE 95]	[BEA 89]
New England	Hydro Quebec	$0	$.1	$10 - $12
$7 - $23*	$44*			

*non-discounted results

Our non-discounted, average estimates for all New England projects are in the lower range, and our estimates for the Hydro Quebec projects are within the upper range of the coal fuel cycle.

Table 25 Externality study results for the coal fuel cycle ($/MWh)

[PACE 90]	[DOE 95]	[EC 95]	Bailly, 1995	Private Studies (from Krupnik, 1996)
$25 - $58	$1.3	$19	$2.9	$54-$64

CHAPTER V

DISCUSSION

5.1 Introduction

Hydroelectricity is widely assumed to be an environmentally benign, renewable energy source, especially when compared to other fuel cycles. Unlike fossil fuel cycles, hydro is commonly thought to emit no greenhouse-gases or heavy metals from the operations-phase (DOE 1995, PACE 1990). Proponents of the hydro fuel cycle argue that life cycle emissions per unit of energy are non-existent, or minimal and site-specific (Gagnon and Chamberland 1993, Duchemin et al. 1995, American Rivers 1998, DOE 1995, PACE 1990). Impacts to local hydrology and land-use changes from flooding reservoirs are thought to be small and have few long-term effects (HQ 1990).

Our results suggest that hydro is not as environmentally benign as it is commonly held. We find that external costs per unit of energy for the majority of individual hydro facilities assessed are small as compared to other fuel cycles. However, a small handful of individual hydro facilities greatly exceed average external costs for other fuel cycles, including the coal fuel cycle. The average external costs for New England hydro projects are lower, but comparable with, average external costs from fossil fuel cycles. The projects with the best siting have very low external impacts, considerably lower than the average estimates from the coal fuel cycle. In contrast, Hydro Quebec projects potentially have higher external costs per unit of energy than average emissions from the coal fuel cycle.

In addition to our findings, which are generalized for all hydro projects within our case study region, numerous biological studies suggest that site-specific impacts external to the price per unit of energy can be significant. Impacts to anadromous fish can have significant local and regional effects on recreation and commercial fishing, as well as initiate long-term changes in biodiversity (PACE 1990, Chambers 1992, Hazel 1991). Changes in hydrology tend to mobilize sediments during the construction phase, and restrict sediment and nutrient transport once dams are in place (Rosenberg et al. 1997, DOE 1995). Land-use changes, such as flooding and clearing transmission lines, can affect aesthetic, cultural and biological resources (Maxwell et al. 1997). These impacts tend to be site-specific and difficult to generalize from one plant to another. In many cases, these impacts would be mitigated through regulation, and the associated externality would be internalized in the price of electricity.

5.2 Implications for Public Policy

Because we have conducted an average assessment of the hydro fuel cycle, the direct implications of our study on public policy are limited. Our results do not include the total array of site-specific damages and benefits needed in state-level electricity capacity planning. Rather, detailed marginal assessments are needed for states to minimize incremental changes in social costs resulting from changes in consumer demand for electricity. However, our results do provide some insight into characteristics of the fuel cycle that have not been included in previous quantitative assessments of hydro, and they are, therefore, important in state-level planning and siting of new hydro facilities, as well as identifying impact pathways to include in marginal assessments.

Our results may be more directly applicable to regional and federal-level policy and planning where average assessments are useful for considering incentive-based environmental regulation. Efforts are underway in New England to adopt uniform information disclosure labels for the deregulated electricity markets. The New England public utility commissioners have received a report from the managers of the National Council that recommends a number of policies and actions for commissions to take in streamlining information disclosure (Austin et al. 1997). At the heart of these recommendations are information standards for emissions release labels that would be published on each electricity bill, and would be made available in marketing materials. Nuclear, coal, oil, gas and renewables are the recommended categories for the fuel mix portion of the label, and average estimates of emissions would be included on the label. Pollutants likely to be included are sulfur dioxides, nitrogen oxides, mercury, particulate, and carbon dioxide releases from the operations-phase. Because the commission assumes that hydro does not emit any of the above listed pollutants, hydro would be lumped in with renewable fuel sources and would not be counted on the emissions portion of the label. The label would present no environmental impacts from any other part of the hydro fuel cycle. Our average assessment of New England hydro provides adequate baseline information for refining the proposed label to include operations-phase emissions from the hydro fuel cycle.

Research indicates that demand for renewable electrical products is likely to increase in deregulated markets (Holt 1997, Austin et al. 1997). Because hydro would be lumped in with renewables, the label under consideration by the New England public utility commissioners would “push” environmentally conscientious electricity consumers toward hydro products and away from fuel cycles that produce the listed air emissions. In addition, considering all hydropower benign allows the largest, lowest-cost hydroelectric generators to dominate the low impact renewable energy market. In New England, this means Hydro-Quebec, with low cost and large quantities of hydropower, would wheel additional electricity into the New England markets. In New England, Hydro Quebec has the lowest market costs, but, as our results indicate, some of the highest external impacts. Significant market shifts toward “green” energy products based on the information disclosure labels could have the unintended impact of increasing demand for products with some of the highest externality costs and largest social and environmental impacts.

Hydro Quebec is still considering the Great Whale project, which would divert the Great Whale River and three other rivers, into the La Grande watershed (Maxwell et al. 1997). If this project were to proceed, then storage in the La Grande complex would more than double with a one eighth to one quarter increase in power output (Amyot et al. 1976). Our results suggest that increases in capacity would release significant additional greenhouse-gases, an issue of global concern. The Great Whale is one of many Canadian hydro projects of similar scale. Hydro Quebec has currently tabled the project in order to develop more accurate electricity demand projections, including those associated with the New England region. It is possible that the regional labels that combine hydro with renewables could precipitating additional Canadian hydro projects with the unintended effect of increasing globally significant social costs.

From a Federal perspective, our average estimates could be useful to the Federal Electric Regulatory Commission (FERC), the agency with regulatory oversight of private hydroelectric projects in the US. FERC is required to balance the benefits of individual projects against external environmental and social costs. Where social and environmental costs are high, the FERC requires mitigation measures. In some cases, the environmental impacts of a project have been high enough for the FERC to require project decommissioning and removal (Reisner 1998). To date, the FERC does not assess indirect or direct emissions from the hydro fuel cycle. Our model would provide additional, average quantitative information about some of the external costs that are not currently considered in the FERC licensing process. Our methods for estimating average, baseline damages could be adapted to different regions of the country and could be improved through more site-specific estimates of local and regional damages.

In addition, the FERC is considering methods to assess the greenhouse-gas emissions avoided by individual hydro projects (see Commission Rulings, including Herbert 2000). The FERC position is based on the assumption that hydro emits no operations-phase emissions. Our results refute this position, and our model could be used to study emissions from individual projects in the context of regional baseline averages, and in the context of emissions from other fuel cycles.

5.3 Limitations of Our Model and Economic Valuation

Significant testing of our results is necessary to validate our findings. Our results indicate that a fundamental shift in perspective with regard to the societal impacts of the hydro fuel cycle may be in order. However, there are a number of limitations to our model.

First, life cycle inventory results are known to have problems with data accuracy and quality. We used input-output life cycle assessment techniques that generalize emissions for products by industry sectors. Environmental matrices used to estimate emissions often require voluntary reporting (Lave 1996). It is possible that material inputs could have more or less emissions per unit of energy than we assessed. In addition, we calculated detailed material inputs for one project, and assumed that these materials are the same for all of the projects in our model. It is likely that dams were constructed with various techniques and materials at individual sites. Sensitivity analysis could be used to further study the effects of small changes in both the input data and the externality data.

Second, we based our estimates of greenhouse-gas emissions on recent and ongoing scientific research. Little work has been done to verify greenhouse-gas emissions outside of the boreal regions. Although based on the best available literature, it is possible that our estimates for New

England are significantly inflated, and our decomposition rates are exaggerated. For the Hydro Quebec projects, where these emissions appear to be very significant, assumptions about the emissions profile could inflate the external costs.

Third, economic valuation data used to convert quantified emissions to externality costs are order-of-magnitude estimates.

Fourth, many identified environmental impacts, as well as external benefits, were not quantified in this study. We determined that these impacts are typically site-specific and are often internalized in the price of power through regulatory oversight. Even if one could quantify these impacts at individual sites, few externality estimates are available with which to convert these impacts into damages.

We considered our results order-of-magnitude estimates of external costs for the projects assessed in this study.

CHAPTER VI

CONCLUSIONS

We had two main objectives in this paper. Our first objective was to identify assumptions and problems in the application of economic valuation to LCA inventory data that can lead to erroneous results. We identified a number of deeply embedded assumptions in economic valuation studies that may conflict with the LCA practitioner's results. We recommended explicit descriptions of the underlying economic valuation studies, and, where possible, we recommended adjusting valuation results to comply with LCA assumptions.

We also found that the Damage Function Approach, used in marginal economic valuation studies, could be combined with LCA impact assessment and would be appropriate for assessments of damages at the margin. We found that expanding the scope of LCA with economic valuation methodology as developed by Craighill and Powell (1996) to include dose-response functions and other attributes of the Damage Function Approach would improve the accuracy and transparency of results.

Our second objective was to develop baseline, average damages for the hydro fuel cycle in order to consider impact pathways excluded from previous studies. We presented a case study of hydroelectric facilities in New England and Quebec in order to compare the relative burdens of small, medium and large hydro projects. In the preceding paper, we used input-output life cycle assessment to quantify the emissions associated with the construction and operations phases of the hydro life cycle. In this paper we used economic valuation to assigned weights to the emissions flows and compared the net external costs from the hydro fuel cycle.

Table 26 summarizes our results. We find that, for the projects assessed, the Hydro Quebec projects have the highest environmental burdens, and that large New England projects have the smallest environmental burdens. We found that CO2 emissions from the operations-phase, and SO2 from the upstream phase, represent the largest external impacts of the fuel cycle.

Table 26 Hydro externality estimates ($/MWh)

	VOCs	NOx	CO	CO2 Construction	SO2
Small	$0.119	$0.530	$0.001	$1.762	$2.635
Medium	$0.069	$0.311	$0.000	$1.033	$1.545
Large	$0.136	$0.607	$0.001	$2.019	$3.018
All NE Dams	$0.108	$0.485	$0.001	$1.613	$2.411
HQ	$0.003	$0.018	$0.000	$0.953	$0.355

	PM10	**Solid Waste Disposal**	**Operations CO2**	**Operations MeHg**
Small	$0.227	$0.00016	$22.50	$0.02
Medium	$0.133	$0.00009	$13.27	$0.03
Large	$0.260	$0.00018	$5.75	$0.02
All NE Dams	$0.208	$0.00014	$19.45	$0.02
HQ	$0.021	$0.08444	$42.99	$0.16

We included new empirical estimates of greenhouse-gas and methyl mercury external costs resulting from impoundment flooding. Previous studies of the hydro fuel cycle cite the lack of greenhouse-gas emissions as a primary benefit of the fuel cycle (DOE 95; PACE 90; Gagnon, et al, 93). Our findings dispute these results and suggest that greenhouse-gas emissions are contributors to the cumulative external burdens from the hydro fuel cycle.

Our study could be expanded in a number of ways. First, with little increased effort, the model could be expanded to include all regions of the U.S. and Canada, which would improve regional, average estimates of externalities. Second, more detailed, site-specific infrastructure data would enhance the accuracy of the model. Third, additional site-specific environmental impacts and external benefits could be included, such as long-term impacts on anadromous fish, degraded water quality, increased recreation activity or increased real-estate value. Last, improved estimates of error, such as sensitivity analysis or Monte Carlo modeling, would provide more accurate estimates of the error in our model.

PART III

TIME VALUE, DISCOUNTING AND LIFE CYCLE ASSESSMENT

CHAPTER I

INTRODUCTION

This paper is the third in a series of three describing a life cycle assessment (LCA) model with economic valuation of the hydro fuel cycle. Our main objective in this paper is to explore the role of time in LCA, and consider discounting as a methodology for more explicit handling of time-related assumptions and values for short-term projects (less than 40 years). To that end, we review economic theory on time-value, and identify assumptions about individual preferences and economic growth that lead to the changing value of resources over time. We point out that these assumptions are both theoretically consistent with maximizing social welfare, and empirically expressed in market behavior. We submit that LCA studies with economic valuation, which appear to reject or ignore discounting, actually apply a discount rate of zero, with a set of assumptions about future economic growth and personal preferences that are implicit in the analysis.

We also consider criticisms of discounting, particularly that the mechanics of discounting can lead to favoring projects that have significant future environmental impacts. This is especially true when the benefits of a project are realized early in the project life, and the costs are deferred to the future. These criticisms are primarily concerned with questions of equitable distribution of the benefits and costs of LCA projects so that society has as a whole benefits from public policy and regulatory action. We follow the lead of conventional economists and suggest that, for short-term projects, discounting is concerned with the efficient allocation resources over time rather than equitable distribution of resources to members of society. We point out that discounting provides insight into efficient projects where the benefits outweigh the costs, but that society may choose the less-efficient project when other criteria, such as intergenerational fairness, are considered. For short-term projects, we suggest that questions of equity or fairness in distributing the costs and benefits of regulatory projects should be handled through distributional weights.

As an illustration, we present the discounted and non-discounted results from a LCA study with economic valuation of hydroelectricity, and compare these results to a simple LCA model of a generic U.S. coal-fired plant. We show that private investment decisions and public policy positions can fundamentally shift when different discount rates are used. In our example, high discount rates would suggest that coal-fired electricity has similar impacts to the hydro fuel cycle.

Discounting is methodologically and philosophically complex, and we do not presume to resolve the debate over what discount rate to use. However, we find that when economic valuation is applied in LCA to assess environmental and social impacts from short-term projects, then discounting is an appropriate tool for making explicit values and assumptions that would otherwise remain deeply embedded in the analysis. We suggest that simple sensitivity analysis at different rates would go a long way toward recognizing time-value issues in LCA. A more comprehensive analysis of time-value in LCA, such as explicitly following the steps in calculating a discount rate, would provide deeper insights into embedded values and assumptions about social preferences and economic growth, even if that rate is zero. Discounting, combined with distributional weights, would provide a more equitable and transparent handling of time-value in LCA models.

CHAPTER II

TIME-VALUE AND EQUITY FOR SHORT-TERM PROJECTS

There is no doubt that the issue of what rate to use for discounting non-market projects, particularly those with time horizons beyond 40 years, is unresolved in economics (see Portney & Weyant 1999). We explore this debate and the methods for calculating a discount rate in the following sections. However, both mainstream and environmental economists tend toward agreement on the question of when to discount costs and benefits. Economists recommend that, for any economic analysis with temporal aspects that do not exceed 40 years, costs and benefits should be discounted at some positive rate (Arrow 1999, Weitzman 1999, Mann 1999, Schelling 1999).

This position follows from the basic economic tenet that resources are subject to declining value over time. The common adage, "A dollar today is worth more than the same dollar one year from now," has real implications when considering external costs borne by society. Time-value, which is central to the question of discounting in welfare economics, indicates that private firms and government officials achieve economic efficiency when they maximized discounted net benefits and costs. Discounting is simply applying temporal weights that adjust benefits and costs to reflect time-value.

Three factors go into creating economic time-value effects. First, opportunities for private and public investment allow for compounded returns (Farber & Hammersbaug 1993). By investment, we refer to the economist's definition of spending on productivity enhancing capital goods by firms and government, which will allow increased production of consumer goods and services in future periods.

Second, investment today requires cash out of hand, forgoing the opportunities for spending on purchases today, or taking advantage of higher-yield investments that may arise. Economists argue that, all things equal, people have time preferences, and the time-value is society's way of compensating for forgone consumption opportunities.

Third, economists generally assume that economic growth will occur, thus improving the standard of living of those in the future. It is likely that in the near future, economies of industrialized countries will continue to expand, making future generations wealthier than present generations. This has the effect of further decreasing the value of a dollar in the future.

These three factors, though theoretical, play out in the real world of private and public finance. Regardless of whether the dollar is spent on the cost or benefit side of the equation, and regardless of whether that dollar represents a cost or benefit that is external or internal to the financial markets, that same dollar is less valuable in the future. Discounting is simply a method for adjusting the real difference between present value and future value, and it provides information about the overall economic efficiency of an investment.

CHAPTER III

CALCULATING THE DISCOUNT RATE

3.1 Introduction

When concerned with external costs borne by society, as we often are in LCA studies, economists recommend discounting at the social discount rate (SDR). Economists define the SDR as the rate at which society as a whole is willing to trade present consumption for future consumption (Sassone & Schaffer 1998). As previously indicated, economists generally agree that discounting is appropriate for short-term projects. However, determination of the appropriate rate for the SDR presents complex methodological problems that are, as of yet, unresolved. We consider these issues in the following section. For our purposes, the question is less about the appropriate rate and more about the assumptions necessary to calculate various rates. Discounting provides a methodological forum for clearly stating assumptions that are otherwise implicit in LCA results.

Brent (1996) defines discounting as temporal weighting of costs and benefits. Net benefits from an investment today are returned over time, and, because the values of these benefits are different at different points in time, they can be weighted with time-dependent parameters relative to the investment.[7] Based on the assumption of time-value, the weights assigned to cost and benefit streams will decline the further they are from the present. This rate of fall in the weights can be thought of as the social discount rate.[8]

Economist advocate two methods for calculating the SDR for near term, present value calculations, the social opportunity cost rate (SOCR), and the social time preference rate (STPR). In general, the SOCR leads to higher discount rates and the STPR leads to lower discount rates.

3.2 Social Opportunity Cost Rate (SOCR)

The SOCR is based on the argument that if public investment could earn a high return, say 10 percent, then accepting projects that would return less would deprive society of more productive investment opportunities. The SOCR is essentially the market rate of return. The SOCR would be the appropriate discount rate if the markets are truly efficient, have no distortions, and future economic conditions are known, conditions that work in theory, but not in practice (Howarth & Norgaard 1993)[9].

---

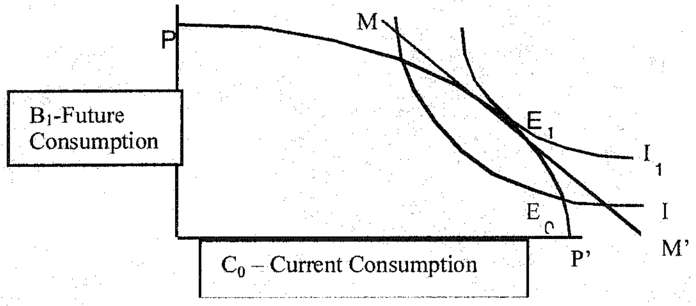
[7] $B_t = -w_0 C_0 + w_1 B_1$ Where B_t = total benefits, C_0 = investment in year zero, B_1 = benefits year 1, and w = weights.

[8] The social discount rate (I) is defined as the falling weights of costs and benefits over time.
$i = \frac{w_0 - w_1}{w_1}$ or $\frac{w_1}{w_0} = \frac{1}{1+i}$

[9] Utilizing the market rate of interest as a proxy for the social discount rate is rejected in the literature (Brent 1996). In a perfectly competitive market with no constraints, it is possible that the STPR (slope of social indifference curve I), SOCR (slope of production possibility indifference curve P), and the market rate of return (slope of market indifference curve M)could be equal at point E_1. However, in the presence of any additional constraints, such as taxes or non-competitive markets, the amount investors are willing to pay and savers are willing to receive are separated. This moves the social indifference curve from I_1 to I_0. Note that the slope of E_0 is no longer tangential to market, or SOCR curves.

A second weakness with this line of reasoning is that it assumes a fixed budget constraint, where a decision-maker has a fixed amount of money to allocate to the investment with the largest present value. The issue of whether an investment is undervalued relative to consumption is more a shadow price issue than an issue of valuing of future resources against today's resources (Brent 1996). Shadow price is a synonym for social value, where the market price of a resource does not reflect the true value society places on that resource. As this relates to efficiency of an investment, analysts would quantify the shadow price of each cost and benefit in the analysis and recommend changes in behavior to bring market prices in accordance with shadow prices. For projects with time dimensions, this requires estimates of numerous discount rates. The Office of Budget and Management (OMB) suggests that the shadow price method is the analytically preferred approach to assessing the impact of public investment on private-sector resources (as cited in Carson 2000). However, because of the complexity of the shadow price analysis, the OMB recommends that public agencies use a single discount rate for assessing the social value of public investment.

Markandya and Pearce (1991) point to a third weakness with the SOCR methodology. If society consumes public funds rather than invests at the best market rates, then the SOCR becomes an irrelevant metric. There is no opportunity cost for consumption.



3.3 Social Time Preference Rate (STPR)

Two methods are used to calculate the social time preference rate. The first method is known as the individual time preference methods, where one quantifies through surveys the value individuals place on the consumption rights of living and future generations. Some economists argue that a degree of consideration of future generations exists in the individual time preferences of current generations. Parents are concerned about the welfare of their children, although such concerns require forgoing consumption today for the benefit of future generations. However, others have argued that humans are myopic when it comes to allocating resources over time (Pigou 1920). We choose to consume non-renewable resources at a rate that could preclude a second and third generation's use of these resources. The myopia of the individual time preferences leads to heavy weights for consumption by current generations and light weights for consumption by future generations. When the SDR is calculated using individual time preferences, we reduce the importance of future generations' needs in the consumption decisions made by living generations, arguably not a socially optimal solution.

The myopia of the living generation has led some economist to argue for an authoritarian time preference method where estimates of socially optimum allocation of resources between generations is used to set the discount rate. This method is based on the assumption that society has an equal responsibility to future generations, a relationship that requires a higher responsibility to future generations than the individual time preference indicates (Brent 1996). Equal consideration, however, does not mean equal weight in the time preferences. Theory holds that future generations can expect to be better off than current generations because economic growth will increase their wealth, a reasonable assumption for near-term projects. In addition, there is a decreasing marginal value to increased consumption.[10] In other words, a unit of benefits is more valuable to a person with fewer resources than to a person with more resources. Economists argue that multiplying the growth rate of income by the change in marginal utility leads to socially optimum discount rates.

Expressed as an equation, the social time preference rate looks as follows:

$$i = \eta g + z$$

Where i = the social time preference rate, η is the percent change in social marginal utility of income, and g is the rate of growth of real future consumption.

Because the individual's time preferences are removed in the authoritarian analysis, other economists advocate the inclusion of the rate of pure time preference, z in the equation above. Brent (1996) suggests that people would want to discount the future simply because it is the future and does not include them. Squire and Van der Tak (1975) recommend "fairly low values (for z), say 0 to 5 percent, on the grounds that most governments recognize their obligation to future generations as well as to the present." Pure time preference has the benefit of allowing the discount rate to be positive when other factors would lead to a zero, or negative SDR.

---

[10] Social discount rate (i) = elasticity of social marginal utility (the first parenthetical statement) times the multi-generation income growth rate (the second parenthetical statement) $(Y_1 - Y_0)/Y_0$ is the percent change in income over generations. $(W_0 - W_1)/W_1$ is the definition of the social discount rate used in footnote 3 to highlight the declining weights assigned to future generations.

$$i = \left[\frac{(w_0 - w_1)/w_1}{(Y_1 - Y_0)/Y_0}\right]\left[\frac{(Y_1 - Y_0)}{Y_0}\right]$$

The STPR should equal the SOCR before taxes and other market distortions are included in the assessment. Taxes drive a "wedge" between individual preferences and the opportunity costs for firms (Lind 1982). For example, in order to fulfill a 2 percent discount rate for personal consumption, firms must invest in projects offering a minimum of 2 percent plus the tax rate. If taxes reduce profits by 50 percent, then the firm will need to earn a 4 percent return in order to give shareholders their 2 percent after-tax return. While the SOCR is 4 percent, the STPR is two percent.

3.4 Subjectivity in Calculations of the STPR

Calculations of each variable in the social time preference equation require a certain degree of subjectivity. On the surface, calculating the growth rate of capital income (g) is straightforward. Coefficients for g are generated through time series regressions of per capita consumption. However, environmental economists suggest that the issue is more complicated. They argue that the GDP does not distinguish between production income and natural resource exploitation income, and the GDP does not make a distinction between reparation costs and expenditures that increase wealth. (Serafy & Lutz 1989, Norgaard 1989, Hueting 1991). This suggests that the GDP is generally overvalued, indicating that better accounting could create situations of low, or even negative growth. Further, England (2000) develops a growth model that includes natural capital, which suggests that a significant portion of perceived growth depends, among other things, on unsustainable appropriation of non-renewable resources. If these claims are true, then the 2 to 3 percent growth rates typically used in the U.S. and Canada could greatly inflate the social discount rate.

Calculating the elasticity of the social marginal utility of income (η) requires value judgements about the importance society places on income inequality between economic classes. Benefits from a project are often broken into low, medium and high income brackets in order to assess the impact additional benefits will have on each group (Hau, 1986). Economists assume that a unit of benefit leads to higher utility in low-income recipients as compared to high-income recipients. In addition, the allocation a unit of benefit to increase the utility of an income group leads to secondary positive effects on the welfare of society.[11] But, quantifying the increase in utility of both the income group and society requires setting distributional weights for both categories (Brent 1996). By "ignoring" the weights in the SDR calculation one is essentially setting the weights at one, and inserting the value judgement that marginal utility is equal among income groups.

Setting the pure time preference rate (z) is also fundamentally a subjective process. Brent states that "there are no theoretically accepted procedures for deriving (z), except for extreme cases . . outside of the extremes, one has little guidance (Brent 1996)." A choice of z=0 assumes that all individuals in society, both future and current are equal, and rejects the notion of allocating a premium to current generations. A choice of z=∞ assumes that the worst-off individual in society is the only one that matters. Society should choose efficient welfare projects that increase the utility of one member at a cost to other members' utility. Some efforts to calculate z have analyzed change in mortality rate, and others simply recommend a value of z=1 or less (Brent 1996, Squire & Tak 1975).

In summary, where capital markets are truly efficient, future economic conditions are "known," and the allocation of wealth between members of society is equitable, then the SOCR is the

---

[11] The most common way to calculate the social marginal utility of income is to set the change in utility of individuals on social welfare ($a_{i)}$) = 1.

$$\eta_i = \left[\frac{\Delta SocialWelfare}{\Delta UtilityGroup(i)}\right]\left[\frac{\Delta UtilityGroup(i)}{\Delta IncomeGroup(i)}\right] = a_i\lambda_i$$

appropriate rate for discounting. However, Howarth and Norgaard (1993) point out that these conditions are stringent, and are often considered "first-best," highly theoretical examples, rather than practical conditions from which to derive the SDR.

Lind (1990) and Hanley (1992) consider a "second best" scenario, where taxes and other factors distort the theoretical versus actual return on a capital investment. Under these conditions, with timeframes of 40 years or less, the STPR is the appropriate discount rate.

3.5 Equity

When considering short-term public investment, efficiency is only one part of the economic analysis. Equity, or who pays the costs and who receives the benefits, is an equally important factor in determining whether a policy option is socially viable (Pearce & Markendaya 1991, Norgaard 1997). For example, a policy option may be economically efficient, with the benefits significantly outweighing the costs, while the poorest sectors of society bear the costs and the richest sectors of society receive the benefits. Though this example may be economically efficient, it is unlikely that such a policy would be taken, as the net benefit of the project would reduce society's overall welfare.

Society's overall welfare would be reduced because, as economists argue, the utility of a dollar in the hands of a poorer person exceeds the utility of dollar in the hands of a richer person. A person with a $1 million annual income is likely to be less concerned with a tax of $100 in comparison to a person with an annual income of $20,000. The welfare of society as a whole is improved if efficient policies are adjusted to fairly reflect the disproportionate utility of those affected by a policy.

In a practical sense, equity issues are dealt with in economics by assigning distributional weights to the costs and benefits, a method that is mathematically similar to discounting with a fundamentally different outcome. Distributional weights are used to value resources to different people in each time period, whereas discounting is used to value resources to the same people at different point in time (Brent 1996). The outcome of equitable allocation may lead to the adoption of an economically inefficient policy that distributes costs and benefits in such a way as to increase social welfare.

Conservationists' concerns about discounting are not unfounded. Economic studies of natural resource management often focus on efficiency, and the consequence of an efficient cost-benefit assessment, such as rapid depletion of non-renewable natural resource, appears to reduce society's, particularly future generations', overall welfare. As Markandya and Pearce (1991) point out, a primary criticism of discounting has to do with the outcome of the costs benefit equation; the management of non-renewable natural resources in a discounted analysis can lead toward rapid depletion of stocks and the inability to sustain basic living standards in the future. Without accommodating for factors in income distribution, the analysis of project efficiency can be destructive to the environment.

Nonetheless, economists argue that much of conservationists' concern about discounting appears to confuse economic efficiency with equitable resource distribution. Portney and Weyant (1999) point out that one could reject inequitable projects even when they pass efficiency tests with extreme net benefits. They argue that tinkering with the discount rate to mitigate for equity issues is not defensible, and remind us that efficiency is "hardly the only criterion that matters in policy analysis." For similar reasons, Markandya and Pearce (1991) argue that discounting "should not be tampered with." They propose a method for including sustainability criteria used as weights in the cost benefit analysis in order to more equitably allocate costs and benefits without overturning a fundamental neo-classical economic tenet: the time-value of money.

Questions of equity and efficiency become increasingly complex as time periods exceed the living generations. Howarth (1996, 1997 & 1998) and Norgaard (1991, 1993, 1998) make compelling arguments that questions of maximizing efficiency within one generation are fundamentally different from questions of resource allocation over many generations. They suggest that if the allocation of resources between present and future generations is equitable, and follows social welfare functions, then economic cost benefit analysis, using the SDR, improves the efficient allocation of resources between generations. However, they suggest that if equitable conditions are not met, such that the distribution of resources between generations does not maximize the welfare of both generations, then cost-benefit methods may not support efficient transfers of resources. In fact, discounting could serve to exaggerate equity disparities between present and future generations (Howarth & Norgaard 1993). With some similarities to Markandya and Pearce, they suggest methods for allocating stock resources to future generations.

3.6 Discounting in LCA & zero discount rate

To date, LCA studies have not applied discounting in the economic valuation step, despite the observation that impacts from emissions typically have a time dimension (Frankhauser 1994, Rudd et al. 1993). Craighill (1996) and Powell (1997) demonstrated the power of economic valuation in impact assessment of LCA modeling. However, they did not allocate their results to different points in time, and their studies do not include discounting. When discounting is not included in LCA impact assessment, then a unit of emissions in year one of a proposed project has the same impact as a unit in year 40.

The Society of Environmental Toxicology and Chemistry (SETAC) has developed best available practice recommendations for conducting LCA studies (SETAC 1999). These recommendations suggest that the impacts identified in LCA studies integrate over time, and that all impacts, irrespective of when they occur, should be equally weighted. This implies that all environmental impacts have infinite lives with no potential for future mitigation. For impacts that have known environmental effects with long time horizons, such as those greenhouse-gases associated with global warming, SETAC recommends assigning long time periods to the project that imitate infinite time, such as 500 years. SETAC assumes that most of the impacts will have taken place and that we can ignore differences between a long time horizon and infinite time. SETAC recognizes that this is an assumption that has yet to be verified.

We consider both the Powell and Craighill approach and the SETAC recommendations for infinite time to be an implicit assumption of a zero discount rate. On the surface, the idea of a zero discount rate is appealing, since a death today and a death tomorrow are considered on some level equal. However, as we are concerned in this paper with discounting within one or two generations, such an assessment makes little sense. From an individual perspective, we are not indifferent about whether we die today or well in the future. In any economic assessment, the effect of utilizing a zero discount rate is two-fold. First, the outcome of applying a zero discount rate can lead to implausible results that do not reflect current understanding of time value and social preferences. Second, and more importantly to our discussion, assumptions about social preferences and time are deeply embedded in the analysis.

Application of a zero discount rate can lead to internal conflicts in cost-benefit analysis (Farber & Hemmersbaugh 1993). If a discount rate is less than the risk-free rate of return from an investment, such as a bond, then this can lead to contradictory solutions. For example, if the present value with a zero discount rate for an environmental clean up program cost $2 million, but society is only willing to pay $1 million, then a socially agreeable solution would be to invest $.5 million in government bonds until it reaches the $2 million value of project. The further the costs occur in the future, the lower the cost of the initial investment. This suggests that the regulatory costs to society are less than the present value of the environmental clean up program, despite the fact that benefits of the investment will outweigh the costs when they occur in the future.

From a private perspective, if a zero discount rate is assumed, then the present value of an investment option equals the value of the same investment in the future. Borrowing capital would be essentially free, and firms would likely borrow to support consumption today rather than in the future.

Calculations of a zero discount rate require a set of assumptions about economic growth and social preferences that are embedded in the LCA valuation step. Although mathematically infinite, in a practical sense, there are numerous combinations that could lead to a zero discount rate, all of which require a set of assumptions about time value and preferences. For $\eta=0$, we assume that 10 dollars of goods and services provides the same utility to the poorest member of society as it does to the richest. For $g=0$, we must assume that the economy will not grow over the period of time of the analysis. For $z=0$, we must assume that society allocates no time preferences for a dollar in hand today over a dollar next year. All of these assumptions are imbedded in any economic valuation step that utilizes a zero discount rate.

Economists debate the merits of various methods used to calculate the SDR, and, as previously demonstrated, the outcome of the various calculations leads to significantly different values.

Tresch (1981) wrote “In our view, it would be difficult to mount a decisive case for or against any rate of discount governments might choose over a range of 3 percent to 20 or even 25 percent.” A review of discount rates used by U.S. government agencies in the late 1960s indicated that the actual range used in evaluating social welfare projects was between zero percent and 12 percent (Staats 1969). This range is significantly smaller than what Tresch suggested might be acceptable, but still large enough to see that establishing the social discount rate is far from an exact science. The Office of Management and Budget recently revised its recommendations for discounting regulatory cost and benefits from 10 percent to 7 percent (OMB 1992). The OMB estimates a 4-percent rate of time preference. In practical application, most economists advocate a social discount rate in the range of 1 to 3 percent (Lind 1990, Howes 1990, Farber et al. 1996). Those economists that include the tax wedge driven between the opportunity cost methods, and the STPR methods typically recommend discount rates from 3 to 6 percent (Arrow 1999, Weitzman 1999).

Choosing the proper discount rate is a challenge. Calculating the discount rate requires significant knowledge of complex economic concepts, and leading economists are clearly divided on what method to follow. We do not presume to resolve the debate in this paper. However, we feel that ignoring time-value in LCA poses additional problems that should not be dismissed. Applying a zero discount rate requires a set of assumptions that do not generally reflect our empirical understanding of preferences and values. As it relates to practical decisions in LCA, we cannot wait for resolution on which method to choose in calculating discount rates, and we cannot necessarily continue to apply a zero rate with its deeply embedded assumptions.

If we accept that economic valuation is a useful method for considering alternative actions, then the actual discount rate is less important than the assumptions that underlie the development of a given rate. Discounting provides a forum for airing assumptions, and basic assumptions and impacts of different rates on time-dependant data can be explored in LCA results through simple sensitivity analysis.

CHAPTER IV

SIMPLE DISCOUNTED MODEL OF THE HYDRO FUEL CYCLE

4.1 Introduction

In order to demonstrate the power of discounting and the impacts of applying a zero discount rate, we performed an Input-Output LCA study of the upstream emissions and the quantifiable operations emissions associated with the hydro fuel cycle. We report our inventory assessment results and our impact assessment, as well as other background information, in the first and second papers in this series (Reference). We used data from all concrete, hydroelectric dams in New England (174 total dams) and the Hydro Quebec La Grande complex (4 dams). We calculated externality costs for each emission category, including conventional air and water pollutants, and greenhouse-gas emissions. We also assessed the upstream toxic chemical emissions to water and air, but we did not include this data in our model. Despite the small per-unit emissions of toxic materials, the externality cost for toxic materials represented over 90 percent of the total externality costs for the hydro fuel cycle and we were uncomfortable with the transparency and accuracy of toxic externality calculations.

We allocated external costs per unit of energy to the hydro fuel cycle to each year for an assumed 40-year project life. We allocated all upstream costs to year zero and all operations costs to their appropriate year in the project life cycle. We calculated the net present value for each individual project at year zero, in year 2000 dollars. The model has change cells for inputting discount rates, allowing us to test the sensitivity of our results to changes in the SDR. Appendix L shows the data included in our model.

4.2 Simple Coal Input-output LCA

For demonstration purposes, we developed simple model of upstream and operations air emissions from a representative coal-fired facility (Appendix M). We used two sources of data for the coal LCA model: facility construction data per kilowatt (DOE 1995), and operations-phase conventional air pollutants and greenhouse-gas emissions per kilowatt . We borrowed coal emissions estimates per unit of energy for New Source Performance Standard (NSPS) plants as cited in PACE 1990. NSPS plants include scrubber control equipment, but do not use clean coal fuel. We used non-discounted, raw data to construct our model and allocate externality cost data to each year of operations. As with the hydro models, we assumed a 50-year project life. Unlike the hydro assessment discussed above, the coal model does not include comprehensive upstream emissions associated with construction of the facility, or upstream emissions from coal mining and transportation of fuel to the generation facility.

Because we developed our coal model for comparison purposes, we were only concerned that our damage estimates fit within the range defined in the literature. A review of the literature indicates that our estimates for coal externalities at $20/MW are middle range between the low estimate of $1.3/ MW and the high estimate of $64/MW. Table 27 summarizes the results of the six studies we consulted in developing our simple LCA of the coal fuel cycle.

Table 27 Externality study results for the coal fuel cycle ($/MWh)

[PACE 90]	[DOE 95]	[EC 95]	Bailly, 1995	Private Studies (from Krupnik, 1996)
$25 - $58	$1.3	$19	$2.9	$54-$64

It is important to note that the studies assessed different impact pathways, considered different site-specific damages, and utilized different methods, making direct comparisons difficult. All of the studies used a 5-percent discount rate and assumed life cycles from 25 to 50 years. The lowest damage estimates are from a comprehensive study conducted by the Department of Energy (DOE 1995) that assessed marginal damages associated with six fuel cycles. The study initially considered all life cycle stages and all pollutant pathways, but reduced the scope of analysis in the face of uncertainty. The highest estimates come from a Pace University study (PACE 1990) and private-sector studies conducted by the Regional Economic Research (RER 1991), and the Triangle Economic Research (TER 1995). Our discounted estimates are consistent with those of the European Commission study (EC1995) which estimated externalities associated with nine fuel cycles located in England and Germany.

In both the hydro and the coal externality models, a number of environmental and health-related impacts are excluded from the analysis. Numerous impacts from the hydro fuel cycle are site-specific and difficult to quantify. These include impacts on water quality, fish and terrestrial resources. We also excluded external benefits, such as increased recreation opportunities and jobs. For both fuel cycles we excluded direct health impacts from operations of the coal facility, including worker fatalities, traffic accidents, and radon poisoning. Neither the hydro nor the coal model includes assessments of the impacts associated with operations, maintenance or decommissioning.

We discounted all future costs to present value and expressed the results in real dollars for the year 2000. We used a 5-percent discount rate and conduct sensitivity assessment with 2 and 10 percent rates. We assumed a 40-year project life for both the hydro and the coal models.

We use externality data from studies of society's willingness to pay to avoid impacts. A review of the externality estimates used in our model is in the second paper in this series (Part II of this thesis). We derived externality estimates using a three-step damage function approach where impacts were estimated, values for the impacts were determined, and the values were summed for each impact pathway.

4.3 Model Results

Net external costs for small, medium and large New England hydro facilities, as well as Hydro Quebec's La Grande project, are summarized in Table 28. Column A shows the results of the externality assessment using a zero discount rate. The results indicate that, though the externalities associated with marginal increases in hydroelectricity are significant, they are not as significant as those associated with the coal fuel cycle. In addition, electricity from a marginal increase in Quebec appears to produce more than twice the emissions of a similar increase in New England.

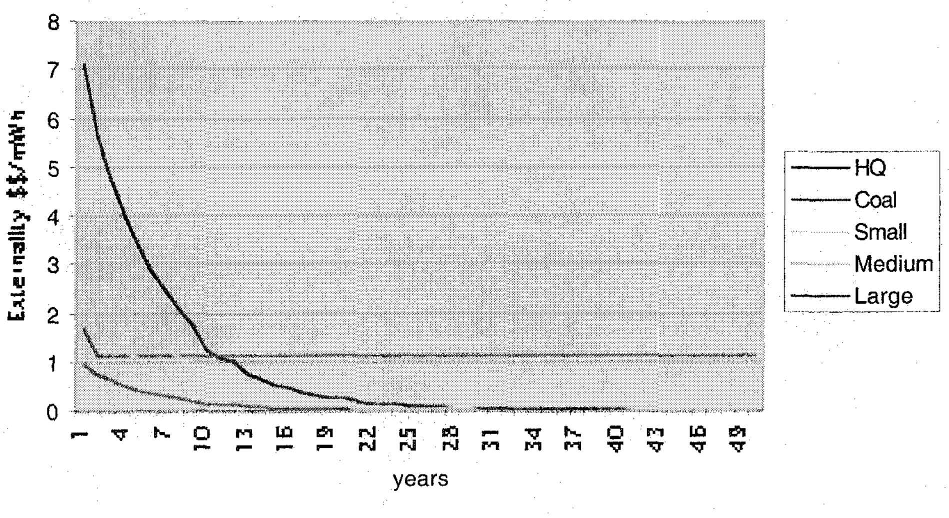
Table 28 Discounted externality results for the hydro and coal fuel cycles

	a) Zero Discount Rate ($/MWh)	b) 5% discount rate Average NPV/MWh	c) NPV % of zero discount	d) 2% discount rate Average NPV/MWh	e) 10%discount rate Average NPV/MWh
Small N.E. Dams	$28.37	$22.03	77.65%	$25.41	$18.08
Medium N.E. Dams	$16.74	$12.99	77.60%	$14.99	$10.66
Large N.E. Dams	$12.56	$10.68	85.02%	$11.70	$9.44
Hydro Quebec	$43.78	$31.63	72.25%	$37.94	$24.49
NSPS Coal Plant	$58.95	$19.46	33.01%	$31.71	$10.79

However, the results and associated policy conclusions become less clear when we discount the external cost stream. Column B shows the results of applying a 5- percent discount rate to the externality costs. The results are fundamentally different from the zero discount models. A marginal increase in coal generation capacity appears to have less impact than that of small New England hydro facilities, or that of Hydro Quebec facilities. When we apply a 10-percent discount rate the differences between models is further magnified. Column E indicates that the coal fuel cycle has similar impacts to those of the most environmentally benign hydro models.

The illustrative results in Table 28 highlight the power of compound interest rates, particularly when an analysis has a long time dimension. In our example, one would be more likely to recommend a marginal increase in hydroelectricity for LCA models that utilize zero discount rates. The analysis is less clear when an SDR of between 2 and 5 percent is used. Because the relative external costs per unit of energy are similar for the various hydro and coal models, other factors would play a larger role in distinguishing between alternative projects. When a firm's opportunity cost rate of approximately 10 percent is applied, a marginal increase of coal-fired electricity appears to have the least external costs.

Figure 18 Diminishing externalities over project life



These contradictory results and policy decisions that change with the discount rates used are due to structural configurations of underlying data. Figure 19 shows the diminishing external costs of the hydro fuel cycle in comparison to the constant emissions associated with coal plants. For the hydro fuel cycle, initial external costs are high due to the effects of upstream emissions and CO2 emissions from flooded reservoirs. In contrast, emissions from the coal fuel cycle are stable throughout the life of the project. When the coal plant is operating, the external costs are uniform. In situations where the majority of costs are borne early in the life cycle, discounting magnifies the relative impact of these burdens. For projects with relatively low initial costs consistent throughout the life of the project, discounting places less weight on the cost side of the equation. As the discount rate increases, projects that defer costs into the future appear attractive to the agency or the firm.

CHAPTER V

CONCLUSIONS

Economic valuation is a powerful methodology for quantifying external costs in the LCA impact assessment. However, LCA, which is often concerned with impacts that accrue over time, must develop methods for handling time-value. In this paper, we consider discounting as a method to more explicitly recognize assumptions about individual preferences and economic growth in the LCA impact assessment.

On the surface, choosing a discount rate appears to be an esoteric process. A brief review of discounting equations is enough to set this opinion. But the technical challenges of calculating a discount rate should not overshadow the purpose of discounting, which is to consider fundamental questions about the economy and philosophical questions about consumption preferences. Answers to these questions have real impacts on time-dependant LCA assessments.

We demonstrated that economic valuation studies that report aggregated results, but do not include discounting, are actually applying at zero discount rate. Discounting at a rate of zero requires a set of assumptions that do not necessarily match social scientists' understanding of time-value and consumption preferences. When we ignore time-value, assumptions about preferences and economic growth, which lead to the value of resources over time, are deeply embedded in the LCA analysis and results.

Consequently, we advocate a more transparent method for discounting. Our bias is consistent with conservationists' concerns that future generations receive inadequate attention in calculating the discount rate. In general, we follow economists' recommendation to discount at some positive social discount rate (between 1-3), although we recognize that economists are divided on what rate to use. At a minimum, LCA models should recognize time-value in their results by conducting sensitivity analysis for a number of different discount rates, and providing access to time-dependant data so that other users can adjust the assessment to comply with their values. A more comprehensive model would include justification for the chosen rates by explicitly expressing assumptions, and calculating a social discount rate. If conclusions do not shift with the changing rate, then analysts can make some claims about the efficiency of one project over another. If conclusions do shift, then other criteria are necessary in making a policy decision.

REFERENCES

Aldred, J., (1994): "Existence Value, Welfare and Altruism" *Environmental Values* 3(4).

(American Rivers 98) Bowman, M (1998): "Guidelines for Effective Participation in the FERC Relicensing Process," Hydropower Reform Coalition, American Rivers, Washington DC, July.

[American Rivers 98] Bowman, M., Rawls, T. (1998): "Hydropower as Low Impact Electric Generation Source" American Rivers & Green Mountain Energy Resources,

Amyot, P., Laliberte, C., and Larocque, G., (1976): "Meeting Quebec's Power Needs for the Eighties" *Water Power and Dam Construction*, July.

Arrow, K., (1999): "Discounting, Morality and Gaming" in *Discounting and Intergenerational Equity*, Eds: Portney, P., and Weyant, J., Resources for the Future, Washington, DC.

Austin, T. et al. (1997): *Uniform Consumer Disclosure Standards for New England: Report and Recommendations to the New England Utility Regulatory Commissions*. The Regulatory Assistance Project, Gardiner, ME.

Austin, T., Moskovitz, D., Harrington, C., (1997): *Uniform Consumer Disclosure Standards for New England: Report and Recommendations to the New England Utility Regulatory Commissions*, The Regulatory Assistance Project, Gardner, ME.

Ayres, R. and J. Walter (1991): "The Greenhouse Effect: Damages, Costs and Abatement," in: *Environmental and Resource Economics* 1:237-270.

[BEA 97] (1997): *Benchmark Input-Output Accounts of the United States, 1992.* U.S. Department of Commerce, Bureau of Economic Analysis, Washington, DC.

Bodaly, R.A., Rosenberg, D.M., Gaboury, M.N. Hecky, R.E., Newbury, R.W., and Patalas, K., (1984): " Ecological effects of hydroelectric development in northern Manitoba, Canada: The Churchill-Nelson diversion" In: *Effects of Pollutants at the Ecosystem Level* P.J. Sheehand (eds.) SCOPE, and John Wiley and Sons, Ltd.

Bockstael, N., Freeman, M., Kopp, J., Portney, P., and Smith, K., (2000): "On Measuring Economic Values for Nature" *Environmental Science and Technology* 34 (8).

[BOR 83] Mohr, R., (1983): *Morrow Point Dam and powerplant : technical record of design and construction : Colorado River Storage Project*, Gunnison Division, Curecanti Unit, Colorado, Denver, Colo.: U.S. Dept. of the Interior, Bureau of Reclamation, Engineering and Research Center, Washington DC.

[BPA 1984] (1984): *Methods for Valuation of Environmental Costs and Benefits of Hydroelectric Facilities: A Case Study of the Sultan River Project,* Prepared by Biosystem Analysis, Inc.,

Brent, R. (1996): *Applied Cost-Benefit Analysis* Edward Elgar Publishing Ltd., Cheltenham.

[BUWAL 95] (1995): *Ecobalance and Packaging Materials* , BUWAL, Environment Series No. 250, Switzerland.

Carson, R. (2000): "Contingent Valuation: A User's Guide" *Environmental Science and Technology,* 34 (8).

Carson, R. T.; Flores, N. E.; Mitchell, R. C. (1999): *Theory and Measurement of Passive-Use Value; In Valuing the Environment Preferences*; Bateman, I., Willis, K., (Eds.) Oxford University Press, Oxford.

[CEC 94] (1994): *Assessment of the External Costs of the Coal Fuel Cycle,* Commission for the European Communities, as cited in Craighill, et al., 1996.

Chamberland, A., (1993): " Emissions from hydroelectric reservoirs and comparison of hydroelectricity, natural gas, and oil" *Ambio*, 22.

Chambers, J., (1992): "Coastal Degradation and Fish Population Losses" Proceedings of the 14th Annual Marine Recreation Fish Symposium, March 7-9., Published in: *Stemming the Tide of Coastal Fish Habitat Loss* Stroud, R., (eds.) National Coalition of marine Conservation, Savannah, GA.

Cline, W., (1999): "Discounting for the Very Long Term," in *Discounting and Intergenerational Equity*, Eds: Portney, P., and Weyant, J., Resources for the Future, Washington, DC.

Cline, W.R. (1992): *The Economics of Global Warming,* Institute for International Economics. Washington, DC.

Costanza, R., and Daly, H., (1987): "Toward an Ecological Economics" *Ecological Modeling*, 38.

[CORPS 96] (1996): *National Inventory of Dams Database*, Army Corps of Engineers, Washington, DC.

Craighill, A., and Powell, J. (1996): "Life cycle Assessment and Economic Valuation of Recycling: A Case Study." *Resources, Conservation and Recycling* 17.

[CSERGE 93] (1993): "Externalities from Landfill and Incineration," Warren Spring Laboratory, and *Economics for the Environmental Consultancy.*

Curran, M. (1993): "Broad-based Environmental Life Cycle Assessment" *Environmental Science Technology*, v27, 3.

Deakin, M. (1999): "Valuation, Appraisal, Discounting, Obsolescence and Depreciation: towards a life cycle analysis and impact assessment of their effects on the environment of cities" *International Journal of Life cycle Assessment* 4 (2).

[DOE 90] Lee, R., (1990): A-12 *The Potential of Renewable Energy an Inter laboratory,* White Paper, US Department of Energy, SERI/TP-260-3674 DE 90000322, March.

[DOE 95a] Lee, R., (1995): *Estimating Externalities of the Hydroelectric Fuel Cycle: Report 6,* US Department of Energy, December.

(DOE 95b) Lee, R., Krupnick, A.J. , Burtraw, D. (1995): *Estimating Externalities of Coal Fuel Cycles additional volumes for other fuel cycle,* McGraw-Hill/Utility Data Institute, Washington, DC.

[DOE 95c] Lee, R., Krupnick, A., Burtraw, D., (1995): *Estimating Externalities of Electric Fuel Cycles: Analytical Methods and Issues*, McGraw-Hill/Utility Data Institute, Washington, DC.

Duchemin, E., Lucotte M., Canuel, R., Chamberland, A., (1995): " Production of the greenhouse-gases CH4 and CO2 by hydroelectric reservoirs of the boreal region" *Global Biogeochemical Cycles*, 9.

Duchemin E., Lucott, M., Canuel, R., Chamberland, A., (1997): "Production of greenhouse-gases CH4 and CO2 by hydroelectric reservoirs of the boreal region" *Global Biogeochemical Cycles*, 9 (4).

[EC 95] (1995): *Externalities of Energy: ExternE Project.* For the Directorate General XII, Prepared by Metroeconomica, CEPN, IER, Eyre Energy-Environment, ETSU, Ecole des Mines.

England, R., (2000): "Natural capital and the theory of economic growth" *Ecological Economics*, 34.

[EPA 95] (1995): *Draft State Workbook: Methodologies for Estimating greenhouse-gas emissions.* U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation. Washington D.C.

[EPA 98] Stone, K., (1998): *Draft: Using Benefit Cost Analysis to Evaluate and Justify Investment Decisions,* US Environmental Protection Agency, National Risk Management Research laboratory, sustainable Technology Division, Cincinnati.

[ETH 94] 1994 *Okoinventare von Energiesystemen* (Environmental Life Cycle Inventories of Energy Systems) Hydro section, ETH-ESU, Switzerland, as translated by AltiVista Online Translation Services.

[ExternE 95] (1995): *Report 6, Wind and Hydro Cycles* European Commission, DGXII, Science, Research and Development, JOULE Externalities of Fuel Cycles "ExternE" Project, Switzerland.

[ExternE 98] (1998): *Methodology Report* European Commission, DGXII, Science, Research and Development, JOULE ExternE Project, 2nd Edition, Switzerland.

[FAL 98] Hunt, B. (1998): *Electric Energy Database* prepared for Research Triangle Institute by Franklin and Associates.

Fang, J. (1997): *Power marketing and Renewable Energy* National Renewable Energy Laboratory, Berkley.

Farber, D. , and Hemmersbaugh. P.,(1993): "The shadow of the future: Discount rates, later generations, and the environment." *Vanderbilt Law Review* ,46.

[FERC 95] (1995): *Impacts of Hydroelectric Plant Tailraces on Fish Passage: A Report on Effects of Tailrace on Migratory Fish and Use of Barriers, Modified Project Operations, and Spills for Reducing Impacts*. Federal Energy Regulatory Commission, Office of Hydropower Licensing, Pub: DPR-9, Washington, DC.

[FERC 98] (1998): *Regulations*:, Federal Energy Regulatory Commission, Office of Hydropower Licensing, pub: 18 CFR Ch1,Washington, DC.

[FERC 99] (1999): *Hydroelectric Dam Database*, Federal Energy Regulatory Commission, Office of Hydropower Licensing, Washington, DC.

Fernside, P., (1995): "Hydroelectric Dams in the Brazilian Amazon as Sources of Greenhouse-gases" *Environmental Conservation*, 22 (1).

Frankhauser, S. (1994): "The Social Costs of Greenhouse-gas Emissions: An Expected Values Approach," *Energy Journal*, 15(2).

Frankhauser, S. (1994): "The Social Costs of Greenhouse-gas Emissions: An Expected Values Approach," *Energy Journal*, 15(2).

Gagnon, L., Chamberland, A., (1993): "Emissions from Hydroelectric Reservoirs and Comparison of Hydroelectricity, Natural Gas, and Oil" *Ambio*, 22.

Galy- Lacauz, C., Delmas, R., & Jambert, C., (1997): "Gaseous emissions and oxygen consumption in hydroelectric dams: A case study in French Guyana" *Global Biogeochemical Cycles*, 11(4).

Goedkoop, M., (1995): *The Eco-indicator 95, Final Report. NOH report 9523*, Pre Consultants, Amersfoort (NL), ISBN 90-72130-77-4.

Goedkoop, M., Spriensma, R., (1999): *The Eco-indicator 99, A Damage Oriented Method for Life Cycle Impact Assessment*, Methodology Report, Pre Consultants, Amersfoort.

Hayashi K., Itsubo, N., Inaba, A., (2000): "Development of Damage Function for Stratospheric Ozone Layer Depletion" *International Journal of Life Cycle Assessment* 5(5)..

Hazel, S. (1991): "Environmental Impacts of Hydro-development In the James Bay Region" *Northeast Indian Quarterly*, Winter.

[HB 95] Hagler Bailly Consulting, Inc. (1995): *The New York State Externalities Cost Study* Oceana Publications, New York.

Holt, E. (1997): *Information Consumers Want in Electricity Choice: Summary of Focus Group Research* Prepared by Ed Holt & Associates for the National Council on Competition and Electric Industry Consumer Information Disclosure Project, Harpswell, ME.

Horvath, A. (1997): *Estimation of Environmental Implications of Construction Materials and Designs Using Life Cycle Assessment Techniques,* Doctoral Dissertation, Carnegie Mellon University, Pittsburgh.

Howarth R., and Norgaard, R. (1993): "Intergenerational Transfers and the Social Discount Rate" *Environmental and Resource Economics,* 3.

Howarth, R., (1996): "Climate Change and Overlapping Generations" *Contemporary Economic Policy,* 107.

Howarth, R., (1997): "Energy Efficiency and Economic Growth" *Contemporary Economic Policy,* October, 10 (5).

Howarth, R., (1998): "Sustainability, Uncertainty, and Intergenerational Fairness" in *Sustainable Development: Concepts, Rationalities and Strategies* , Faucheax, S., O'Connor, M., Vander Straaten, J., (eds.) Kluwer Academic, Boston.

Howes, C., (1990): "Introduction: The Social Discount Rate" *Journal of Environmental Economics and Management.* S-3, S-4 .

Hueting, R., (1991): "Correcting National Income for Environmental Losses: A Practical Solution for Theoretical Dilemma." In *Ecological Economics: The Science and Management of Sustainability* ed Costanza R., Columbia University Press, New York.

Hunt, R., and Franklin, W. (1995): "LCA – How it Came About – Personal reflections on the Origin and Development of LCA in the USA." *International Journal of LCA* 1 (1).

[HQ 90] (1990): *Electricity in Quebec: Briefing Book* Hydro Quebec, September.

[IPCC 90] (1990): *Climate Change - The IPCC Scientific Assessment.* J.T. Houghton (eds.), Cambridge University Press, Cambridge.

[IPCC 96] (1995): *Climate Change 1995: The Science of Climate Change.* Intergovernmental Panel on Climate Change. J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell, (eds.) Cambridge University Press, Cambridge.

Isaksen, Il, Ramaswamy, V., Rodhe, H. & Wigley, T. (1992): "Radiative forcing of climate in Climate Change 1992" *The Supplementary Report to the IPCC Scientific Assessment* , J. T. Houghton, B, A. Callander, & S. K. Varney. (eds.), Cambridge University Press, Cambridge.

Itsubo, N. (2000): "Screening Life Cycle Impact Assessment with Weighting methodology Based on Simplified Damage Functions" *International Journal of Life Cycle Assessment* 5(5).

Joshi, S. (1998): *Comprehensive Product Life-Cycle Analysis Using Input Output Techniques* Doctoral Dissertation, Carnegie Mellon University, Pittsburgh.

Joskow, P. (1996): "Restructuring, Competition and Regulatory Reform in the U.S. Electricity Sector." *Journal of Economic Perspectives,* Summer.

Kahneman, D., and Knetch, J. (1992): "Valuing Public Goods: The Purchase of Moral Satisfaction" *Journal of Environmental Economics and Management*, 22(1).

Kelly, C., Rudd, J., Bodaly, R., Roulet, N., St. Louis, V., Heyes, A., Moore, T., Schiff, S., Aravena, R., Scott, K., Dyke, B., Harris, R., Warner, B., & Edwards, G. (1997): " Increases in Fluxes of Greenhouse-gases and Methyl Mercury following Flooding of an Experimental Reservoir" *Environmental Science and Technology* 31(5).

Krewitt, W., Heck, T., Friedrich R. (1999): "Environmental Damage Costs from Fossil Electricity Generation in Germany and Europe" *Energy Policy* 27, 173-.

Krewitt, W., Mayhofer,P., Trunkenmuller, A., Friedrich, R. (1998): "Application of the Impact Pathway, Analysis in the Context of LCA" *International Journal of Life Cycle Assessment*, 3 (2) 86-94.

Krewitt, W., Trukenmüller, A., Bachmann, T., Heck, T. (2001): "Country specific damage factors for air pollutants – a step towards site dependent Life Cycle Impact Assessment" Draft paper accepted for publication in the *International Journal of Life Cycle Assessment.*

Krupnik, A., and Burtraw, D. (1996): "The Social Costs of Electricity: Do the Numbers Add Up" Resources for the Future Discussion Paper, Washington, DC.

Krutilla, J.V. (1967): "Conservation Reconsidered," *American Economic Review*, 57.

Lave, L. Cobas-Flores, E.; McMichaels, F. (1996): "Using Input-output Analysis to estimate Economy-wide Discharges" *Environmental Science and Technology*, v29, 9.

Lazzari, S. (2000): *Energy Tax Policy, An Economic Analysis* Congressional Research Service, Report for Congress, RL30406.

Lee, R. (1995): "Externality Studies: Why are the numbers different?" Paper prepared for the Third International Workshop on Externality Costs, Ladenburg, Germany, May 27-30.

Lee, R., and Dummer, C. (1994): *The Latest on What State Regulators are Doing About Externalities and Renewable Energy Set-asides,* ORNL-6786, Oak Ridge National Laboratory, Oak Ridge, TN.

Legarth, J., Akesson, S., Ashkin, A., Imrell, A. (2000): "A Screening Level LCA of the ABB EU 2000 Air Handling Unit" *International Journal of Life Cycle Assessment*, 5(1).

Leontief, W. (1986): *Input Output Economics* Oxford University Press, New York.

Lind, R. (1990): "Reassessing the Government's Discount Rate Policy in Light of New Theory and Data in a World Economy with a High Degree of Capital Mobility" *Journal of Environmental Economics and Management*. S-8, S-24.

Lodenius, M., Seppanen A., Herranen, M. (1982): "Accumulation of Mercury in Fish and Man from Reservoirs in Northern Finland" *Water, Air and Soil Pollution*, 19.

Maxwell, J.; Lee, J.; Brisco,F.; Stewart, A.; Suzuki, T. (1997): "Locked on Course: Hydro-Quebec's Commitment to Mega-projects" *Environmental Impact Assessment Review*, 17.

[MEPUC 00] (2000): "Electric Deregulation Agenda" Maine Public Utilities Commission, [Electronic] http://janus.state.me.us/mpuc/

Medsker, L. (1982): *Side Effects of Renewable Energy Sources,* National Audubon Society, EPRD Report #15, Washington, DC.

Meyer, P. (1986): *Calculation of Environmental Costs and Benefits Associated with Hydropower Development in the Pacific Northwest* Bonneville Power Administration, Portland.

Miller, R.E., Blair, P. (1985): *Input Output Analysis: Foundations and Extensions,* Prentice-Hall, Englewood Cliffs, NJ.

Mitchell, R., and Carson, R. (1989): *Using Surveys to Value Public goods: The contingent Valuation Method.* Resources for the Future, Washington, D.C.

[MN 94] Desvousges, W., Johnson R., Banzhaf, S. (1996): *Minnesota Externality Costing Study, Environmental Costs of Electricity*, [electronic] Prepared by Triangle Economic Research for Sustainability Minnesota ftp://ftp.ter.com/pub/g_9402.pdf.

Moskovitz, D. (1997): "Full Environmental Disclosure for Electricity: Tracking and Reporting Key Information" (4 papers for the Consumer Information Disclosure Series) National council on Competition and the Electric Industry, Gardner, ME.

Newbery, D. (1990): "Pricing and Congestion: Economic Principles Relevant to Pricing Roads," *Oxford Review of Economic Policy,* 6 (2).

Nordhaus, W. (1991): "To Slow or Not to Slow: The Economics of the Greenhouse Effect," *The Economic Journal* 101 (6).

Nordhaus, W. (1994): *Managing the Global Commons. The Economics of Climate Change*, Cambridge MA: MIT Press.

Norgaard, R. (1998): "Next, the value of God, and other reactions" *Ecological Economics*, October, 25.

Norgaard, R. (1989): "Three Dilemmas for Environmental Accounting" *Ecological Economics*, December.

Norris, G. (1997): *Guide to using LCNetBase* Sylvatica, North Berwick, ME.

Norris, G. (1998): "Upstream Environmental Burdens of *Detailed* Inputs to the Construction, Maintenance, and Repair of Infrastructure for Water Supply, Sewer Systems, Electricity Supply and Waste Treatment Facilities" Working paper for Center for Maximum Potential Building Systems, Sylvatica, North Berwick, ME.

[OMB 92] (1992): *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, Office of Management and Budget 57 Fed. Reg. 35163.

[OMB 94] (1994): *Circulate* [electronic] Office of Management and Budget, A-94, Washington, DC, http://www.whitehouse.gov/WH/EOP/OMB/html/circulars/a094/a094.html#5

[PACE 90] (1990): *Environmental Costs of Electricity,* Pace University Center for Environmental Legal Studies, Richard Ottinger, ed., Oceana Press, White Plains, NY.

Parker, A., (1971): *Planning and Estimating Dam Construction*, McGraw Hill, New York.

[PURPA 99] (1999): "Why PURPA is Responsible for $42 Billion in Utility Above-market Costs" Published on PURPA Reform Group internet site: http://www.purpareform.org/facts8.htm

[PCC 96] (1995): *The Science of Climate Change* Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell, (eds.), Cambridge University Press. Cambridge, U.K.

Pearce, D., Turner, R. (1990): *Economics of Natural Resources and the Environment* Harvester Wheatsheaf, London.

Portney, P., Weyant, J., (1999): *Discounting and Intergenerational Equity* Resources for the Future, Washington, DC.

Powell, J. et al. (1996): "A Life cycle Assessment and Economic Valuation of Recycling" *Journal of Environmental Planning and Management*, 39 (1).

Powell, J., Pearce, D., and Craighill, A. (1997.): "Approaches to Valuation in LCA Impact Assessment" *International Journal of Life Cycle Assessment* 2 (1)

Rafenberg, C., Mayer, E., (1999): " Life Cycle Analysis of the Newspaper Le Monde" *International Journal of Life Cycle Assessment*, 3(3).

Reilly, J., and Richards, K. (1993): "Climate Change Damage and the Trace Gas Index Issue," *Environmental and Resource Economics*, 3.

Reisner, M., (1998): "Coming Undammed" *Audubon*, September-October.

[RER 91] (1991): *Estimating the Air quality Impacts of Alternative energy Resources, Phase IV.* Report to the California Energy Commission, Regional Economic Research, Sacramento, CA. December, as cited in DOE 95.

Rosenber,D., Berkes,F., Bodaly, R., Hecky,R., Kelly, C., Rudd, J. (1997): "Large-scale Impacts of Hydroelectric Development" *Environmental Review*, 5.

Rosenberg, D, Bodaly, R., Hecky, R., & Newbury, R. (1987): " The environmental assessment of hydroelectric impoundment and diversion in Canada" In: *Canadian Aquatic Resources*.

[RSMeans 98a] (1998): *Means Heavy Construction Cost Data* Kingston, MA : R.S. Means Co. ISBN# 0-87629-554-5.

[RSMeans 98b] (1998): *Means Concrete & Masonry Cost Data 2000 Book* Kingston, MA : R.S. Means Co. ISBN# 0-87629-554-5.

[RSMeans 99] (1999): Means Building Construction Cost Data Kingston, MA : R.S. Means Co. ISBN# 0-87629-554-5.

Rosenberg, D., Berks, F., Bodaly,R., Hecky, R., Kelly, C., and Rudd, J. (1997): "Large-scale impacts of hydroelectric development." *Environmental Review*, 5.

Rudd, J, Harris, R, Kely, C & Hecky, R. (1993): "Are hydroelectric reservoirs significant sources of greenhouse-gasses?" *Ambio*, 22(4).

[SETAC 96] (1996): *Towards a methodology for life cycle impact assessment,* . Udo de Haes, H.A. (eds.), SETAC- Europe. Brussels.

[SETAC 99] Finnveden, (1998): *Best Available Practice Regarding Impact Categories and Category Indicators in Life Cycle Impact Assessment*, Background Document for the Second Working Group on Life Cycle Impact Assessment of SETAC-Europe, (WIA-2).

Shankle, S., and Humphreys, K. (1998): *Draft: Issues Involved in Instituting Life Cycle Assessment for Federal Energy and Product Purchases* Prepared for the U.S. Department of Energy, Pacific Northwest National Laboratory, Richland, WA.

[SIMAPRO 97] (1997): *SimaPro 4.0 User Manual* PRE Consultants, Netherlands.

[SPOLD 95] Hemming, C. (1995): *Directory of Life Cycle Inventory Data Sources* , SPOLD, Brussels.

Tathy, J., Cros,B., Delmas, R., Marcenco, A., Servant, J., Labat, M. (1992): "Methane emissions from flooded forests in central Africa." *Journal of Geophysical Research*, 97 (D6).

[TER 95] (1995): Desvousges, W., Johnson, R., Banzhaf, S., *Assessing the Environmental Costs of Electricity,* Triangle Economic Research and Research Triangle Institute, TER Working Report, # G-9402.

Trembaly, A., Lucotte, M. (1997): "Accumulation of Total Mercury and Methyl mercury in Inset Larae of Hydroelectric Reservoirs" *Canadian Journal of Fish and Aquatic Sciences*, 54.

[UKDOT 94] (1993): Valuation of Road Accidents," United Kingdom Department of Transportation, *Highways Economics*, as cited in Criaghill, et al., 1996.

[USCOM 98] (1998): *Benchmark Input-Output Accounts of the United States, 1992, data diskettes.* U.S. Department of Commerce, Bureau of Economic Analysis, Washington, DC.

Weitzman, M. (1999): "Just Keep Discounting, But. . ." in *Discounting and Intergenerational Equity,*: Portney, P., and Weyant, J., (eds.), Resources for the Future, Washington, DC.

Wenzel, H.; hauschild, M.; Alting, L. (1997): *Environmental Assessment of Products* Chatman and Hall, New York.

Wiser, R. & Pickle, S. (1997): *Green Marketing, Renewable and Free Riders: Increasing Customer Demand for a Public Good*, Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley..

APPENDICES

APPENDIX A Material Inputs to the Morrow Point Dam 1 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
481	120	c	Landscaping			12.03	100%	lump sum	9,100.00	9,100	0.270	0.215	0.196	2,903	1,957
694	318	c	Furnishing and constructing the following 13.8	t	2491	20.0800	2	each	560	1,120	0.220		0.217912791	630	0
695	319	c	Type SS with 40-foot pole	t	2491	20.0800	3	each	600	1,800	0.220		0.217912791	1,012	0
696	320	c	Type SS with 45-foot pole	t	2491	20.0800	5	each	630	3,150	0.220		0.217912791	1,771	0
697	321	c	Type SS with 50-foot pole	t	2491	20.0800	12	each	700	8,400	0.220		0.217912791	4,722	0
698	322	c	Type SS with 55-foot pole	t	2491	20.0800	0	each	750	0	0.220		0.217912791	0	0
699	323	c	Type SS with 60-foot pole	t	2491	20.0800	1	each	960	960	0.220		0.217912791	540	0
700	324	c	Type SD with 45-foot pole	t	2491	20.0800	2	each	725	1,450	0.220		0.217912791	815	0
701	325	c	Type ST with 40-foot pole	t	2491	20.0800	0	each	660	0	0.220		0.217912791	0	0
702	326	c	Type ST with 45-foot pole	t	2491	20.0800	4	each	750	3,000	0.220		0.217912791	1,686	0
703	327	c	Type ST with 50-foot pole	t	2491	20.0800	3	each	770	2,310	0.220		0.217912791	1,298	0
704	328	c	Type ST with 55-foot pole	t	2491	20.0800	1	each	800	800	0.220		0.217912791	450	0
705	329	c	Type SA with 55-foot pole	t	2491	20.0800	1	each	750	750	0.220		0.217912791	422	0
706	330	c	Type SAT with 60-foot pole	t	2491	20.0800	1	each	820	820	0.220		0.217912791	461	0
707	331	c	Terminal type with 50-foot pole and per drawi	t	2491	20.0800	0	each	610	0	0.220		0.217912791	0	0
81	84	b	Furnishing and placing 1 inch 1.16520 corkboard joint filler		2499	20.0903	582	ft2	2	1,165	0.090		0.217912791	806	0
89	92	b	Furnishing and installing miscellaneous metal work in powerplant		2542	23.0500	93,942	lb	1	50,729	0.345		0.217912791	22,173	0
107	110	b	installing non-embedded metal work except for powerplant		2542	23.0500	26,936	lb	0	10,745	0.345		0.217912791	4,696	0
108	111	b	installing embedded metalwork except for powerplant		2542	23.0500	5,288	lb	1	2,644	0.345		0.217912791	1,156	0
468	107	c	Furnishing and installing miscellaneous metalwork for powerplant and		2542	23.0500	65.5	lb	1	65,500	0.345		0.217912791	28,629	0
475	114	c	Trimming makeup piece ends		2542	23.0500	4	each	225	900	0.345		0.217912791	393	0
638	262	c	Furnishing and installing miscellaneous metalwork in substation		2542	23.0500	255.7	lb	$3.50	895	0.345		0.217912791	391	0
435	74	c	Furnishing and installing one steel work bench		2599	23.0700	100%	lump sum	400	400	0.297208267		0.217912791	194	0
418	57	c	Furnishing installing,and testing filter paper drying		2679	24.0706	100%	lump sum	1020	1020	0.297208267		0.217912791	495	0
380	19	c	Furnishing and applying soil- applied herbicide		2879	27.0300	2,180	yd2	0.22	480	0.297208267		0.217912791	233	0
80	83	b	Furnishing and placing sponge rubber joint filler		2891	27.0402	3,090	ft2	1	3,091	0.090		0.217912791	2,139	0
182	b	b	Furnishing and installing 1 inch type B elastic joint filler		2891	27.0402	68	lb	6	374	0.090		0.217912791	259	0
183	c	b	furnishing and installing type B rubber water stop		2891	27.0402	16	lin ft	5	72	0.090		0.217912791	50	0
37	40	b	Pressure grouting foundations		2899	27.0406	76,644	sack	1	76,644	0.110		0.217912791	51,511	0
40	43	b	Pressure grouting contract on joints and cooling systems		2899	27.0406	5,228	sack	5	26,663	0.110		0.217912791	17,920	0
77	80	b	Furnishing and placing metal grout grooves covers		2899	27.0406	3,269	lin ft	3	8,827	0.110		0.217912791	5,933	0
85	88	b	Furnishing and applying two- coats concrete floor hardener		2899	27.0406	603	yd2	2	1,207	0.110		0.217912791	811	0
192	b	b	Furnishing cement for and grouting rock bolts requiring more than one		2899	27.0406	23	sack	5	121	0.110		0.217912791	81	0
310	(f)	b	As an adjustment for overrun quantity under schedule item 40		2899	27.0406	1	lump sum	17,344	17,344	0.110		0.217912791	11,657	0
553	192	c	Furnishing and installing one125-volt, 60-cell, station storage battery		2899	27.0406	100%	lump sum	15.000.00	15,000	0.110		0.217912791	10,081	0
632	255	c	Furnishing and handling cement		2899	27.0406	99.4	bbl	9	895	0.110		0.217912791	601	0
752	(g)	c	Grouting flat jacks in powerplant100%		2899	27.0406	100%	lump sum	234.61	235	0.110		0.217912791	158	0
829	(h)	c	Assisting in grouting post- tensioned tendons		2899	27.0406	100%	lump sum	240.71	241	0.110		0.217912791	162	0
212	d	b	For returning 15.75 tons of type II coal tar patch to manufacture		2821	28.0100	1	lump sum	-802	-802	0.110		0.217912791	-539	0
501	140	c	Furnishing and installing the following sizes of exposed rigid polyvinyl		2821	28.0100	863.5	lin ft	1.8	1,554	0.110		0.217912791	1,045	0
502	141	c	1 inch in diameter		2821	28.0100	846	lin ft	2.8	1,692	0.110		0.217912791	1,137	0
82	85	b	Furnishing and placing type E rubber water stops		2822	28.0200	66	lin ft	4	264	0.370		0.217912791	109	0
83	86	b	Furnishing and placing type F rubber water stops		2822	28.0200	2,122	lin ft	5	9,549	0.370		0.217912791	3,935	0
84	87	b	Furnishing and installing rubber joint strips		2822	28.0200	33	lin ft	2	68	0.370		0.217912791	28	0
461	100	c	Furnishing and placing urethane foam seals		2822	28.0200	100%	lump sum	600	600	0.370		0.217912791	247	0
513	152	c	Ozone-resisting butyl rubber,No.6 AWG		2822	28.0200	396	lin ft	0.2	79	0.370		0.217912791	33	0
205	j	b	Furnishing material. cleaning. and painting pier nose protection plates		2851	30.0000	1	lump sum	1,505	1,505	0.588		0.217912791	292	0
235	j	b	furnishing materials for and painting the exterior surfaces at the ends		2851	30.0000	1	lump sum	430	430	0.588		0.100	134	0
247	b	b	Furnishing and delivering to the Government warehouse at Cimarran.		2851	30.0000	1	lump sum	540	540	0.588		0.100	168	0
291	(b)	b	Painting weather door hoists for the spillways and outlet works		2851	30.0000	1	lump sum	89	89	0.588		0.217912791	17	0
296	(e)	b	Painting metal ceiling support assemblies		2851	30.0000	1	lump sum	529	529	0.588		0.217912791	103	0
345	(i)	b	Prime painting spiral stairways for dam		2851	30.0000	1	lump sum	81	2,437	0.588		0.217912791	473	0
404	43	c	Painting generators		2851	30.0000	5,145	ft2	0.4	2,058	0.588		0.217912791	399	0
405	44	c	Painting existing handrails and rolling door No.405		2851	30.0000	100%	lump sum	700	700	0.588		0.217912791	136	0
406	45	c	Painting existing rock bolts		2851	30.0000	100%	lump sum	3,200.00	3,200	0.588		0.217912791	621	0
407	46	c	Painting existing access tunnel portals		2851	30.0000	100%	lump sum	800	800	0.588		0.217912791	155	0
408	47	c	Painting surfaces of concrete walls in powerplant		2851	30.0000	1,267	ft2	0.6	760	0.588		0.217912791	148	0
409	48	c	Painting concrete and grout surfaces between generator stator wrapp		2851	30.0000	1,000	ft2	1	1,000	0.588		0.217912791	194	0
480	119	c	Constructing entrance and visitor facilities		2851	30.0000	100%	lump sum	108,125.00	108,125	0.297208267		0.217912791	52,428	0
626	O	c	Painting existing metal roof arch ceiling and appurtenant Sgutters		2851	30.0000	16.496	ft2	0.25	4,124	0.588		0.100	1,287	0
721	(d)	c	Repairing and painting access tunnel rolling door		2851	30.0000	100%	lump sum	635	635	0.588		0.217912791	123	0
742	(o)	c	Cleaning and painting steel supports in cable tunnel		2851	30.0000	100%	lump sum	1,472.92	1,473	0.588		0.217912791	286	0
789	(e)	c	Furnishing, installing, and painting cover plates for 4 tendons and repai		2851	30.0000	100%	lump sum	1,256.79	1,257	0.588		0.217912791	244	0
811	(h)	c	Painting servomotor to shifting ring links		2851	30.0000	100%	lump sum	81.14	81	0.588		0.217912791	16	0
812	(i)	c	Cleaning and painting lighting panels		2851	30.0000	100%	lump sum	40.52	41	0.588		0.217912791	8	0
813	(i)	c	Painting walls in control room		2851	30.0000	100%	lump sum	213.8	214	0.588		0.217912791	41	0

APPENDIX A Material Inputs to the Morrow Point Dam 2 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
814	(k)	c	Cleaning and painting gate section of log boom		2851	30.0000	100%	lump sum	113.53	114	0.588		0.217912791	22	0
815	(l)	c	Repairing damaged paint on transformer cooling water discharge pipin		2851	30.0000	100%	lump sum	20.39	20	0.588		0.217912791	4	0
451	90	c	Furnishing and installing flexible oil hose		3052	32.0500	5280%	lb	4	211	0.588		0.217912791	41	0
399	38	c	Constructing brick masonry walls		3251	36.0200	100%	lump sum	20,000.00	20,000	0.580		0.217912791	4,042	0
233	h	b	Placing a pneumatically applied mortar protective coating over shear z		3255	36.0400	1	lump sum	12,750	12,750	0.297208267		0.217912791	6,182	0
56	59	b	Concrete in dam		3272	36.1100	365,179	yd3	13	4,747,334	0.400		0.217912791	1,813,895	0
57	60	b	Concrete intake structure		3272	36.1100	7,360	yd3	21	154,566	0.400		0.217912791	59,058	0
58	61	b	Concrete in trashrack structures		3272	36.1100	254	yd3	180	45,823	0.400		0.217912791	17,508	0
59	62	b	concrete in curbs. parapets and miscellaneous structures		3272	36.1100	322	yd3	150	48,317	0.400		0.217912791	18,461	0
60	63	b	Second-stage concrete in out et works		3272	36.1100	49	yd3	68	3,356	0.400		0.217912791	1,282	0
61	64	b	Concrete backfill in existing foundation tunnels		3272	36.1100	247	yd3	53	13,142	0.400		0.217912791	5,022	0
62	65	b	Concrete in blockouts		3272	36.1100	219	yd3	261	57,102	0.400		0.217912791	21,818	0
63	66	b	Concrete in floor of foundation tunnels		3272	36.1100	360	yd3	100	36,058	0.400		0.217912791	13,777	0
64	67	b	Concrete in penstock tunnel		3272	36.1100	4,126	yd3	27	111,427	0.400		0.217912791	42,575	0
65	68	b	Concrete in stilling basin lining		3272	36.1100	1,916,368	yd3	0	306,619	0.400		0.217912791	117,155	0
66	69	b	Concrete in stilling basin weir		3272	36.1100	10,619	yd3	15	159,248	0.400		0.217912791	60,846	0
67	70	b	First stage concrete in powerplant Structure		3272	36.1100	3,538	yd3	68	240,601	0.400		0.217912791	91,930	0
68	71	b	Concrete in draft tube tunnel linings		3272	36.1100	4,478	yd3	75	335,904	0.400		0.217912791	128,345	0
69	72	b	Concrete n draft tuba gate structures		3272	36.1100	667	yd3	44	29,366	0.400		0.217912791	11,221	0
70	73	b	Concrete in portals of access cable. and ventilation tunnels		3272	36.1100	557	yd3	150	83,621	0.400		0.217912791	31,950	0
71	74	b	Concrete in floor of access and cable tunnels		3272	36.1100	110	yd3	54	5,948	0.400		0.217912791	2,273	0
72	75	b	Concrete in bridge		3272	36.1100	214	yd3	100	21,491	0.400		0.217912791	8,211	0
73	76	b	Cooling concrete		3272	36.1100	364,370	yd3	1	437,244	0.400		0.217912791	167,065	0
123	126	b	Installing one 3.5- by 40-foot tandem outlet gate for outlet works		3272	36.1100	1	lump sum	24,500	24,500	0.400		0.217912791	9,361	0
135	138	b	Furnishing two 2.500-gallon storage tanks		3272	36.1100	1	lump sum	4,300	4,300	0.400		0.217912791	1,643	0
159	165	b	Constructing foundation deformation wells		3272	36.1100	3	each	500	1,500	0.400		0.217912791	573	0
213	e	b	Furnishing and placing concrete for cable tunnel linning between stati		3272	36.1100	176	yd3	161	28,355	0.400		0.217912791	10,834	0
223	o	b	Furnishing and placing concrete in grouting and drainage tunnel floor.		3272	36.1100	26	yd3	167	4,330	0.400		0.217912791	1,654	0
243	h	b	Furnishing and placing concrete in crest road retaining walls		3272	36.1100	65	yd3	151	9,787	0.400		0.217912791	3,739	0
245	a	b	Furnishing and Installing 25 post tensioned tendons and furnishing an		3272	36.1100	1	lump sum	130,067	130,067	0.400		0.217912791	49,697	0
252	g	b	Furnishing and placing concrete for protective wall above penstock ir		3272	36.1100	158	yd3	161	25,360	0.400		0.217912791	9,690	0
254	i	b	Furnishing and placing concrete lining in penstock makeup piece reces		3272	36.1100	88	yd3	158	13,870	0.400		0.217912791	5,300	0
258	(a)	b	Order for Changes No. 13 Furnishing and placing concrete for retain		3272	36.1100	191	yd3	150	28,704	0.400		0.217912791	10,967	0
264	(a)	b	Constructing concrete center pier support in draft tube gate deck		3272	36.1100	1	lump sum	3,300	3,300	0.400		0.217912791	1,261	0
279	(d)	b	Furnishing and placing 12-inchdiameter concrete pipe with bedding		3272	36.1100	154	lin ft	18	2,767	0.400		0.217912791	1,057	0
287	(e)	b	Constructing a concrete protective wall above left abutment parking		3272	36.1100	1	lump sum	8,465	8,465	0.400		0.217912791	3,234	0
290	(a)	b	Order for Changes No. 17 Constructing a concrete retaining wall on		3272	36.1100	1	lump sum	83,920	83,920	0.400		0.217912791	32,065	0
292	(a)	b	Order for Changes No. 18 Constructing theodolite piers and collimati		3272	36.1100	1	lump sum	20,204	20,204	0.400		0.217912791	7,720	0
333	(b)	b	Constructing a concrete buttress at downstream toe of right keyway		3272	36.1100	1	lump sum	17,800	17,800	0.400		0.217912791	6,801	0
334	(c)	b	Constructing a concrete buttress above and downstream of cable tur		3272	36.1100	1	lump sum	63,228	63,228	0.400		0.217912791	24,159	0
377	16	c	Sand backfill in high-voltage cable trench	t	3272	36.1100	1,076.70	yd3	10	10,767	0.400		0.217912791	4,114	0
387	26	c	Second-stage concrete in powerplant structure		3272	36.1100	5,950	yd3	60	357,006	0.400		0.217912791	136,407	0
388	27	c	Concrete in blockouts 77.10		3272	36.1100	77.1	yd3	300	23,183	0.400		0.217912791	8,858	0
389	28	c	Miscellaneous concrete in powerplant structure 15.04		3272	36.1100	15.04	yd3	150	2,256	0.400		0.217912791	862	0
390	29	c	Concrete floor fill		3272	36.1100	18.34	yd3	200	3,668	0.400		0.217912791	1,402	0
391	30	c	Concrete in entrance and visitor facilities		3272	36.1100	974.52	yd3	135	131,561	0.400		0.217912791	50,268	0
392	31	c	Concrete in switchyard structures		3272	36.1100	88.09	yd3	110	9,689	0.400		0.217912791	3,702	0
395	34	c	Furnishing and applying concrete floor hardener in powerplant structu		3272	36.1100	658.7	yd2	2	1,317	0.400		0.217912791	503	0
396	*35*	*c*	*Constructing planter area rock masonry walls*		3272	36.1100	738.7	ft4	10	7,387	0.400		0.217912791	2,822	0
485	124	c	Furnishing and installing single switch-operatin	t	3272	36.1100	1	each	335	335	0.400		0.217912791	128	0
486	125	c	Furnishing and installing double switch-operati	t	3272	36.1100	1	each	568	568	0.400		0.217912791	217	0
500	139	c	Furnishing and installing nonmetallic conduit 3 inches in diameter		3272	36.1100	54	lin ft	1.5	81	0.400		0.217912791	31	0
637	260	c	Concrete in substation structures		3272	36.1100	78.72	yd3	140	11,021	0.400		0.217912791	4,211	0
642	266	c	Furnishing and installing single switch-operating platforms in substatio		3272	36.1100	1	each	335	335	0.400		0.217912791	128	0
680	304	c	Concrete in transmission line tower footings	t	3272	36.1100	32.45	yd3	150	4,867	0.400		0.217912791	1,860	0
750	(e)	c	Placing concrete in overbreak in rock excavation for visitor facilities		3272	36.1100	175.42	yd3	70	12,280	0.400		0.217912791	4,692	0
397	36	c	Furnishing and installing quarry tile for floors		3281	36.1500	100%	lump sum	15,000.00	15,000	0.360		0.217912791	6,331	0
398	37	c	Furnishing and installing vinyl- asbestos floor tile and vinyl 3 cove bas		3292	36.1700	100%	lump sum	2.700.00	2,700	0.330		0.217912791	1,221	0
459	98	c	Furnishing and installing pipe insulation		3292	36.1700	100%	lump sum	500	500	0.410		0.217912791	186	0
22	24	b	Compacted backfill		3295	36.1900	867	yd3	4	3,208	0.180	0.640	0.160	64	2,053
23	25	b	Backfill		3295	36.1900	1,659	yd3	1	1,659	0.180	0.640	0.160	33	1,062
24	26	b	Riprap		3295	36.1900	539	yd3	3	1,671	0.180	0.640	0.160	33	1,069
164	170	b	Compacted backfill		3295	36.1900	3,333	yd3	5	16,665	0.180	0.640	0.160	333	10,666
176	182	b	Gravel or crushed-rock surfacing		3295	36.1900	2,461	yd3	5	12,307	0.180	0.640	0.160	246	7,876
195	e	b	Increased cost of resloping certain reaches of crest access road		3295	36.1900	29,899	yd3	2	74,747	0.180	0.640	0.160	1,495	47,838
201	f	b	Placing rock fill material from required excavation for dam and stillir		3295	36.1900	899	yd3	0	422	0.180	0.640	0.160	8	270

APPENDIX A Material Inputs to the Morrow Point Dam 3 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
249	d	b	Furnishing and placing free draining non-compacted backfill downstre		3295	36.1900	225	ton	3	787	0.180	0.640	0.160	16	504
272	(i)	b	Furnishing and placing non compacted backfill for drop structure		3295	36.1900	2,344	yd3	1	2,344	0.180	0.640	0.160	47	1,500
278	(c)	b	Furnishing and placing rockfill		3295	36.1900	4,881	yd3	2	8,395	0.180	0.640	0.160	168	5,373
281	(f)	b	Furnishing and placing backfill concrete in walls of power plant chan		3295	36.1900	980	yd3	27	26,754	0.180	0.640	0.160	535	17,123
282	(g)	b	Furnishing and placing backfill concrete for support of shear zone A		3295	36.1900	1	lump sum	3,770	3,770	0.180	0.640	0.160	75	2,413
366	5	c	Placing and compacting backfill for entrance and visitor facilities		3295	36.1900	304	yd3	5.6	1,702	0.180	0.640	0.160	34	1,090
367	6	c	Placing and compacting backfill for switchyard	t	3295	36.1900	298	yd3	5.5	1,639	0.180	0.640	0.160	33	1,049
376	15	c	Sand backfill and timber protection for buried i	t	3295	36.1900	147	lin ft	3.6	529	0.180	0.640	0.160	11	339
378	17	c	Gravelfills, except in substation		3295	36.1900	258.48	yd3	15	3,877	0.180	0.640	0.160	78	2,481
379	18	c	Placing 4-inch-thick gravel surfacing		3295	36.1900	2,656	yd2	3.5	9,296	0.180	0.640	0.160	186	5,949
629	252	c	Placing and compacting backfill for substation structures		3295	36.1900	529	yd3	4	2,116	0.180	0.640	0.160	42	1,354
630	253	c	Sand backfill and timber protection for buried insulated electrical cabl		3295	36.1900	51	lin ft	4	204	0.180	0.640	0.160	4	131
631	254	c	Gravelfills in substation		3295	36.1900	4	yd3	14	56	0.180	0.640	0.160	1	36
678	302	c	Placing and compacting backfill around transm	t	3295	36.1900	169	yd3	4.5	761	0.180	0.640	0.160	15	487
208	m	b	Furnishing and installing fiberglass insulation in the five weather doors		3296	36.2000	1	lump sum	902	902	0.180	0.640	0.160	18	577
401	40	c	Furnishing and installing suspended acoustical ceilings in powerplant s		3296	36.2000	100%	lump sum	3,000	3,000	0.180	0.640	0.160	60	1,920
636	259	c	Insulating intersections of reinforcing bars		3296	36.2000	417	each	10	4,170	0.180	0.640	0.160	83	2,669
16	17	b	Furnishing and placing permanent steel tunnel supports		3312	37.0101	29,910	lb	0	10,469	0.240	0.020	0.260	5,025	209
19	20	b	Furnishing and installing steel bearing plates		3312	37.0101	60,226	lb	0	13,250	0.240	0.020	0.260	6,360	265
131	134	b	Furnishing and installing steel liners and piping complete with accesso		3312	37.0101	1	lump sum	560,000	560,000	0.240	0.020	0.260	268,800	11,200
189	e	b	Furnishing and constructing corner post structures		3312	37.0101	7	each	75	525	0.240	0.020	0.260	252	11
190	f	b	Furnishing and constructing end post and brace post structures		3312	37.0101	16	each	50	800	0.240	0.020	0.260	384	16
196	a	b	Order for Changes No 4 Furnishing and constructing 8 inch galvanied		3312	37.0101	495	lin ft	5	2,489	0.240	0.020	0.260	1,195	50
229	d	b	Relocating 8-inch standard pipe drain from elevation 67760 to eleva		3312	37.0101	1	lump sum	243	243	0.297208267		0.217912791	118	0
251	f	b	Performing corrective works on piping		3312	37.0101	1	lump sum	223	223	0.297208267		0.217912791	108	0
293	(b)	b	installing piezometer piping for tandem outlet gate		3312	37.0101	1	lump sum	1,049	1,049	0.297208267		0.217912791	509	0
355	(s)	b	Furnishing and delivering surplus bin-type retaining wall		3312	37.0101	1	lump sum	6,812	6,812	0.240	0.020	0.260	3,270	136
374	13	c	Furnishing and installing steel bearing plates		3312	37.0101	11,562.91	lb	1.7	19,657	0.240	0.020	0.260	9,435	393
452	91	c	Furnishing and installing cast iron soil pipe		3312	37.0101	14,397.90	lb	0.6	8,639	0.240	0.020	0.260	4,147	173
453	92	c	Furnishing and installing cast iron bell-and-spigot and flanged pipe and		3312	37.0101	22,714	lb	0.4	9,086	0.240	0.020	0.260	4,361	182
454	93	c	Furnishing and installing steel pipe, fittings, and valves 2		3312	37.0101	10726.3	lb	2.5	26,816	0.240	0.020	0.260	12,872	536
455	94	c	Furnishing and installing steel pipe, fittings and valves 2.5		3312	37.0101	110,232.40	lb	1	110,232	0.240	0.020	0.260	52,912	2,205
457	96	c	Furnishing and installing stainless steel pipe, fittings.		3312	37.0101	130.3	lb	12	1,564	0.297208267		0.217912791	758	0
458	97	c	Furnishing and installing metal tubing, fittings and valves		3312	37.0101	219.96	lb	4	880	0.240	0.020	0.260	422	18
633	256	c	Furnishing and placing the following sizes of reinforcment bars:.#2 &		3312	37.0101	159	lb	0.4	64	0.240	0.020	0.260	31	1
634	257	c	4 and 5		3312	37.0101	3.25	lb	0.35	1,138	0.240	0.020	0.260	546	23
635	258	c	6 and 7		3312	37.0101	1.496	lb	0.34	509	0.240	0.020	0.260	244	10
675	299	c	1-inch iron-pipe-size		3312	37.0101	85	lin ft	6	510	0.240	0.020	0.260	245	10
731	(d)	c	Relocating, replacing and cleaning pipe sleeves and fittings		3312	37.0101	100%	lump sum	358.76	359	0.297208267		0.217912791	174	0
756	(c)	c	Removing, cleaning, and V reinstalling filling pipe on unfiltered oil tank		3312	37.0101	100%	lump sum	279.77	280	0.297208267		0.217912791	136	0
762	(i)	c	Refabricating cooling water piping		3312	37.0101	100%	lump sum	803.41	803	0.240	0.020	0.260	386	16
765	(l)	c	Replacing 0.5-inch-diameter piping with 1-inch-diameter piping in brak		3312	37.0101	100%	lump sum	100.58	101	0.240	0.020	0.260	48	2
783	(r)	c	Furnishing and installing steel bearing plates		3312	37.0101	2817.7	lb	2.02	5,692	0.240	0.020	0.260	2,732	114
785	(a)	c	Order for Changes No7: Cutting, cleaning and rewelding overflow pip		3312	37.0101	100%	lump sum	$353.37	353	0.297208267		0.217912791	171	0
821	(r)	c	Furnishing bearing plates		3312	37.0101	363	each	0.8	290	0.240	0.020	0.260	139	6
833	(l)	c	Performing miscellaneous modifications to piping systems		3312	37.0101	100%	lump sum	391.59	392	0.297208267		0.217912791	190	0
844	(w)	c	Refabricating piping for 0 turbine grease system		3312	37.0101	100%	lump sum	2,869.72	2,870	0.297208267		0.217912791	1,391	0
21	22	b	Furnishing and installing chain-link fabric in underground excavation		3315	37.0103	4,536	yd2	3	15,135	0.420		0.280	4,541	0
187	c	b	Furnishing and constructing four-wire, barbed-wire fence with steel p		3315	37.0103	5,425	lin ft	0	2,712	0.420		0.280	814	0
188	d	b	Furnishing and constructing fence crossing river channel		3315	37.0103	202	lin ft	3	606	0.420		0.280	182	0
300	(i)	b	Removing and reinstalling wire cable for 25-ton gantry crane		3315	37.0103	1	lump sum	345	345	0.420		0.280	104	0
371	10	c	Furnishing and installing chain link fabric on rock faces		3315	37.0103	12,811.79	yd2	5	64,059	0.420		0.280	19,218	0
487	126	c	Furnishing and erecting switchyard fence	t	3315	37.0103	440	lin ft	46.00	20,240.00	0.420		0.280	6,072	0
781	(P)	c	Furnishing and installing chain link fabric		3315	37.0103	3,399.97	yd2	5.93	20,162	0.420		0.280	6,049	0
819	(P)	c	Furnishing chain link fabric		3315	37.0103	12	roll	45.63	548	0.420		0.280	164	0
35	38	b	Furnishing and placing metal pipe and fittings for foundation grouting a		3317	37.0105	49,134	lb	1	31,937	0.420		0.280	9,581	0
38	41	b	Furnishing and installing metal tubing and fittings for Grouting contrac		3317	37.0105	57,402	lb	1	80,364	0.420		0.280	24,109	0
94	97	b	Furnishing and installing steel pipe and fittings 2 inches and smaller in		3317	37.0105	386	lb	2	580	0.420		0.280	174	0
95	98	b	Furnishing and installing steel pipe and fittings 25 inches and larger in		3317	37.0105	7,146	b	1	8,576	0.420		0.280	2,573	0
132	135	b	Furnishing and installing steel drain piping and fittings		3317	37.0105	25,477	lb	1	30,573	0.420		0.280	9,172	0
133	136	b	Furnishing makeup pieces complete with supports, bolts and coupling		3317	37.0105	1	lump sum	20,000	20,000	0.420		0.280	6,000	0
240	e	b	seal welding tandem outlet gate liners		3317	37.0105	1	lump sum	578	578	0.420		0.280	173	0
241	f	b	Furnishing and Installing 6-nchdiamster standard steel pipe drain		3317	37.0105	1	lump sum	7,829	7,829	0.420		0.280	2,349	0
350	(n)	b	As an adjustment for overrun in quantity under schedule item 38		3317	37.0105	1	lump sum	13,314	13,314	0.420		0.280	3,994	0
92	95	b	Furnishing and installing cast iron soil pipe and fittings including bell tr		3321	37.0200	15,847	lb	1	14,262	0.290		0.197	7,317	0
93	96	b	Furnishing and installing cal iron bell-and-spigot and flanged pipe. wall		3321	37.0200	49,855	lb	1	29,913	0.290		0.197	15,346	0

APPENDIX A Material Inputs to the Morrow Point Dam 4 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
121	124	b	Installing and 666- by 612- foot bulkhead gate for outlet works		3321	37.0200	1	lump sum	1,400	1,400	0.290		0.197	718	0
122	125	b	Installing one set of guides for 6.66 by 6.27 foot bulkhead		3321	37.0200	1	lump sum	2,500	2,500	0.290		0.197	1,283	0
125	128	b	Installing two bulkhead gates for draft tube tunnel		3321	37.0200	1	lump sum	16,500	16,500	0.290		0.197	8,465	0
757	(d)	c	Furnishing and installing 4-inch-diameter perforated drain for visitor fa		3321	37.0200	100%	lump sum	512.19	512	0.290		0.197	263	0
96	99	b	Furnishing and installing one 24-inch flanged flap valve and one Cinch		3462	37.0300	1	lump sum	900	900	0.190		0.210	540	0
171	177	b	Furnishing and setting guideposts		3462	37.0300	0	each	12	0	0.190		0.210	0	0
276	(a)	b	Order for Changes No. 15 Furnishing and setting steel guideposts		3462	37.0300	284	each	7	1,988	0.190		0.210	1,193	0
456	95	c	Furnishing and installing one 20 inch flanged flap valve		3462	37.0300	100%	lump sum	800	800	0.190		0.210	480	0
352	(p)	b	Providing temporary electrical facilities for dam and powerplant		3355	38.0800	1	lump sum	8,967	8,967	0.280		0.195	4,708	0
484	123	c	Furnishing and erecting switchyard aluminum structures		3354	38.0800	995.5	lb	1.82	1,812	0.280		0.195	951	0
514	153	c	Installing the following sizes of single-conductor, 600-volt insulated al		3355	38.0800	3.767	lin ft	0.25	942	0.280		0.195	494	0
515	154	c	1/0 AWG		3355	38.0800	3.921	lin ft	0.27	1,059	0.280		0.195	556	0
516	155	c	3/0 AWG		3355	38.0800	3.79	lin ft	0.35	1,327	0.280		0.195	696	0
517	156	c	4/0 AWG		3355	38.0800	843	lin ft	0.4	337	0.280		0.195	177	0
518	157	c	250,000 circular mil		3355	38.0800	789	lin ft	0.45	335	0.280		0.195	176	0
519	158	c	Installing the following sizes of single-conductor 600-volt insulated al		3355	38.0800	648	lin ft	0.55	356	0.280		0.195	187	0
520	159	c	500.000 circular mil		3355	38.0800	753	lin ft	0.65	489	0.280		0.195	257	0
521	160	c	700.000 circular mil		3355	38.0800	261	lin ft	0.8	209	0.280		0.195	110	0
522	161	c	Installing 15,000-volt insulated No.2 AWG, single- conductor shieldd c		3355	38.0800	80	lin ft	3	240	0.280		0.195	126	0
657	281	c	No.3/0 AWG, 600-volt,insulated aluminum electrical wire and cable		3355	38.0800	0	lin ft	0	0	0.280		0.195	0	0
658	282	c	Intalling 3-conductor, No.1		3355	38.0800	1022	lin ft	0.86	879	0.280		0.195	461	0
674	298	c	Furnishing and installing the following sizes of outdoor rigid aluminum		3355	38.0800	180	lin ft	9	1,620	0.280		0.195	851	0
719	(b)	c	Installing 300-million circular mill, single-conductor, 600-volt, insulated		3355	38.0800	4,218	lin ft	0.6	2,531	0.280		0.195	1,329	0
178	184	b	Furnishing and installing the following sizes of sing conductor 600 vol		3357	38.1000	2,887	lin ft	0	433	0.280		0.195	227	0
179	185	b	No 10 AWG		3357	38.1000	10,937	lin ft	0	2,187	0.280		0.195	1,148	0
180	186	b	No 8 AWG		3357	38.1000	5,105	lin ft	0	1,276	0.280		0.195	670	0
283	(a)	b	Order for Changes No. 16 Furnishing and installing about 2.000 line		3357	38.1000	0	lin ft		0	0.280		0.195	0	0
284	(b)	b	Furnishing and installing about 600 linear feet of No. 10 d		3357	38.1000	0	lin ft		0	0.280		0.195	0	0
285	(c)	b	Furnishing and installing about 3.000 linear feet of No. 8 AWG. single		3357	38.1000	860	lin ft	0	180	0.280		0.195	95	0
318	(d)	b	Furnishing and installing bare, stranded, copper cable for complete gro		3357	38.1000	1	lump sum	25,335	25,335	0.280		0.195	13,301	0
507	146	c	Installing the following sizes of single-conductor, 600-volt insulated e		3357	38.1000	915	lin ft	0.11	101	0.290		0.197	52	0
508	147	c	14 AWG		3357	38.1000	16486.6	lin ft	0.12	1,978	0.280		0.195	1,039	0
509	148	c	12 AWG		3357	38.1000	60591.3	lin ft	0.13	7,877	0.280		0.195	4,135	0
510	149	c	10 AWG		3357	38.1000	30,084.50	lin ft	0.14	4,212	0.280		0.195	2,211	0
511	150	c	8 AWG		3357	38.1000	6,681	lin ft	0.16	1,069	0.280		0.195	561	0
512	151	c	6 AWG		3357	38.1000	6450.2	lin ft	0.18	1,161	0.280		0.195	610	0
523	162	c	Installing the following tarmored (vertical riser),multiconductor, 600-v		3357	38.1000	878	lin ft	0.9	790	0.280		0.195	415	0
524	163	c	12-conductor No.10 AWG		3357	38.1000	1.3	lin ft	0.8	1,040	0.280		0.195	546	0
525	164	c	50-pair No.l9 AWG		3357	38.1000	380	lin ft	0.75	285	0.280		0.195	150	0
526	165	c	Installing the following multiconductor, 600-volt insulated, copper ele		3357	38.1000	2.172	lin ft	0.14	304	0.280		0.195	160	0
527	166	c	4-conductor No		3357	38.1000	2,134	lin ft	0.21	448	0.280		0.195	235	0
528	167	c	12-conductor No		3357	38.1000	528	lin ft	0.6	317	0.280		0.195	166	0
529	168	c	2-conductor No.10 AWG		3357	38.1000	7,843	lin ft	0.18	1,412	0.280		0.195	741	0
530	169	c	3-conductor No.10 AWG		3357	38.1000	2,664	lin ft	0.23	613	0.280		0.195	322	0
531	170	c	4-conductor No.10 AWG		3357	38.1000	2,606	lin ft	0.3	782	0.280		0.195	410	0
532	171	c	5-conductor No.10 AWG		3357	38.1000	969	lin ft	0.34	329	0.280		0.195	173	0
533	172	c	7-conductor No.10 AWG		3357	38.1000	2,692	lin ft	0.42	1,131	0.280		0.195	594	0
534	173	c	9-conductor No.10 AWG		3357	38.1000	647	lin ft	0.5	324	0.280		0.195	170	0
535	174	c	12-conductor No.10 AWG		3357	38.1000	5.977	lin ft	0.7	4,184	0.280		0.195	2,197	0
536	175	c	Installing the following armored multiconductor,600-volt copper cont		3357	38.1000	0	0	0.4	0	0.280		0.195	0	0
537	176	c	12-conductor No.10 AWG		3357	38.1000	8.103	lin ft	0.8	6,482	0.280		0.195	3,403	0
538	177	c	Installing 25-pair telephone cable		3357	38.1000	778	lin ft	0.45	350	0.280		0.195	184	0
539	178	c	Installing 50-pair telephoner cable		3357	38.1000	771	lin ft	0.8	617	0.280		0.195	324	0
540	179	c	Installing 3-conductor No AWG copper 600 volt insulated armored c		3357	38.1000	591	lin ft	1	591	0.280		0.195	310	0
541	180	c	Installing 15,000-volt insulated No.l AWG, 3-conductor (aluminum) ar		3357	38.1000	2.221	lin ft	1	2,221	0.280		0.195	1,166	0
542	181	c	Furnishing and installing completely cutfitted and ready to operate 3-		3357	38.1000	100%	lump sum	196,800.00	196,800	0.280		0.195	103,320	0
620	I.	c	Installing 3/c-1/0 AWG larmored (vertical riser), multi- rconductor60		3357	38.1000	400	lin ft	0.56	224	0.280		0.195	118	0
621	J	c	Installing 3/c-1/0 AWG multi- conductor600-volt insulated copper e		3357	38.1000	935	lin ft	0.51	477	0.280		0.195	250	0
622	K.	c	Installing 3/c-3/0 AWG multi- conductor600-volt insulated copper el		3357	38.1000	479	lin ft	0.6	287	0.280		0.195	151	0
623	L.	c	Installing 7/c-10 AWG >armored multi-conductor,600-volt copper cc		3357	38.1000	2.021	lin ft	0.42	849	0.280		0.195	446	0
652	276	c	Installing the following sizes of single-conductor, 600-volt,insulated c		3357	38.1000	373	lin ft	0.14	52	0.280		0.195	27	0
653	277	c	8 AWG		3357	38.1000	90	lin ft	0.15	14	0.280		0.195	7	0
654	278	c	6 AWG		3357	38.1000	225	lin ft	0.19	48	0.280		0.195	25	0
655	279	c	1/c-750,000-circular mil AWG		3357	38.1000	258	lin ft	0.75	194	0.280		0.195	102	0
656	280	c	4/0 AWG		3357	38.1000	86	lin ft	0.43	37	0.280		0.195	19	0
659	283	c	Complete installation and make connections of control cable		3357	38.1000	100%	lump sum	1,100.00	1,100	0.280		0.195	578	0

APPENDIX A Material Inputs to the Morrow Point Dam 5 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
713	337	c	Furnishing and installing suspension-type asser	t	3357	38.1000	29	each	30	870	0.280		0.195	457	0
714	338	c	Furnishing and installing tension-type assembli	t	3357	38.1000	12	each	60	720	0.280		0.195	378	0
715	339	c	Furnishing and stringing three No.2 AWG, ACS	t	3357	38.1000	1.72	mi	$7,720.00	13,263	0.280		0.195	6,963	0
716	340	c	Furnishing and attaching spiral type vibration d	t	3357	38.1000	126	each	14	1,764	0.280		0.195	926	0
726	(i)	c	Furnishing color coded No.10 600-volt, single- conductor, type THW		3357	38.1000	4	lin ft		240	0.280		0.195	126	0
727	(i)	c	Furnishing color coded No.12AWG, 600-volt, single- conductor type T		3357	38.1000	15,000	lin ft	0.04	600	0.280		0.195	315	0
732	(e)	c	Mounting and connecting wiring to terminals of transfer switch in trar		3357	38.1000	100%	lump sum	49.61	50	0.280		0.195	26	0
738	(k)	c	Furnishing and installing 3-inch electrical conduit for telephone cables		3357	38.1000	235.6	lin ft	10	2,356	0.280		0.195	1,237	0
749	(d)	c	Installing Government- furnished, 6-pair communications cable		3357	38.1000	2,183	lin ft	0.45	982	0.280		0.195	516	0
760	(g)	c	Furnishing additional 230-kilovolt cable		3357	38.1000	125	lin ft	4	500	0.280		0.195	263	0
766	(a)	c	Order for Changes No6: Furnishing oil for the 230 kilovolt insulated c		3357	38.1000	3	bbl	$81.50	245	0.280		0.195	128	0
471	110	c	Furnishing and installing aluminum covers in switchyard620		3363	38.1100	620	lb	$2.00	1,240	0.379		0.251	459	0
639	263	c	Furnishing and installing aluminum covers in substation		3363	38.1100	486.2	lb	2	972	0.379		0.251	360	0
472	111	c	Furnishing and installing aluminum handrail for crest road and service a		3364	38.1300	100%	lump sum	4.900.00	4,900	0.379		0.251	1,813	0
836	(o)	c	Furnishing and installing service sink in oil purifier room		3431	40.0100	100%	lump sum	585.63	586	0.502		0.282	126	0
169	175	b	Furnishing and constructing metal bin-type retaining walls.5.5-foot bas		3441	40.0400	2,106	ft2	10	21,653	0.196	0.065	0.213	11,400	1,407
170	176	b	Furnishing and constructing metal bin-type retaining walls1.75-foot ba		3441	40.0400	746	ft	10	7,466	0.196	0.065	0.213	3,931	485
177	183	b	Furnishing and erecting structural steel for bridge		3441	40.0400	48,556	lb	0	9,711	0.196	0.065	0.213	5,113	631
219	k	b	For deleting the eight ice prevention system nozzles.associated tubin		3441	40.0400	1	lump sum	-14	-14	0.196	0.065	0.213	-7	-1
226	a	b	Order for Changes No 7 Bonding field joints in rubber series s for pe		3441	40.0400	1	lump sum	587	587	0.196	0.065	0.213	309	38
230	e	b	Furnishing and installing modified support jackets on power plant meta		3441	40.0400	102	each	156	15,922	0.196	0.065	0.213	8,383	1,035
250	e	b	Furnishing materials for and performing corrective works on power pl		3441	40.0400	1	lump sum	444	444	0.196	0.065	0.213	234	29
253	h	b	Furnishing and placing reinforcing steel for protective wall above pen		3441	40.0400	723	lb	0	166	0.196	0.065	0.213	87	11
257	(a)	b	Order for changes No. 12 installing the 20 Government furnished fla		3441	40.0400	1	lump sum	22,281	22,281	0.196	0.065	0.213	11,731	1,448
294	(c)	b	Straightening Government furnished fixed-wheel gate for spillway No.		3441	40.0400	1	lump sum	338	338	0.196	0.065	0.213	178	22
483	122	c	Furnishing and erecting switchyard steel structures		3441	40.0400	50.029	lb	0.5	25,015	0.196	0.065	0.213	13,170	1,626
640	264	c	Furnishing and erecting substation steel structures		3441	40.0400	9,307	lb	0.6	5,584	0.196	0.065	0.213	2,940	363
641	265	c	Moving and reinstalling existing substation steel structures		3441	40.0400	100%	lump sum	1,300.00	1,300	0.196	0.065	0.213	684	85
681	305	c	Furnishing and erecting transmission line steel	t	3441	40.0400	52,556	lb	0.47	24,701	0.196	0.065	0.213	13,005	1,606
686	310	c	Furnishing and installing tower leg grounds witl	t	3441	40.0400	8	each	65	520	0.196	0.065	0.213	274	34
690	314	c	At Curecanti end of Morrow Point-Curecanti 23	t	3441	40.0400	100%	lump sum	4.000.00	4,000	0.196	0.065	0.213	2,106	260
691	315	c	Furnishing materials for second and third spans	t	3441	40.0400	100%	lump sum	2,200.00	2,200	0.196	0.065	0.213	1,158	143
724	(g)	c	Modifying pipe jack turbine supports to extend to existing rock		3441	40.0400	100%	lump sum	1,011.95	1,012	0.196	0.065	0.213	533	66
88	91	b	Furnishing and installing metal rolling doors		3442	40.0500	840	ft3	6	5,040	0.101		0.137	3,840	0
99	102	b	Furnishing and installing weather doors		3442	40.0500	1	lump sum	18,000	18,000	0.101		0.137	13,716	0
103	106	b	Furnishing and installing nine industrials-type steel swinging doors		3442	40.0500	1	lump sum	3,500	3,500	0.101		0.137	2,667	0
104	107	b	Furnishing and installing one steel window		3442	40.0500	1	lump sum	170	170	0.101		0.137	130	0
204	i	b	Furnishing and Installing one additional double steel swinging door in a		3442	40.0500	1	lump sum	678	678	0.101		0.137	517	0
402	41	c	Furnishing and installing steel swinging doors in powerplant structure		3442	40.0500	100%	lump sum	5,100.00	5,100	0.101		0.137	3,886	0
403	42	c	Furnishing and installing metal- clad fire doors		3442	40.0500	100%	lump sum	1.100.00	1,100	0.101		0.137	838	0
627	P	c	Furnishing and installing four spillway weather door l operators		3442	40.0500	100%	lump sum	10,500	10,500	0.101		0.137	8,001	0
818	(o)	c	Furnishing and handling electric-operated sliding weather door		3442	40.0500	100%	lump sum	1,322.50	1,323	0.101		0.137	1,008	0
105	108	b	installing trashrack and slot closure		3443	40.0600	224,250	lb	0	16,819	0.297208267		0.217912791	8,155	0
344	(h)	b	As an adjustment for underrun in quantity under schedule item 108		3443	40.0600	1	lump sum	4,500	4,500	0.297208267		0.217912791	2,182	0
416	55	c	Installing three aftercoolers		3443	40.0600	100%	lump sum	625	625	0.297208267		0.217912791	303	0
417	56	c	Installing six air receivers		3443	40.0600	100%	lump sum	1,520.00	1,520	0.297208267		0.217912791	737	0
470	109	c	Furnishing and installing cable trays		3443	40.0600	100%	lump sum	3,018.00	3,018	0.297208267		0.217912791	1,463	0
476	115	c	Furnishing and installing penstock filling line		3443	40.0600	100%	lump sum	13,500.00	13,500	0.297208267		0.217912791	6,546	0
477	116	c	Furnishing and installing hydropneumatic tank		3443	40.0600	100%	lump sum	3.400.00	3,400	0.297208267		0.217912791	1,649	0
478	117	c	Furnishing, testing, and installing all material and equipment for modif		3443	40.0600	100%	lump sum	9,000.00	9,000	0.297208267		0.217912791	4,364	0
479	118	c	Furnishing and installing engine-generator set		3443	40.0600	100%	lump sum	14,740.00	14,740	0.297208267		0.217912791	7,147	0
718	(a)	c	Order for Changes No2: Installing two Government- S furnished 2,50		3443	40.0600	100%	lump sum	$ 1.300.00	1,300	0.297208267		0.217912791	630	0
91	94	b	Furnishing and installing embedded heating and ventilating ducts		3444	40.0700	3,888	lb	2	6,999	0.174	0.034	0.165	4,389	238
165	171	b	Furnishing and laying 24-inch- diameter No. 1Cgaugs corrugated-meta		3444	40.0700	460	lin ft	11	5,060	0.174	0.034	0.165	3,173	172
166	172	b	Furnishing and installing 30-inch diameter No. 14 gauge corrugated-m		3444	40.0700	11	each	85	935	0.174	0.034	0.165	586	32
167	173	b	Furnishing and erecting 168 inch diameter No 3 gage multiple-plate c		3444	40.0700	76	lin ft	150	11,400	0.174	0.034	0.165	7,148	388
168	174	b	Furnishing and erecting 168inch~diamefer No gage multiple plate cor		3444	40.0700	108	lin ft	130	14,040	0.174	0.034	0.165	8,803	477
175	181	b	Furnishing and installing metal railing for bridge		3444	40.0700	181	lin ft	6	1,087	0.174	0.034	0.165	682	37
224	p	b	Constructing forms for blocks 8. 10. and 12 made obsolete by chang		3444	40.0700	1	lump sum	948	948	0.174	0.034	0.165	594	32
227	b	b	re-fabricating and recalculating leaders and gutters in power plant		3444	40.0700	1	lump sum	133	133	0.174	0.034	0.165	83	5
228	c	b	constructing formed air ducts below elevation 7164.97 in penstock		3444	40.0700	1	lump sum	4,897	4,897	0.174	0.034	0.165	3,070	166
280	(e)	b	For additional costs for furnishing additional metalwork required in pov		3444	40.0700	8,598	lb	0	995	0.174	0.034	0.165	624	34
97	100	b	Furnishing and installing access stairways		3446	40.0800	1	lump sum	12,000	12,000	0.196	0.016	0.219	6,828	192
98	101	b	Installing spiral stairways in dam		3446	40.0800	129,854	lb	0	23,374	0.196	0.016	0.219	13,300	374
102	105	b	Furnishing and installing handrail		3446	40.0800	661	lin ft	15	9,918	0.196	0.016	0.219	5,644	159
237	b	b	As an adjustment for increased cost for f Furnishing and Installing mc		3446	40.0800	1	lump sum	4,747	4,747	0.196	0.016	0.219	2,701	76

APPENDIX A Material Inputs to the Morrow Point Dam 6 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
266	(c)	b	Furnishing and installing platform and ladder support assemblies in pov		3446	40.0800	9	each	156	1,404	0.196	0.016	0.219	799	22
267	(d)	b	Furnishing and installing additional handrail in powerplant chamber		3446	40.0800	130	lb	1	132	0.196	0.016	0.219	75	2
465	104	c	Furnishing and installing steel railing for sidewalks and retaining walls		3446	40.0800	11,649	lb	1.5	17,474	0.196	0.016	0.219	9,942	280
753	(h)	c	Installing protective handrail in cable tunnel		3446	40.0800	100%	lump sum	109.25	109	0.196	0.016	0.219	62	2
792	(h)	c	Modifying handrailing at a pproach to visitor facilities		3446	40.0800	100%	lump sum	48.61	49	0.196	0.016	0.219	28	1
793	(i)	c	Repairing and painting handrailing at draft tube gate deck		3446	40.0800	100%	lump sum	415.46	415	0.196	0.016	0.219	236	7
808	(e)	c	Realining handrail for powerplant access road		3446	40.0800	100%	lump sum	218.26	218	0.196	0.016	0.219	124	3
87	90	b	Furnishing and installing metal ceiling		3448	40.0901	11,709	ft2	3	31,615	0.297208267		0.217912791	15,330	0
48	51	b	Furnishing and handling cement. except for grouting		3449	40.0902	436,265	bbl	5	2,050,446	0.231	0.066	0.450	518,763	135,329
49	52	b	Furnishing and handling sacked cement for grouting foundations and c		3449	40.0902	81,803	sack	2	139,066	0.231	0.066	0.450	35,184	9,178
50	53	b	Furnishing and handling spec al cement for grouting contraction joints		3449	40.0902	4,240	sack	2	7,632	0.231	0.066	0.450	1,931	504
51	54	b	Furnishing and handling sacked cement for grouting rock bolts		3449	40.0902	1,289	sack	2	2,578	0.231	0.066	0.450	652	170
52	55	b	Furnishing and placing reinforcement bars of the following sizes No 3		3449	40.0902	137	lb	0	29	0.231	0.066	0.450	7	2
53	56	b	No.s 4 and 5		3449	40.0902	117,501	b	0	17,625	0.231	0.066	0.450	4,459	1,163
54	57	b	No.s 6 and 7		3449	40.0902	602,075	lb	0	90,311	0.231	0.066	0.450	22,849	5,961
55	58	b	No 8 and larger		3449	40.0902	2,225,510	lb	0	333,827	0.231	0.066	0.450	84,458	22,033
217	i	b	furnishing cement for grout and grouting cable tunnel linning voids		3449	40.0902	287	sack	4	1,248	0.231	0.066	0.450	316	82
259	(b)	b	Furnishing and installing reinforcement steel for retaining wall betwee		3449	40.0902	10,103	lb	0	2,323	0.231	0.066	0.450	588	153
297	(f)	b	Performing backfill grouting of outlet works steel liner		3449	40.0902	1	lump sum	2,113	2,113	0.231	0.066	0.450	535	139
351	(o)	b	As an adjustment for overrun in quantity under schedule item 52		3449	40.0902	1	lump sum	5,006	5,006	0.231	0.066	0.450	1,267	330
382	21	c	Furnishing and handling cement		3449	40.0902	9,268.75	bbl	9	83,419	0.231	0.066	0.450	21,105	5,506
383	22	c	Furnishing and placing the following sizes of reinforcement bars: 2 an		3449	40.0902	4.86	lb	0.3	1,458	0.231	0.066	0.450	369	96
384	23	c	4 and 5		3449	40.0902	60.316	lb	0.25	15,079	0.231	0.066	0.450	3,815	995
385	24	c	6 and 7		3449	40.0902	49,297	lb	0.24	11,831	0.231	0.066	0.450	2,993	781
386	25	c	8 and larger		3449	40.0902	361.416	lb	$0.23	83,126	0.231	0.066	0.450	21,031	5,486
679	303	c	Furnishing and handling cement	t	3449	40.0902	38.38	bbl	9	345	0.231	0.066	0.450	87	23
682	306	c	Furnishing and placing the following sizes of re	t	3449	40.0902	110	lb	0.4	44	0.231	0.066	0.450	11	3
683	307	c	4 and 5	t	3449	40.0902	597	lb	0.35	209	0.231	0.066	0.450	53	14
684	308	c	6 and 7	t	3449	40.0902	2,910	lb	0.35	1,019	0.231	0.066	0.450	258	67
685	309	c	8 and	t	3449	40.0902	1,877	lb	0.35	657	0.231	0.066	0.450	166	43
816	(m)	c	As an equitable adjustment for substitution of Prostrata junipers in liet		3449	40.0902	100%	lump sum	2,500.00	2,500	0.231	0.066	0.450	633	165
817	(n)	c	Furnishing and installing metal lath for quarry tile installation		3449	40.0902	100%	lump sum	120	120	0.231	0.066	0.450	30	8
17	18	b	Furnishing and installing grouted rock bolts in powerplant chamber anc		3452	41.0100	66,613	lin ft	4	286,436	0.517		0.308	50,126	0
18	19	b	Furnishing and installing ungrouted rock bolts in powerplant chamber a		3452	41.0100	918	lin ft	2	1,652	0.517		0.308	289	0
20	21	b	Furnishing and installing ungrouted rock bolts in open-cut excavation a		3452	41.0100	47,488	lin ft	3	132,910	0.517		0.308	23,259	0
36	39	b	hookups to foundation grout holes		3452	41.0100	1,684	hookup	20	33,680	0.517		0.308	5,894	0
39	42	b	Hookups to contraction joint 9"Yf1"8 system		3452	41.0100	196	hookup	45	8,820	0.517		0.308	1,544	0
100	103	b	installing Government furnished anchor bolts		3452	41.0100	17,463	lb	0	5,239	0.517		0.308	917	0
101	104	b	Furnishing and installing anchor bolts		3452	41.0100	5,544	lb	1	4,436	0.517		0.308	776	0
158	164	b	Installing rock bolt load cells		3452	41.0100	26	each	250	6,500	0.517		0.308	1,138	0
185	a	b	Order for Changes No 2 Furnishing and installing expansion bolts of		3452	41.0100	3,201	each	4	14,404	0.517		0.308	2,521	0
191	a	b	Order for change # 3 Furnishing and constructing 1-inch diameter gro		3452	41.0100	17,826	ft	16	276,303	0.517		0.308	48,353	0
193	c	b	Furnishing and constructing 0.75inch-diameter ungrouted rock bolts v		3452	41.0100	19,140	ft	7	129,960	0.517		0.308	22,743	0
194	d	b	Furnishing and constructing 0.75inch-diameter ungrouted rock bolts		3452	41.0100	3,008	ft	15	46,323	0.517		0.308	8,107	0
207	l	b	Furnishing and installing modified rock bolts		3452	41.0100	67,531	lin ft	0	8,103	0.517		0.308	1,418	0
210	b	b	Furnishing and Installing grouting rock bolts around portal of ventilatio		3452	41.0100	276	lin ft	10	2,760	0.517		0.308	483	0
211	c	b	Furnishing and Installing groutable rock bolts within ventilation adit		3452	41.0100	36	lin ft	9	318	0.517		0.308	56	0
234	l	b	furnishing and installing 148 anchor bars and drilng holes for MPBX		3452	41.0100	1	lump sum	49,700	49,700	0.517		0.308	8,698	0
238	c	b	Furnishing and Installing 1375inch hollow core rock bolts		3452	41.0100	1,534	lin ft	31	47,354	0.517		0.308	8,287	0
288	(f)	b	As an adjustment for overrun in quantity under schedule item 18		3452	41.0100	1	lump sum	19,209	19,209	0.517		0.308	3,362	0
372	11	c	Furnishing and installing rock bolts		3452	41.0100	736	lin ft	7	5,152	0.517		0.308	902	0
373	12	c	Furnishing and installing expansion bolts		3452	41.0100	4,500	each	10	45,000	0.517		0.308	7,875	0
469	108	c	Installing generator anchor bolts		3452	41.0100	100%	lump sum	5,500	5,500	0.517		0.308	963	0
474	113	c	Installing penstock makeup pieces complete with supports, bolts and		3452	41.0100	100%	lump sum	8,000	8,000	0.517		0.308	1,400	0
780	(o)	c	Furnishing surplus rock bolts		3452	41.0100	8,250	lin ft	0.5	4,125	0.517		0.308	722	0
782	(q)	c	Furnishing and installing 2-foot expansion bolts		3452	41.0100	1,112	each	11.86	13,188	0.517		0.308	2,308	0
784	(s)	c	Furnishing and installing rock bolts		3452	41.0100	100	lin ft	8.3	830	0.517		0.308	145	0
820	(q)	c	Furnishing expansion bolts		3452	41.0100	291	each	3.13	911	0.517		0.308	159	0
400	39	c	Furnishing and installing movable metal partitions		3469	41.0203	100%	lump sum	5,400	5,400	0.297208267		0.217912791	2,618	0
449	88	c	Furnishing and installing hose adapters		3429	42.0300	123.3	lb	7	863	0.297208267		0.217912791	418	0
74	77	b	Furnishing and pacing 1-inch- outside-diameter metal pipe or tubing a		3498	42.0800	311,063	lin ft	1	202,191	0.297208267		0.217912791	98,038	0
124	127	b	Installing one hydraulic control system for the 3.5- by 40-foot tande		3491	42.0800	1	lump sum	2,300	2,300	0.451		0.265	653	0
130	133	b	Furnishing and installing reservoir level gauge well heating system		3492	42.0800	1	lump sum	160	160	0.125		0.137	118	0
157	163	b	Installing reinforcement meters		3492	42.0800	6	each	400	2,400	0.125		0.137	1,771	0
186	b	b	Furnishing and installing pielometer piping for outlet works		3498	42.0800	1	lump sum	4,479	4,479	0.451		0.265	1,272	0
197	b	b	Furnishing and Installing hangers for one or two pipes		3498	42.0800	19	sack	36	690	0.451		0.265	196	0

APPENDIX A Material Inputs to the Morrow Point Dam 7 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
198	c	b	Furnishing and Installing hangers for three pipes		3498	42.0800	11	each	38	418	0.451		0.265	119	0
206	k	b	deleting the salt velocity piping and connector for penstock steel line		3498	42.0800	1	lump sum	-1,275	-1,275	0.451		0.265	-362	0
214	f	b	Furnishing and Installing 3-inch pipe for weep holes in cable tunnel lir		3498	42.0800	58	lin ft	6	343	0.451		0.265	97	0
215	g	b	Furnishing and Installing 15inch pipe in cab e tunnel lining for back fill g		3498	42.0800	212	lb	2	350	0.451		0.265	99	0
218	j	b	For deleting the 16-inchair vent piping from penstock intake Structur		3498	42.0800	1	lump sum	-1,525	-1,525	0.451		0.265	-433	0
246	a	b	Order for Changes No. 11 Furnishing and Installing additional piping fo		3498	42.0800	1	lump sum	76	76	0.451		0.265	22	0
255	j	b	Furnishing and Installing weep pipe in lining of penstock makeup piece		3498	42.0800	3	lin ft	9	28	0.451		0.265	8	0
256	k	b	Removing tight rock from penstock makeup piece recess		3498	42.0800	1	lump sum	324	324	0.451		0.265	92	0
260	(c)	b	Furnishing and installing weep pipe for retaining wall between station		3498	42.0800	206	lin ft	2	506	0.451		0.265	144	0
265	(b)	b	Furnishing and installing 1.5inch-diameter standard pipe extensions to		3498	42.0800	1,209	lb	3	3,361	0.451		0.265	955	0
298	(g)	b	As an adjustment for overrun in quantity under schedule item 58		3498	42.0800	1	lump sum	27,578	27,578	0.451		0.265	7,832	0
420	59	c	Furnishing installing and testing motor-operated valves		3491	42.0800	2,491	lb	4	9,964	0.451		0.265	2,830	0
425	64	c	Furnishing and installing pressure gages		3492	42.0800	23	each	45	1,035	0.451		0.265	294	0
426	65	c	Furnishing and installing differential pressure gauges		3492	42.0800	5	each	150	750	0.451		0.265	213	0
440	79	c	Furnishing and installing air-release valve		3491	42.0800	135	lb	2	270	0.451		0.265	77	0
441	80	c	and vacuum valves		3491	42.0800	672	lb	2.5	1,680	0.451		0.265	477	0
442	81	c	Furnishing and installing air- operated butterfly valves		3491	42.0800	1.292	lb	6	7,752	0.451		0.265	2,202	0
443	82	c	Furnishing and installing relief valves		3491	42.0800	53800%	lb	4	2,152	0.451		0.265	611	0
444	83	c	Furnishing and installing pressure-regulating valves		3491	42.0800	118400%	lb	$4.50	5,328	0.451		0.265	1,513	0
445	84	c	Furnishing and installing weight-operated valve		3491	42.0800	100%	lump sum	190	190	0.451		0.265	54	0
446	85	c	Furnsihing and installing electro-hydraulic-operated valves		3491	42.0800	6200%	lb	12.5	775	0.451		0.265	220	0
447	86	c	Furnishing and installing solenoid valves		3491	42.0800	72.5	lb	10	725	0.451		0.265	206	0
460	99	c	Furnishing and installing pipe hangers and supports		3498	42.0800	8,602.60	lb	3	25,808	0.451		0.265	7,329	0
787	(c)	c	Furnishing and installing a 2.5l inch gate valve		3491	42.0800	100%	lump sum	188.31	188	0.451		0.265	53	0
410	49	c	Installing and testing two 83.000-horsepower hydraulic turbines		3511	43.0100	100%	lump sum	301.755.00	301,755	0.297208267		0.217912791	146,315	0
411	50	c	Installing and testing two184,000-foot-pound governors for hydraulic		3511	43.0100	100%	lump sum	19.600.00	19,600	0.297208267		0.217912791	9,504	0
482	121	c	Constructing irrigation system		3523	44.0001	100%	lump sum	2.800.00	2,800	0.297208267		0.217912791	1,358	0
86	89	b	Furnishing and erecting steel for powerplant crane runway		3531	45.0100	288,957	lb	0	54,902	0.297208267		0.217912791	26,621	0
106	109	b	Installing 30-ton gantry crane Rack		3531	45.0100	1	lump sum	2,600	2,600	0.297208267		0.217912791	1,261	0
109	112	b	Installing one 300-ton overhead traveling crane		3531	45.0100	1	lump sum	34,000	34,000	0.297208267		0.217912791	16,486	0
110	113	b	Installing one 30-ton gantry crane		3531	45.0100	1	lump sum	11,500	11,500	0.297208267		0.217912791	5,576	0
111	114	b	Installing one 20-ton gantry crane		3531	45.0100	1	lump sum	8,000	8,000	0.297208267		0.217912791	3,879	0
112	115	b	Installing one 6ton Dingle I-beam crane		3531	45.0100	1	lump sum	850	850	0.297208267		0.217912791	412	0
231	f	b	Furnishing and installing pipe sleeves for crane runway column and g		3531	45.0100	154	each	53	8,111	0.297208267		0.217912791	3,933	0
466	105	c	Modifying crane girders		3531	45.0100	100%	lump sum	3.000.00	3,000	0.297208267		0.217912791	1,455	0
643	267	c	Furnishing and installing double switch-operating platforms in substatic		3531	45.0100	1	each	568	568	0.297208267		0.217912791	275	0
772	(g)	c	Replacing hydraulic brake system on 250-ton traveling crane		3531	45.0100	100%	lump sum	504.41	504	0.297208267		0.217912791	245	0
773	(h)	c	Furnishing and installing new rectifiers in hoist motors of250-ton trav		3531	45.0100	100%	lump sum	234.98	235	0.297208267		0.217912791	114	0
778	(m)	c	Replacing defective brake coil on auxiliary hoist of 250-ton traveling		3531	45.0100	100%	lump sum	124.97	125	0.297208267		0.217912791	61	0
353	(q)	b	installing dam sump pumps and controls		3561	49.0100	1	lump sum	2,957	2,957	0.297208267		0.217912791	1,434	0
412	51	c	Installing and testing two sump pumping units		3561	49.0100	100%	lump sum	3,420.00	3,420	0.297208267		0.217912791	1,658	0
413	52	c	Furnishing, installing and testing three cooling water pumping units		3561	49.0100	100%	lump sum	6,100.00	6,100	0.297208267		0.217912791	2,958	0
414	53	c	Furnishing, installing, and testing two oil pumping units		3561	49.0100	100%	lump sum	1,720.00	1,720	0.297208267		0.217912791	834	0
415	54	c	Installing and testing three air compressors		3563	49.0100	100%	lump sum	1,390.00	1,390	0.297208267		0.217912791	674	0
431	70	c	Furnishing and installing sump eductor		3561	49.0100	100%	lump sum	1,100.00	1,100	0.297208267		0.217912791	533	0
438	77	c	Furnishing installing and testing one sump pumping		3561	49.0100	100%	lump sum	3,200.00	3,200	0.297208267		0.217912791	1,552	0
90	93	b	Furnishing and erecting enclosures for penstock intake structure gate		3569	49.0700	1	lump sum	29,000	29,000	0.020	0.012	0.106	24,998	348
114	117	b	Installing two 13.5 by 1607-foot. fixed-wheel gates for penstock ins		3569	49.0700	1	lump sum	6,400	6,400	0.020	0.012	0.106	5,517	77
115	118	b	installing two frames for 13.5- by 16.07-foot. fixed-wheel gates		3569	49.0700	1	lump sum	4,500	4,500	0.020	0.012	0.106	3,879	54
116	119	b	Installing two hydraulic hoists for 13.5- by 1601-foot fixed-wheel ga		3569	49.0700	1	lump sum	4,500	4,500	0.020	0.012	0.106	3,879	54
118	121	b	installing four 15- by 1683- foot. fixed-wheel gates for spillways		3569	49.0700	1	lump sum	12,000	12,000	0.020	0.012	0.106	10,344	144
119	122	b	Installing four frames for 15- by 1683-foot. fixed-wheel gates		3569	49.0700	1	lump sum	8,500	8,500	0.020	0.012	0.106	7,327	102
120	123	b	Installing four Hoists for 15- by 1683-foat. fixed-wheel gates		3569	49.0700	1	lump sum	8,400	8,400	0.020	0.012	0.106	7,241	101
127	130	b	Installing seats and guides for bulkheads gates for draft tunnel and fc		3569	49.0700	128,430	lb	0	17,338	0.020	0.012	0.106	14,945	208
128	131	b	Installing lifting frames and fitting beam		3569	49.0700	1	lump sum	700	700	0.020	0.012	0.106	603	8
129	132	b	Furnishing and installing one reservoir level gauges well and piping		3569	49.0700	1	lump sum	5,400	5,400	0.020	0.012	0.106	4,655	65
199	d	b	Furnishing and Installing extensoometer protection assemblies		3569	49.0700	3	each	227	682	0.020	0.012	0.106	588	8
421	60	c	Installing and testing fixed carbon dioxide fire-extinguishing system		3569	49.0700	100%	lump sum	3.380.00	3,380	0.297208267		0.217912791	1,639	0
448	87	c	Furnshing and installing flanged twin strainers		3569	49.0700	100%	lump sum	13000	13,000	0.020	0.012	0.106	11,206	156
838	(g)	c	Mounting two motor starters f for dam sump pumps		3569	49.0700	100%	lump sum	45.86	46	0.020	0.012	0.106	40	1
450	89	c	Furnishing and installing flexible metal hose		3599	50.0400	80	lb	10	800	0.020	0.012	0.106	690	10
547	186	c	Installing main control board CCA and sequential operations recorder		3577	51.0104	100%	lump sum	$ 8.250.00	8,250	0.297208267		0.217912791	4,000	0
134	137	b	Furnishing and installing ice prevention air systems		3585	52.0300	1	lump sum	26,000	26,000	0.098		0.129	20,098	0
463	102	c	Furnishing and installing water coolers in powerplant structure		3585	52.0300	100%	lump sum	720	720	0.098		0.129	557	0
473	112	c	Furnishing and installing heating, ventilating, and air-conditioning syste		3585	52.0300	100%	lump sum	155,000.00	155,000	0.098		0.129	119,815	0
419	58	c	Installing and testing chlorinating equipment		3589	52.0500	100%	lump sum	660	660	0.297208267		0.217912791	320	0

APPENDIX A Material Inputs to the Morrow Point Dam 8 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
467	106	c	Furnishing and installing transformer vault enclosure		3612	53.0200	100%	lump sum	31,000.00	31,000	0.037	0.008	0.104	26,381	248
550	189	c	Installing transformer remote- indicating panel KSA		3612	53.0200	100%	lump sum	600	600	0.037	0.008	0.104	511	5
554	193	c	Furnishing and installing one9-kilovolt-ampere480/208/120-volt cont		3612	53.0200	100%	lump sum	700	700	0.037	0.008	0.104	596	6
564	203	c	Installing generator voltage isolated-phase bus structure		3612	53.0200	100%	lump sum	13.325.00	13,325	0.037	0.008	0.104	11,340	107
565	204	c	Installing generator voltage segregated-phase bus structures with prc		3612	53.0200	100%	lump sum	2,000.00	2,000	0.037	0.008	0.104	1,702	16
566	205	c	Installing two generator neutral grounding transformers resistors, and		3612	53.0200	100%	lump sum	2,000.00	2,000	0.037	0.008	0.104	1,702	16
584	223	c	Furnishing and installing lighting transformers for dam and appurtenan		3612	53.0200	1.951	lb	3	5,853	0.037	0.008	0.104	4,981	47
624	M	c	Furnishing and installing three ldifferential relays, one t differential loc		3612	53.0200	100%	lump sum	760	760	0.037	0.008	0.104	647	6
625	N	c	Installing one 150-kilovolt ampere lighting transformer K2E (formerly		3612	53.0200	100%	lump sum	850	850	0.037	0.008	0.104	723	7
720	©	c	type G lighting fixtures in powerplant		3612	53.0200	26	each	30	780	0.037	0.008	0.104	664	6
761	(h)	c	Moving d-c lighting contactor100%		3612	53.0200	100%	lump sum	210.36	210	0.037	0.008	0.104	179	2
767	(b)	c	Modifying lighting and power panels and transfer switches		3612	53.0200	100%	lump sum	185	185	0.037	0.008	0.104	157	1
117	120	b	installing two hydraulic control systems for 13.5- by 1607- foot. fixe		3613	53.0300	1	lump sum	4,800	4,800	0.077		0.110	3,902	0
137	143	b	Furnishing and installing 600- volt. BO-ampere power receptacles con		3613	53.0300	2	each	100	200	0.077		0.110	163	0
138	144	b	Furnishing and installing 600 volt100-ampere power receptacles com		3613	53.0300	3	each	200	600	0.077		0.110	488	0
427	66	c	pressure switches		3613	53.0300	6	each	56	336	0.077		0.110	273	0
428	67	c	switches		3613	53.0300	2	each	145	290	0.077		0.110	236	0
430	69	c	Furnishing and installing combination float and pressure switch		3613	53.0300	100%	lump sum	764	764	0.077		0.110	621	0
505	144	c	Furnishing and installing 480 volt, 60-ampere power receptacles com		3613	53.0300	6	each	100	600	0.077		0.110	488	0
506	145	c	Furnishing and installing 480 volt, 100-ampere power receptacle com		3613	53.0300	1	each	120	120	0.077		0.110	98	0
551	190	c	Installing 480-volt station- service switchgear DCA		3613	53.0300	100%	lump sum	4,000.00	4,000	0.077		0.110	3,252	0
556	195	c	Furnishing and installing 16automatic transfer switches		3613	53.0300	100%	lump sum	8,400.00	8,400	0.077		0.110	6,829	0
557	196	c	Furnishing and installing five alternating-current distribution boards M1/		3613	53.0300	100%	lump sum	8.500.00	8,500	0.077		0.110	6,911	0
558	197	c	Furnishing and installing two 460-volt alternating-current emergency		3613	53.0300	100%	lump sum	2,785.00	2,785	0.077		0.110	2,264	0
559	198	c	Furnishing and installing one direct-current distribution board BCA		3613	53.0300	100%	lump sum	3.500.00	3,500	0.077		0.110	2,846	0
563	202	c	Installing two 14.4-kilovolt station-type generator switchgear assemt		3613	53.0300	100%	lump sum	4.400.00	4,400	0.077		0.110	3,577	0
567	206	c	Installing 230-kilovolt, 3-pole manually gang-operated air switch with 3		3613	53.0300	100%	lump sum	$2.470.00	2,470	0.077		0.110	2,008	0
568	207	c	Installing 14.4-kilovolt 3-pole. manually gang-operated air switch		3613	53.0300	100%	lump sum	1.000.00	1,000	0.077		0.110	813	0
569	208	c	Installing 14.4-kilovolt single-pole hook-operated disconnecting fuses		3613	53.0300	5	each	50	250	0.077		0.110	203	0
570	209	c	Installing 13.2-kilovolt single- phase, 15-kilovolt ampere switchyard c		3613	53.0300	100%	lump sum	150	150	0.077		0.110	122	0
574	213	c	Installing 240/120-volt switchyard station-service distribution panelt		3613	53.0300	1	each	500	500	0.077		0.110	407	0
575	214	c	Installing 15-kilovolt current transformer		3613	53.0300	1	each	200	200	0.077		0.110	163	0
576	215	c	Furnishing and installing 1.431,000-circular mid ACSR, strain and jump		3613	53.0300	372.6	lin ft	1,490.40		0.077		0.110	0	0
577	216	c	Furnishing and installing No.2AWG, ACSR, jumper bus		3613	53.0300	24	lin ft	72		0.077		0.110	0	0
578	217	c	Furnishing and installing No.4/0 AWG copper jumper bus		3613	53.0300	2	lin ft	3	6	0.077		0.110	5	0
579	218	c	Furnishing and installing 1-inch iron-pipe-size rigid aluminum bus		3613	53.0300	149	lin ft	6	894	0.077		0.110	727	0
581	220	c	Furnishing and installing instrument transformer terminal box		3613	53.0300	0	each	100	0	0.077		0.110	0	0
595	234	c	Furnishing and installing eight lighting panelboards in dam and appurte		3613	53.0300	100%	lump sum	8,313.00	8,313	0.077		0.110	6,758	0
596	235	c	Furnishing and installing time switches in dam and appurtenant structu		3613	53.0300	1	each	130	130	0.077		0.110	106	0
597	236	c	Furnishing and installing miscellaneous electrical equipment items in d		3613	53.0300	8,077.40	lb	7	56,542	0.077		0.110	45,968	0
610	249	c	Installing recessed-type panelboards L1B L2B, L2C,and LCA in glazed		3613	53.0300	3	each	110	330	0.077		0.110	268	0
611	250	c	Removing and reinstalling panelboard fronts on formed concrete rece		3613	53.0300	3	each	25	75	0.077		0.110	61	0
619	H	c	Removing three single-pole i breakers and furnishing and t installing a		3613	53.0300	100%	lump sum	36	36	0.077		0.110	29	0
662	286	c	Installing 15-kilovolt, 3-pole,gang-operated air switch		3613	53.0300	1	each	1,150.00	1,150	0.077		0.110	935	0
663	287	c	Installing 230-kilovolt, 10,000-ampere power circuit breaker		3613	53.0300	0	0	0	0	0.077		0.110	0	0
664	288	c	Installing 14.4-kilovolt 250-megavolt ampere power circuit breaker		3613	53.0300	1	each	$3,200.00	3,200	0.077		0.110	2,602	0
665	289	c	Installing 14.4-kilovolt, single- phase, current-limiting reactors		3613	53.0300	3	each	300	900	0.077		0.110	732	0
667	291	c	Installing 14.4-kilovolt potential transformers		3613	53.0300	3	each	150	450	0.077		0.110	366	0
669	293	c	Reinstalling 14.4-kilovolt fused disconnecting switches		3613	53.0300	3	each	50	150	0.077		0.110	122	0
670	294	c	Reinstalling 13.2-kilovolt, 50,l kilovolt ampere single-phase transform		3613	53.0300	3	each	210	630	0.077		0.110	512	0
671	295	c	Furnishing and installing954.000-circular mid ACSR,strain and jumper I		3613	53.0300	299	lin ft	4	1,196	0.077		0.110	972	0
672	296	c	Furnishing and installing No.2		3613	53.0300	55	lin ft	3	165	0.077		0.110	134	0
673	297	c	Reinstalling 230-kilovolt pedestal insulators, technical reference No.2		3613	53.0300	11	each	100	1,100	0.077		0.110	894	0
676	300	c	Furnishing and installinginstrument transformer terminal boxes		3613	53.0300	2	each	105	210	0.077		0.110	171	0
825	(d)	c	Installing load and frequency cabinet CCD 100%		3613	53.0300	100%	lump sum	572.47	572	0.077		0.110	465	0
136	139	b	Furnishing and installing parapet lighting units		3646	55.0200	28	each	60	1,680	0.290		0.200	857	0
139	145	b	design, furnish and install lighting in powerplant, access tunnel and ver		3646	55.0200	1	lump sum	33,000	33,000	0.290		0.200	16,830	0
317	(c)	b	Fabricating and installing mounting brackets for type GG lighting fixtur		3646	55.0200	1	lump sum	645	645	0.290		0.200	329	0
319	(e)	b	As an adjustment for increased costs for furnishing type DD, EE, and		3646	55.0200	1	lump sum	14,502	14,502	0.290		0.200	7,396	0
320	(f)	b	Providing temporary storage for lighting equipment. materials. and fi		3646	55.0200	1	lump sum	977	977	0.290		0.200	498	0
323	(i)	b	As an adjustment for changes in lighting system requirements unde		3646	55.0200	1	lump sum	-7,068	-7,068	0.290		0.200	-3,605	0
582	221	c	Furnishing and installing switchyard tapered-pole type t lighting units		3645	55.0200	2	each	250	500	0.290		0.200	255	0
585	224	c	Furnishing and installing lighting system wiring devices in dam and app		3645	55.0200	340	each	15	5,100	0.290		0.200	2,601	0
586	225	c	Furnishing and installing the following types of lighting fixtures for dan		3645	55.0200	106	each	30	3,180	0.290		0.200	1,622	0
587	226	c	Type DB		3645	55.0200	2	each	42	84	0.290		0.200	43	0
588	227	c	Type DC		3645	55.0200	14	each	$30.00	420	0.290		0.200	214	0

APPENDIX A Material Inputs to the Morrow Point Dam 9 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
589	228	c	Type DE		3645	55.0200	3	each	46	138	0.290		0.200	70	0
590	229	c	Type DF		3645	55.0200	13	each	25	325	0.290		0.200	166	0
591	230	c	Type DG		3645	55.0200	7	each	55	385	0.290		0.200	196	0
593	232	c	Type DJ		3645	55.0200	4	each	290	1,160	0.290		0.200	592	0
594	233	c	Type DK		3645	55.0200	4	each	45	180	0.290		0.200	92	0
598	237	c	Installing the following types of lighting fixtures for the powerplant: T		3645	55.0200	3	each	27	81	0.290		0.200	41	0
599	238	c	Type A in second-stage concrete		3645	55.0200	21	each	27	567	0.290		0.200	289	0
600	239	c	Type B		3645	55.0200	59	each	20	1,180	0.290		0.200	602	0
601	240	c	Type E		3645	55.0200	6	each	17	102	0.290		0.200	52	0
602	241	c	Type J		3645	55.0200	8	each	27	216	0.290		0.200	110	0
603	242	c	Type		3645	55.0200	8	each	20	160	0.290		0.200	82	0
604	243	c	Type M		3645	55.0200	6	each	13	78	0.290		0.200	40	0
605	244	c	Type N		3645	55.0200	2	each	20	40	0.290		0.200	20	0
606	245	c	Type AA		3645	55.0200	12	each	26	312	0.290		0.200	159	0
607	246	c	Type BB		3645	55.0200	7	each	26	182	0.290		0.200	93	0
608	247	c	Furnishing and installing type T lighting fixtures inside heating and vent		3645	55.0200	6	each	25	150	0.290		0.200	77	0
609	248	c	Installing lighting system wiring devices		3645	55.0200	80	each	10	800	0.290		0.200	408	0
617	F	c	Furnishing and installing type HH lighting fixtures in access tunnel		3645	55.0200	100%	lump sum	6.550.00	6,550	0.290		0.200	3,341	0
618	G	c	Access tunnel lighting conduit t modification for circuit 6LSB		3645	55.0200	0	lump sum	$330.00	0	0.290		0.200	0	0
140	146	b	Furnishing and installing embedded electrical rigid metal conduit::0.5 ir		3644	55.0300	1,145	lin ft	1	1,260	0.483		0.269	312	0
141	147	b	O.75 inch in diameter		3644	55.0300	7,783	lin ft	2	11,676	0.483		0.269	2,896	0
142	148	b	inch in diameter		3644	55.0300	3,648	lin ft	2	7,298	0.483		0.269	1,810	0
143	149	b	I5 inches in diameter		3644	55.0300	5,487	lin ft	3	13,718	0.483		0.269	3,402	0
144	150	b	2 inches in diameter		3644	55.0300	3,925	lin ft	3	11,776	0.483		0.269	2,920	0
145	151	b	25 inches in diameter		3644	55.0300	1,837	lin ft	4	6,431	0.483		0.269	1,595	0
146	152	b	3 inches in diameter		3644	55.0300	2,450	lin ft	5	11,028	0.483		0.269	2,735	0
147	153	b	35 inches in diameter		3644	55.0300	2,904	lin ft	5	14,524	0.483		0.269	3,602	0
148	154	b	5 inches in diameter		3644	55.0300	12	lin ft	8	101	0.483		0.269	25	0
149	155	b	4 inches in diameter		3644	55.0300	437	lin ft	6	2,623	0.483		0.269	650	0
236	a	b	Order for Changes No 8 As an adjustment for increased costs for ins		3644	55.0300	1	lump sum	306	306	0.483		0.269	76	0
321	(g)	b	As an adjustment for furnishing 480-volt power receptacles in lieu c		3643	55.0300	1	lump sum	215	215	0.483		0.269	53	0
324	(j)	b	Furnishing and installing conduit and grounding system for crest road		3644	55.0300	1	lump sum	2,117	2,117	0.483		0.269	525	0
330	(P)	b	Furnishing and installing additional 0.75-inch rigid metal conduit in out		3644	55.0300	1	lump sum	67	67	0.483		0.269	17	0
331	(q)	b	Furnishing and installing additional 2.5-inch rigid metal conduit for inst		3644	55.0300	1	lump sum	295	295	0.483		0.269	73	0
464	103	c	Furnishing and installing bus enclosure		3643	55.0300	120	lin ft	120	14,400	0.483		0.269	3,571	0
492	131	c	Furnishing and installing the following sizes of embedded and/or expo		3644	55.0300	1,207.80	lin ft	1.5	1,812	0.483		0.269	449	0
493	132	c	0.75 inch in diameter		3644	55.0300	8975.4	lin ft	2	17,951	0.483		0.269	4,452	0
494	133	c	1 inch in diameter		3644	55.0300	3224.5	lin ft	2.5	8,561	0.483		0.269	2,123	0
495	134	c	1.5 inches in diameter		3644	55.0300	3,921.60	lin ft	3.5	13,726	0.483		0.269	3,404	0
496	135	c	2 inches in diameter		3644	55.0300	3,163.10	lin ft	4.5	14,234	0.483		0.269	3,530	0
497	136	c	2.5 inches in diameter		3644	55.0300	1,170.10	lin ft	5.5	6,436	0.483		0.269	1,596	0
498	137	c	3 inches in diameter		3644	55.0300	643.3	lin ft	$6.50	4,181	0.483		0.269	1,037	0
499	138	c	5 inches in diameter		3644	55.0300	88	lin ft	10	880	0.483		0.269	218	0
503	142	c	Furnishing and installing No.1 cast metal outlet boxes		3644	55.0300	80	each	20	1,600	0.483		0.269	397	0
504	143	c	Furnishing and installing No.2 cast metal outlet boxes		3644	55.0300	50	each	25	1,250	0.483		0.269	310	0
543	182	c	Furnishing and installing fabricated sheet steel boxes and wireways		3644	55.0300	1,360.40	lb	4.5	6,122	0.483		0.269	1,518	0
552	191	c	Installing one main lighting board LCA		3644	55.0300	100%	lump sum	800	800	0.483		0.269	198	0
555	194	c	Installing indoor electronic equipment		3644	55.0300	1	each	750	750	0.483		0.269	186	0
560	199	c	Furnishing and installing one indoor terminal and cooling control cabine		3644	55.0300	100%	lump sum	2.800.00	2,800	0.483		0.269	694	0
572	211	c	Installing 192-kilovolt station class lightning arresters		3644	55.0300	3	each	150	450	0.483		0.269	112	0
573	212	c	Installing 15-kilovolt intermediate-type lighting s arresters		3644	55.0300	3	each	70	210	0.483		0.269	52	0
583	222	c	Furnishing and installing outdoor power receptacles		3644	55.0300	0	each	30	0	0.483		0.269	0	0
648	272	c	Furnishing and installing the following electrical rigid metal conduit: 5 i		3644	55.0300	1.005	lin ft	7.5	7,538	0.483		0.269	1,869	0
649	273	c	4 inches in diameter		3644	55.0300	7	lin ft	6	42	0.483		0.269	10	0
650	274	c	2 inches in diameter		3644	55.0300	11	lin ft	5	55	0.483		0.269	14	0
651	275	c	1 inch in diameter		3644	55.0300	94	lin ft	4	282	0.483		0.269	70	0
666	290	c	Installing 15-kilovolt,N intermediate class lightning arresters		3644	55.0300	6	each	70	420	0.483		0.269	104	0
708	332	c	Furnishing and placing plate or cone guy ancho	t	3644	55.0300	30	each	90	2,700	0.483		0.269	670	0
709	333	c	Furnishing and placing grouted guy anchors	t	3644	55.0300	11	each	110	1,210	0.483		0.269	300	0
710	334	c	Furnishing and constructing single guys	t	3644	55.0300	25	each	75	1,875	0.483		0.269	465	0
711	335	c	Furnishing and constructing double guys	t	3644	55.0300	20	each	115	2,300	0.483		0.269	570	0
712	336	c	Furnishing and installing guy protectors	t	3644	55.0300	7	each	22	154	0.483		0.269	38	0
763	(i)	c	Rewiring current limiting resistors on 250-ton crane		3644	55.0300	100%	lump sum	36.5	37	0.483		0.269	9	0
768	(c)	c	Furnishing and installing two 51-pair telephone terminal blocks		3661	56.0300	100%	lump sum	845	845	0.440		0.254	259	0
646	270	c	Processing insulating oil		3663	56.0500	0	gal	0.16	0	0.297208267		0.217912791	0	0
491	130	c	Furnishing and installing all materials for grounding system		3662	57.0300	10899.01	lb	3	32,697	0.264		0.185	18,016	0

APPENDIX A Material Inputs to the Morrow Point Dam 10 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
561	200	c	Installing two 3-phase 1000 - kilovolt ampere station- service transfo		3677	57.0300	100%	lump sum	3.000.00	3,000	0.483		0.269	744	0
562	201	c	Installing three single-phase.12.2- to 230-kilovolt.52,000-kilovolt am		3677	57.0300	100%	lump sum	19.500.00	19,500	0.483		0.269	4,836	0
571	210	c	Installing 230-kilovolt coupling b capacitor potential devices		3675	57.0300	3	each	300	900	0.483		0.269	223	0
660	284	c	Installing 230-kilovolt coupling capacitor potential devices		3675	57.0300	3	each	300	900	0.483		0.269	223	0
75	78	b	Furnishing and installing thermocouples		3823	62.0200	9,039	lin ft	1	10,576	0.120		0.130	7,932	0
222	n	b	Installing additional joint meters in dam		3823	62.0200	26	each	117	3,048	0.120		0.130	2,286	0
225	a	b	Order for Changes No. 6 Furnishing all materials labor for work and (		3823	62.0200	1	lump sum	4,949	4,949	0.120		0.130	3,712	0
432	71	c	Furnishing and installing industrial-type thermometers		3823	62.0200	3	each	80	240	0.297208267		0.217912791	116	0
434	73	c	Furnishing and installing two water-level switches		3823	62.0200	100%	lump sum	250	250	0.297208267		0.217912791	121	0
436	75	c	Furnishing and installing gauge boards for miscellaneous instruments		3823	62.0200	1,960	lb	0.2	392	0.297208267		0.217912791	190	0
439	78	c	Furnishing and installing rate-of flow indicators		3823	62.0200	3	each	500	1,500	0.297208267		0.217912791	727	0
741	(n)	c	Installing Chemonitor CF-1chemical feeder in dam pump chamber		3823	62.0200	100%	lump sum	325.98	326	0.297208267		0.217912791	158	0
150	156	b	Installing sets of thermostats		3822	62.0300	11	set	160	1,760	0.321		0.210	825	0
151	157	b	A groups		3822	62.0300	73	group	395	28,800	0.321		0.210	13,507	0
152	158	b	B groups		3822	62.0300	6	group	600	3,600	0.321		0.210	1,688	0
153	159	b	C groups		3822	62.0300	4	group	500	2,000	0.321		0.210	938	0
154	160	b	D group		3822	62.0300	7	group	400	2,800	0.321		0.210	1,313	0
155	161	b	E group		3822	62.0300	8	group	1,000	8,000	0.321		0.210	3,752	0
156	162	b	F groups		3822	62.0300	2	group	1,500	3,000	0.321		0.210	1,407	0
220	l	b	Installing two groups of eight pore pressure meters in dam block 1C		3822	62.0300	2	group	532	1,064	0.321		0.210	499	0
221	m	b	Installing one group of eight pole pressure metals in dam block 10 at		3822	62.0300	1	group	847	847	0.321		0.210	397	0
429	68	c	Furnishing and installing two pneumatic liquid level l		3822	62.0300	100%	lump sum	2,480.00	2,480	0.321		0.210	1,163	0
462	101	c	Processing lubricating and governor oil		3822	62.0300	1116500%	gal	0.15	1,675	0.321		0.210	785	0
78	81	b	Furnishing and placing type Z metal seals		3953	64.0503	22,566	lin ft	4	85,754	0.297208267		0.217912791	41,580	0
79	82	b	Furnishing and placing type N2 metal seals		3953	64.0503	1,627	lin ft	3	4,721	0.297208267		0.217912791	2,289	0
394	33	c	Furnishing and placing type N2 metal seals		3953	64.0503	269	lin ft	8	2,152	0.297208267		0.217912791	1,043	0
433	72	c	Nameplates		3993	64.1100	390	each	7.5	2,925	0.210		0.181	1,781	0
488	127	c	Furnishing and installing equipment identification signs		3993	64.1100	6	each	16	96	0.210		0.181	58	0
489	128	c	Furnishing and installing phase identification signs		3993	64.1100	17	each	8	136	0.210		0.181	83	0
490	129	c	Furnishing and installing warning and safety signs		3993	64.1100	4	each	35	140	0.210		0.181	85	0
644	268	c	Furnishing and installing equipment identification signs		3993	64.1100	21	each	22	462	0.210		0.181	281	0
645	269	c	Furnishing and installing phase identification signs		3993	64.1100	15	each	11	165	0.210		0.181	100	0
687	311	c	Danger signs	t	3993	64.1100	4	each	$35.00	140	0.210		0.181	85	0
688	312	c	Tower number signs	t	3993	64.1100	2	each	24	48	0.210		0.181	29	0
422	61	c	Installing hand-portable carbon dioxide fire extinguishers		3999	64.1200	100%	lump sum	360	360	0.180		0.158	238	0
423	62	c	Furnishing and installing firehose reels firehose.		3999	64.1200	100%	lump sum	1,210.00	1,210	0.180		0.158	801	0
424	63	c	Furnishing and installing miscellaneous fire protection equipment		3999	64.1200	100%	lump sum	460	460	0.180		0.158	305	0
437	76	c	Furnishing and installing three wheeled-portable carbon dioxide fire ex		3999	64.1200	100%	lump sum	900	900	0.180		0.158	596	0
857			Onsight Trucking and Excavation			65.0301								3,711,364	
693	317	c	Clearing land and right-of-way for 13.8-kilovolt	t	clear land	clear land	100%	lump sum	5.500.00	5,500	0.392	0.368	0.240	0	2,024
173	179	b	Removing and disposing of county bridge No. 3		disposal	disposal	1	lump sum	1,760	1,760	0.413	0.329	0.258	0	579
322	(h)	b	As an adjustment for disposing of surplus ti-inch-diameter electrical r		disposal	disposal	1	lump sum	1,076	1,076	0.413	0.329	0.258	0	354
328	(n)	b	As an adjustment for extra costs in disposing of excess conduit		disposal	disposal	1	lump sum	188	188	0.413	0.329	0.258	0	62
8	9	b	Drilling line holes for opencut rock excavate		drill	drill	7,820	lin ft	1	6,859	0.364	0.395	0.240	7	2,709
15	16	b	Drilling line holes for underground rock excavation		drill	drill	5,187	lin ft	1	4,668	0.364	0.395	0.240	5	1,844
26	28	b	Core drilling NX holes in stage between the depths of: O and 50 feet		drill	drill	330	lin ft	10	3,301	0.364	0.395	0.240	3	1,304
27	29	b	50 and 100 feet		drill	drill	73	lin ft	10	737	0.364	0.395	0.240	1	291
28	31	b	Drilling grout Holes in stage between depth of: O and 30 feet		drill	drill	43,253	lin ft	2	90,832	0.364	0.395	0.240	91	35,879
29	32	b	30 and BO feet		drill	drill	32,375	lin ft	2	64,752	0.364	0.395	0.240	65	25,577
30	33	b	60 and 1IO feet		drill	drill	16,899	lin ft	2	33,799	0.364	0.395	0.240	34	13,351
31	34	b	110 and 160 feet		drill	drill	4,023	lin ft	2	9,254	0.364	0.395	0.240	9	3,655
32	35	b	160 and 210 feet		drill	drill	1,605	lin ft	2	3,692	0.364	0.395	0.240	4	1,458
33	36	b	21O and 26O feet		drill	drill	757	lin ft	3	2,271	0.364	0.395	0.240	2	897
34	37	b	260 and 310 feet		drill	drill	255	lin ft	5	1,148	0.364	0.395	0.240	1	453
41	44	b	Drilling drainage holes in stage between the depths of: O and 25 feet		drill	drill	6,485	lin ft	4	23,346	0.364	0.395	0.240	23	9,222
42	45	b	25 and 50 feet		drill	drill	6,687	lin ft	4	24,073	0.364	0.395	0.240	24	9,509
43	46	b	50 and 75 feet		drill	drill	4,871	lin ft	4	17,536	0.364	0.395	0.240	18	6,927
44	47	b	75 and 100 feet		drill	drill	3,141	lin ft	4	12,878	0.364	0.395	0.240	13	5,087
45	48	b	lO0 and 150 feet		drill	drill	2,703	lin ft	4	10,812	0.364	0.395	0.240	11	4,271
46	49	b	150 and 200 feet		drill	drill	74	lin ft	5	370	0.364	0.395	0.240	0	146
47	50	b	Drilling holes for anchor bars and grouting bars in place		drill	drill	28,170	lin ft	1	33,804	0.364	0.395	0.240	34	13,353
76	79	b	Drilling 10-inch-diametsr cores in concrete		drill	drill	237	lin ft	20	4,752	0.364	0.395	0.240	5	1,877
263	(f)	b	As an adjustment for the underrun in quantity under schedule item 16		drill	drill	1	lump sum	15,108	15,108	0.364	0.395	0.240	15	5,968
299	(h)	b	Drilling NX drain holes in left abutment of dam		drill	drill	705	lin ft	17	12,337	0.364	0.395	0.240	12	4,873
302	(a)	b	Order for Changes No. 19 Drilling and grouting fan holes in stilling ba		drill	drill	1	lump sum	12,056	12,056	0.364	0.395	0.240	12	4,762
303	(b)	b	Drilling and grouting horizontal holes in stilling basin		drill	drill	1	lump sum	15,068	15,068	0.364	0.395	0.240	15	5,952

APPENDIX A Material Inputs to the Morrow Point Dam 11 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
304	(c)	b	Drilling and grouting horizontal holes in penstock intake structure Tota		drill	drill	1	lump sum	40,169	40,169	0.364	0.395	0.240	40	15,867
306	(b)	b	As an adjustment for overrun quantity under schedule item 32		drill	drill	1	lump sum	22,185	22,185	0.364	0.395	0.240	22	8,763
307	(c)	b	As an adjustment for overrun quantity under schedule item 33		drill	drill	1	lump sum	9,157	9,157	0.364	0.395	0.240	9	3,617
308	(d)	b	As an adjustment for overrun quantity under schedule item 36		drill	drill	1	lump sum	313	313	0.364	0.395	0.240	0	124
309	(e)	b	As an adjustment for overrun quantity under schedule item 37		drill	drill	1	lump sum	-6	-6	0.364	0.395	0.240	0	-2
311	(g)	b	As an adjustment for overrun in quantity under schedule item 46		drill	drill	1	lump sum	5,454	5,454	0.364	0.395	0.240	5	2,154
312	(h)	b	As an adjustment for overrun in quantity under schedule item 47		drill	drill	1	lump sum	8,093	8,093	0.364	0.395	0.240	8	3,197
313	(i)	b	As an adjustment for overrun in quantity under schedule item 48		drill	drill	1	lump sum	2,878	2,878	0.364	0.395	0.240	3	1,137
314	(a)	b	Order for Changes No. 21 Drilling drain holes in powerplant a-line tun		drill	drill	1	lump sum	91,705	91,705	0.364	0.395	0.240	92	36,223
316	(b)	b	Performing additional drilling for rock anchors in powerplant chamber		drill	drill	1	lump sum	1,285	1,285	0.364	0.395	0.240	1	508
329	(o)	b	Drilling and tapping power receptacle		drill	drill	1	lump sum	14	14	0.364	0.395	0.240	0	6
337	(a)	b	Order for Changes No. 24Performing corrective work on left side tra		drill	drill	1	lump sum	188	188	0.364	0.395	0.240	0	74
381	20	c	Drilling holes for anchor bars and grouting bars in place		drill	drill	1,589	lin ft	2.5	3,973	0.364	0.395	0.240	4	1,569
393	32	c	Drilling 3-inch-diameter holes in reinforced concrete		drill	drill	34	lin ft	20	680	0.364	0.395	0.240	1	269
717	(a)	c	Order for Changes No1 : Drilling holes and injecting asphalt into left a		drill	drill	100%	lump sum	$67,640.57	67,641	0.364	0.395	0.240	68	26,718
1	2	b	Removal of unstable rock from canyon walls		exc	exc	3,095	yd3	18	55,717	0.341	0.436	0.223	0	24,293
2	3	b	Excavation. common. in open cut rock dam. stilling basin, and weir		exc	exc	135,155	yd3	1	135,155	0.341	0.436	0.223	0	58,928
3	4	b	Excavation. rock. in open cut for dam. stilling basin. and weir		exc	exc	22,675	yd3	30	680,250	0.341	0.436	0.223	0	296,589
4	5	b	Excavation. common. in open cut for penstock intake structure		exc	exc	1,866	yd3	2	3,172	0.341	0.436	0.223	0	1,383
5	6	b	Excavation. rock. in open cut for penstock inisLB structure		exc	exc	19,185	yd3	4	76,740	0.341	0.436	0.223	0	33,459
6	7	b	Excavation. all classes. in open cut far powerplant appurtensnces		exc	exc	144,419	yd3	3	397,152	0.341	0.436	0.223	0	173,158
7	8	b	Excavation. all classes. for channel improvement		exc	exc	23,534	yd3	2	42,541	0.341	0.436	0.223	0	18,548
9	10	b	Excavation. all classes. far access. cable. and ventilation tunnels		exc	exc	3,542	yd3	23	81,466	0.341	0.436	0.223	0	35,519
10	11	b	Excavation. all classes. for drain tube tunnels		exc	exc	9,897	yd3	15	143,507	0.341	0.436	0.223	0	62,569
11	12	b	Excavation. all classes for penstock funnels		exc	exc	9,183	yd3	29	266,307	0.341	0.436	0.223	0	116,110
12	13	b	Excavation. all classes. for foundation tunnels		exc	exc	2,307	yd3	46	106,122	0.341	0.436	0.223	0	46,269
13	14	b	Excavation. all classes. for powerplant. above elevation 6820.00		exc	exc	7,135	yd3	14	99,894	0.341	0.436	0.223	0	43,554
14	15	b	Excavation. all classes. for powerplant, below elevation 6820.00		exc	exc	35,825	yd3	17	623,438	0.341	0.436	0.223	0	271,819
160	166	b	Excavation. al classes. for roadway		exc	exc	242,171	yd3	3	726,513	0.341	0.436	0.223	0	316,760
162	168	b	Excavation, common, for structures		exc	exc	3,179	yd3	2	6,358	0.341	0.436	0.223	0	2,772
163	169	b	Excavation. rock. for structures		exc	exc	298	yd3	6	1,643	0.341	0.436	0.223	0	717
181	a	b	Order for Changes No 1 Diversion and care of river during construc		exc	exc	1	lump sum	1,272,239	1,272,239	0.341	0.436	0.223	0	554,696
184	d	b	Excavating exploratory tunnels in dam abutments		exc	exc	510	yd3	108	55,177	0.341	0.436	0.223	0	24,057
200	e	b	Excavating, hauling. and placing impervious material in upstream coffe		exc	exc	899	yd3	2	1,492	0.341	0.436	0.223	0	651
202	g	b	Excavating and removing materials required to be placed in cofferdar		exc	exc	1,798	yd3	2	2,912	0.341	0.436	0.223	0	1,270
203	h	b	excavating an additional 75 feet of grouting and drainage tunnel in l		exc	exc	178	yd3	83	14,774	0.341	0.436	0.223	0	6,441
209	a	b	Order for changes No 5 Excavating ventilation adit and shaft		exc	exc	65	yd3	146	9,519	0.341	0.436	0.223	0	4,150
244	a	b	Order for Changes No 9 Excavating the power plant drainage tunnel		exc	exc	1	lump sum	81,172	81,172	0.341	0.436	0.223	0	35,391
248	c	b	Performing rock excavation in left key way at elevation 70250		exc	exc	1	lump sum	3,662	3,662	0.341	0.436	0.223	0	1,597
261	(d)	b	Performing excavation for retaining wall between stations 5+13 and		exc	exc	1	lump sum	5,307	5,307	0.341	0.436	0.223	0	2,314
262	(e)	b	Performing additional excavation in downstream comers of power pla		exc	exc	1	lump sum	1,145	1,145	0.341	0.436	0.223	0	499
270	(g)	b	Performing structure excavation for drop structure		exc	exc	5,189	yd3	1	3,372	0.341	0.436	0.223	0	1,470
273	(j)	b	Furnishing and placing riprap for drop structure		exc	exc	295	yd3	3	914	0.496	0.199	0.305	0	182
274	(k)	b	Performing river channel diversion for drop structure		exc	exc	1	lump sum	240	240	0.341	0.436	0.223	0	105
275	(o)	b	Performing additional excavation in left abutment area of stilling basin		exc	exc	1	lump sum	541	541	0.341	0.436	0.223	0	236
277	(b)	b	Removing part of cut-and-cover section of diversion tunnel		exc	exc	1	lump sum	6,786	6,786	0.341	0.436	0.223	0	2,959
286	(d)	b	Performing additional cuts in penstock intake structure gantry crane r		exc	exc	1	lump sum	105	105	0.341	0.436	0.223	0	46
289	(g)	b	As an adjustment for underrun in quantity under schedule item 9		exc	exc	1	lump sum	3,731	3,731	0.341	0.436	0.223	0	1,627
332	(a)	b	Order for Changes No. 23 As an adjustment in compensation for the		exc	exc	1	lump sum	1,886,888	1,886,888	0.341	0.436	0.223	0	822,683
336	(e)	b	For the cost increase in performing the penstock shaft excavation be		exc	exc	1	lump sum	289,678	289,678	0.341	0.436	0.223	0	126,300
362	1	c	Excavation, common for entrance and visitor facilities		exc	exc	2,046.90	yd3	$3.65	7,417	0.341	0.436	0.223	0	3,234
363	2	c	Excavation, rock, for entrance and visitor facilities		exc	exc	883.5	yd3	18.5	16,345	0.341	0.436	0.223	0	7,126
364	3	c	Excavation, all classes for switchyard structures		exc	exc	435	yd3	5.6	2,436	0.341	0.436	0.223	0	1,062
365	4	c	Excavation from borrow for switchyard embankments		exc	exc	737	yd3	3	2,211	0.341	0.436	0.223	0	964
369	8	c	Compacting switchyard embankments		exc	exc	1,115	yd3	3.5	3,903	0.496	0.199	0.305	0	777
370	9	c	Removal of unstable rock from canyon walls		exc	exc	380	yd3	42	15,960	0.341	0.436	0.223	0	6,959
375	14	c	Furnishing and erecting rock deflector fence		exc	exc	265.8	lin ft	17	4,519	0.341	0.436	0.223	0	1,970
628	251	c	Excavation common for substation structures		exc	exc	1019.4	yd3	$4.00	4,078	0.341	0.436	0.223	0	1,778
677	301	c	Excavation, common, for transmission line tov t		exc	exc	200	yd3	4.5	900	0.341	0.436	0.223	0	392
25	27	b	Mobilization and demobilization for drilling and grouting		labor	labor	1	lump sum	18,100	18,100				18,100	0
113	116	b	Testing crane		labor	labor	1	lump sum	9,500	9,500				9,500	0
216	h	b	mobilizing and demobilizing grouting equipment for grouting cable tunr		labor	labor	1	lump sum	150	150				150	0
232	g	b	For shortening power plant chamber		labor	labor	1	lump sum	19,924	19,924				19,924	0
268	(e)	b	Performing corrective work on Government-furnished 3.5- by 4.0-foo		labor	labor	1	lump sum	405	405				405	0
269	(f)	b	Performing additional sandblasting on Government furnished outlet wo		labor	labor	1	lump sum	126	126				126	0
271	(h)	b	Erecting Government-furnished bin wall for drop structure		labor	labor	3,440	ft2	4	13,932				13,932	0

APPENDIX A Material Inputs to the Morrow Point Dam 12 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
295	(d)	b	Performing corrective work on ladders for spillway fixedwheel gates		labor	labor	1	lump sum	271	271				271	0
301	(j)	b	Cutting bearing plates for hoists of 13.5- by 16.07-foot fixed-whee		labor	labor	1	lump sum	106	106				106	0
305	a)	b	Order for Changes No. 20 As an adjustment for overrun quantity ur		labor	labor	1	lump sum	33,481	33,481				33,481	0
315	(a)	b	Order for Changes No. 22 As an adjustment for aesthetic changes i		labor	labor	1	lump sum	1,207	1,207				1,207	0
325	(k)	b	As an adjustment for closure of access to powerplant		labor	labor	1	lump sum	1,285	1,285				1,285	0
326	(l)	b	Performing corrective wiring on control cabinets for the 13.5by 16.		labor	labor	1	lump sum	225	225				225	0
327	(m)	b	Furnishing labor to aid Government personnel in photographing of ligh		labor	labor	1	lump sum	9	9				9	0
335	(d)	b	As an adjustment for increases in cost due to design changes in spill		labor	labor	1	lump sum	137,508	137,508				137,508	0
338	(b)	b	Furnishing labor and equipment to aid Government personnel during i		labor	labor	1	lump sum	1,516	1,516				1,516	0
339	(c)	b	Performing corrective work on seals for 15- by 16.83-foot fixed-wh		labor	labor	1	lump sum	619	619				619	0
340	(d)	b	Performing corrective work on seals for 13.5- by 16.07-foot fixed-w		labor	labor	1	lump sum	1,021	1,021				1,021	0
341	(e)	b	Performing corrective work on guide pin plates for spillway gate hois		labor	labor	1	lump sum	56	56				56	0
342	(f)	b	Performing corrective work on defective eccentric pins for penstock		labor	labor	1	lump sum	596	596				596	0
343	(g)	b	Repairing hanger stud for outlet works tandem gate hoist		labor	labor	1	lump sum	2,635	2,635				2,635	0
346	(j)	b	Repairing coupling between motor and pump for tandem outlet gate		labor	labor	1	lump sum	85	85				85	0
347	(k)	b	Pressure testing ~Q-inch stainless steel filling and vent lines for outle		labor	labor	1	lump sum	59	59				59	0
348	(l)	b	Repairing hanger stud and upper cylinder head of hoist for penstock f		labor	labor	1	lump sum	1,325	1,325				1,325	0
349	(m)	b	Rotating lower cylinder head of both penstock fixed-wheel gate hoist		labor	labor	1	lump sum	146	146				146	0
354	(r)	b	Thawing outlet works piezometer line		labor	labor	1	lump sum	492	492				492	0
544	183	c	Making electrical connections of equipment installed by others		labor	labor	100%	lump sum	6.000.00	6,000				6,000	0
545	184	c	Making additions and revisions of wiring and devices on electrical equ		labor	labor	286	hour	12.5	3,575				3,575	0
546	185	c	Making panel cutouts for mounting equipment on station-service cont		labor	labor	85.6	lin ft	3	257				257	0
614	C.	c	Furnishing pumping services		labor	labor	444	days	170	75,480				75,480	0
668	292	c	Removing electrical equipment and materials in existing substation		labor	labor	100%	lump sum	1.000.00	1,000				1,000	0
689	313	c	Performing work required for removing three s	t	labor	labor	100%	lump sum	19.500.00	19,500				19,500	0
692	316	c	Installing materials for second and third spans	t	labor	labor	0	lump sum	4.000.00	40,000				40,000	0
722	(e)	c	Clearing Morrow Point-Curecanti, 230-kilovolt	t	labor	labor	100%	lump sum	1.593.64	1,594				1,594	0
723	(f)	c	Cleaning and greasing cables on 250-ton overhead crane		labor	labor	100%	lump sum	3,003.20	3,003				3,003	0
725	(h)	c	Repairing 250-ton overhead crane		labor	labor	100%	lump sum	122.51	123				123	0
728	(a)	c	aOrder for Changes No3: Increasing interrupting ratings of molded ca		labor	labor	100%	lump sum	$1,926.25	1,926				1,926	0
729	(b)	c	As an adjustment for revising the water collection system for powerp		labor	labor	100%	lump sum	1,000.00	1,000				1,000	0
730	(c)	c	Furnishing labor to assist in transporting and handling test weights		labor	labor	100%	lump sum	2,118.99	2,119				2,119	0
733	(f)	c	Modifying stress cones on 15 kilovolt potheads100%		labor	labor	100%	lump sum	563.45	563				563	0
734	(g)	c	Fabricating and installing support for 15-kilovolt potheads' 100%		labor	labor	100%	lump sum	21.16	21				21	0
735	(h)	c	Furnishing and installing additional flanges, modifying oil piping to gov		labor	labor	100%	lump sum	1.183.64	1,184				1,184	0
736	(i)	c	Reversing doors on governor actuator cabinets		labor	labor	100%	lump sum	117.63	118				118	0
737	(i)	c	Repairing damage to paint on governor actuator tanks		labor	labor	100%	lump sum	635	635				635	0
739	(l)	c	Repairing cribbing over steel supports in cable tunnel		labor	labor	100%	lump sum	273.91	274				274	0
740	(m)	c	Modifying caulking ring for a-line tunnel drain		labor	labor	100%	lump sum	67.58	68				68	0
743	Pa)	c	Government in inspection of shipping damage to high-voltage bushing		labor	labor	100%	lump sum	140.19	140				140	0
744	(q)	c	Assisting Government in testing 13.8-kilovolt 3/c No.1 underground		labor	labor	100%	lump sum	130.33	130				130	0
745	(r)	c	Repairing coupling and checking alinement on motor- generators for		labor	labor	100%	lump sum	464.32	464				464	0
746	(a)	c	Order for Changes No4: Repairing damaged concrete around handra		labor	labor	100%	lump sum	$2,844.40	2,844				2,844	0
747	(b)	c	As an adjustment for performing groove-weld tests in lieu of fillet-we		labor	labor	100%	lump sum	353.22	353				353	0
748	(c)	c	Modifying support for check valve on water supply piping		labor	labor	100%	lump sum	210	210				210	0
751	(f)	c	Cleaning calcium carbonate s deposits from formed drains in dam		labor	labor	100%	lump sum	2,808.92	2,809				2,809	0
754	(a)	c	Order for Changes No5: Cleaning turbine grease pumps		labor	labor	100%	lump sum	73.93	74				74	0
755	(b)	c	Installing additional equipment X mounting pads		labor	labor	100%	lump sum	439.78	440				440	0
758	(e)	c	Replacing two one-quarter bends in sewer line for visitor facilities wit		labor	labor	100%	lump sum	219.9	220				220	0
759	(f)	c	Removing a buried reinforced concrete pad and foundation from high		labor	labor	100%	lump sum	1.259.19	1,259				1,259	0
764	(k)	c	Removing broken strands from posttensioned tendon No.5100%		labor	labor	100%	lump sum	420.8	421				421	0
769	(d)	c	Cleaning and unplugging floor drain in powerplant pump room		labor	labor	100%	lump sum	2.450.19	2,450				2,450	0
770	(e)	c	Modifying 12-inch turbine vent piping 100%		labor	labor	100%	lump sum	773.95	774				774	0
771	(f)	c	Removing and cleaning form material in keyways and blockouts100%		labor	labor	100%	lump sum	255.43	255				255	0
774	(i)	c	Removing and cleaning up debris under unit 2 penstock100%		labor	labor	100%	lump sum	219.25	219				219	0
775	(i)	c	Repairing a damaged and embedded piezometer coupling in unit 1 pe		labor	labor	100%	lump sum	57.95	58				58	0
776	(k)	c	Repairing damaged areas of paint on unit 1 penstock100%		labor	labor	100%	lump sum	369.59	370				370	0
777	(l)	c	Revising stops on 250-ton traveling crane		labor	labor	100%	lump sum	168.9	169				169	0
786	(b)	c	Disassembling, cleaning and reassembling 4-inch gate valve, and inst		labor	labor	100%	lump sum	170.36	170				170	0
788	(d)	c	Modifying support for transformer fire protection waterline		labor	labor	100%	lump sum	55.71	56				56	0
790	(f)	c	Lowering weather doors onto spillways		labor	labor	100%	lump sum	268.08	268				268	0
791	(g)	c	Cleaning and removing debris from a-line drainage tunnel		labor	labor	100%	lump sum	165.38	165				165	0
794	(i)	c	Changing location of control valves on generator carbon dioxide syst		labor	labor	100%	lump sum	157.93	158				158	0
795	(k)	c	Unwatering spiral case		labor	labor	100%	lump sum	92.54	93				93	0
796	(l)	c	Resetting clearance on 375 cubic-foot-per minute air compressor and		labor	labor	100%	lump sum	202.66	203				203	0
797	(m)	c	Modifying 1.5-inch service air line		labor	labor	100%	lump sum	36.37	36				36	0

APPENDIX A Material Inputs to the Morrow Point Dam 13 of 13

count	line	appndx	Pay Item	type	SIC	BEA	Volume	Unit	Unit Cost	Total Cost	% Labor	%Equip	% Profit	Adjusted Total	Truck
798	(n)	c	Modifying holes for ground cable in unit 1 switchgear100%		labor	labor	100%	lump sum	10.42	10				10	0
799	(a)	c	existing type 3A structure at station 11 + 11.	t	labor	labor	100%	lump sum	2,971.45	2,971				2,971	0
800	(P)	c	Relocate guys on structure at station 7+56.7	t	labor	labor	100%	lump sum	1,106.04	1,106				1,106	0
801	(q)	c	Furnishing and installing six height adaptors on pedestal insulators f		labor	labor	100%	lump sum	170.66	171				171	0
802	(r)	c	Relocating temperature relay for 65-cubic-foot-per-minute compress		labor	labor	100%	lump sum	15.64	16				16	0
804	(a)	c	Order for Changes No8: Relocating a section of 8-inch turbine pit dra		labor	labor	100%	lump sum	$62.98	63				63	0
805	(b)	c	Repositioning power transformer		labor	labor	100%	lump sum	111.1	111				111	0
806	(c)	c	Cleaning concrete from handrail blockouts100%		labor	labor	100%	lump sum	239.21	239				239	0
807	(d)	c	Repairing overhead rolling door		labor	labor	100%	lump sum	3,521.68	3,522				3,522	0
809	(f)	c	Assisting Government in moving electrical test equipment		labor	labor	100%	lump sum	75.89	76				76	0
810	(g)	c	Leveling and turning flanges on turbine and draft tube vent piping		labor	labor	100%	lump sum	183.72	184				184	0
822	(a)	c	Order for Changes No9: Repairing and cleaning hoist block, brakes,		labor	labor	100%	lump sum	$271.22	271				271	0
823	(b)	c	Modifying transformer and generator cooling water piping		labor	labor	100%	lump sum	272.57	273				273	0
824	(c)	c	Performing miscellaneous work on electrical systems		labor	labor	100%	lump sum	$ 1,618.66	1,619				1,619	0
826	(e)	c	Bundling and wrapping control cable in high-voltage cable trench		labor	labor	100%	lump sum	330.87	331				331	0
827	(f)	c	Installing temporary power to penstock fixed-wheel gates		labor	labor	100%	lump sum	250.21	250				250	0
828	(g)	c	Cleaning out drains in dam and powerplant		labor	labor	100%	lump sum	594.38	594				594	0
830	(i)	c	Inspecting and testing spare cooler for A-phase transformer		labor	labor	100%	lump sum	557.84	558				558	0
831	(j)	c	Repairing, bushing, and chipping first-stage concrete		labor	labor	100%	lump sum	187.04	187				187	0
832	(k)	c	Modifying and repairing miscellaneous metal work		labor	labor	100%	lump sum	752.03	752				752	0
835	(n)	c	Assisting Government with inspection of stilling basin		labor	labor	100%	lump sum	509.76	510				510	0
837	(P)	c	Installing temporary controls in outlet gate control cabinet		labor	labor	100%	lump sum	173.84	174				174	0
839	(r)	c	Constructing ventilation slots in generator foundations		labor	labor	100%	lump sum	4,335.19	4,335				4,335	0
840	(s)	c	Constructing gutters in existing concrete		labor	labor	100%	lump sum	295.91	296				296	0
841	(t)	c	Chipping out concrete to clear irrigation waterline		labor	labor	100%	lump sum	404.4	404				404	0
843	(v)	c	Pressure testing embedded gravity drainage, unwatering and vent pip		labor	labor	100%	lump sum	3.993.91	3,994				3,994	0
126	129	b	resting and storing stop logs		storage	storage	1	lump sum	20,000	20,000				20,000	0
172	178	b	Dismantling and storing county bridges #3 and 4		storage	storage	1	lump sum	19,400	19,400				19,400	0
242	g	b	Furnishing and delivering to Government storage area the obsolete fr		storage	storage	1	lump sum	16	16				16	0
356		b	Payment for increase in State Sales Tax (6-1-65 to 12-31-65)		tax	tax				5,614				5,614	0
357		b	Payment for increase in State Use Tax (6-1 -6 5 to		tax	tax				900				900	0
358		b	Payment for increase in State Sales Tax(1-1-66 to 12-31-66)		tax	tax				8,417				8,417	0
359		b	Payment for increase in State Sales Tax(1-1-67 to 12-31-67)		tax	tax				3,246				3,246	0
161	167	b	Watering		water	water	309	M gal	2	650				650	0
368	7	c	Water for flooding switchyard site		water	water	3.62	M gal	3	10,860				10,860	0
360		b	Payment for increase in forming galleries, adits, shafts, and chambers within mass concrete of				8,332	ft	2	15,415				15,415	0
361		b	Back Charges to Contractor							-5,427				-5,427	0
548	187	c	Installing hydraulic board CCB				100%	lump sum	1,800.00	1,800	0.297208267		0.217912791	873	0
549	188	c	Installing unit gauge boards H1A and H2A				100%	lump sum	1,600.00	1,600	0.297208267		0.217912791	776	0
580	219	c	Furnishing and installing pedestal insulators, technical reference No.415				15	each	100	1,500	0.297208267		0.217912791	727	0
615	D	c	Furnishing and instating water collection system and ladder safety cage				100%	lump sum	4.800.00	4,800	0.297208267		0.217912791	2,327	0
616	E	c	Furnishing and installing mechanically held contactor in cable gallery and cable tunnel				1	each	210	210	0.297208267		0.217912791	102	0
647	271	c	Furnishing and installing all materials for grounding system additions				797	lb	3	2,391	0.297208267		0.217912791	1,159	0
661	285	c	Installing 230-kilovolt 3-pole, manually gang-operated air switch with 3-pole manually gang-ope				0	0	0	0	0.297208267		0.217912791	0	0
779	(n)	c	Reduction in contract price because motors furnished under schedule items 52 and 53 did not				100%	lump sum	-55	-55	0.297208267		0.217912791	-27	0
803	(s)	c	As an adjustment under the contract for additional costs incurred by reason of interference by				100%	lump sum	$2,877.15	2,877	0.297208267		0.217912791	1,395	0
834	(m)	c	As an equitable adjustment for increased costs of installing acoustical ceiling				100%	lump sum	388.7	389	0.297208267		0.217912791	188	0
842	(u)	c	As an adjustment under the contract for increased costs of cutting, fitting, and Lining isolated-				100%	lump sum	15,538.00	15,538	0.297208267		0.217912791	7,534	0
845	(a)	c	Order for Changes No10: For increased costs caused by disruptions and delays due to Gove				100%	lump sum	$141.043.07	141,043				141,043	0
846	(b)	c	For increases in cost due to increases in 1971 wage scales				100%	lump sum	29,991.07	29,991				29,991	0
847	(c)	c	For increases in cost in completion of part 6 due to disruption caused by faulty adhesive spe				100%	lump sum	$16.771.90	16,772				16,772	0
848	(a)	c	Order for Changes No11: As an adjustment for increased overhead and profit for work under				100%	lump sum	1.671.61	1,672				1,672	0
849	(b)	c	As an adjustment for payment of the remaining portion of the isolated-phase bus work for whic				100%	lump sum	27,009.06	27,009				27,009	0
850	(c)	c	As an adjustment for increased overhead and profit for work under Order for Changes No.9 (U				100%	lump sum	2,022.29	2,022				2,022	0
851	(d)	c	As an adjustment for a portion of the increased costs of removing mineral deposits				100%	lump sum	10,000.00	10,000				10,000	0
852	(e)	c	For furnishing one additional spare pothead				100%	lump sum	6,849.38	6,849				6,849	0
853		c							Subtotal	11,509,561				11,509,561	0
854		c	Plus:							7,002				7,002	0
855		c	Contractor operation of crane for Government in accordance with paragraph 53							7,726				7,726	0
856		c	Total-For Completion Contract							3,447,376					3,709,408

APPENDIX B Federal Energy Regulatory Commission Database 1 OF5

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
2441	453	CT	GREENVILLE	LOW	SHETUCKET RIVER	1888	15	453	65,630	410	15	10.671625	66935	TC	373	80	1264
2576	3120	CT	BULLS BRIDGE	SIGNIFICANT	HOUSATONIC RIVER	1902	22	3120	49,059	203	22	10.98505	45000	CNPG	1800	120	784
2576	3120	CT	SPOONER	SIGNIFICANT	HOUSATONIC RIVER	1902	20	3120	33,994	156	20	10.8955	45000	ERCN	1800	120	784
2576	3120	CT	BULLS BRIDGE CANAL SPIL	SIGNIFICANT	HOUSATONIC RIVER	1902	22	3120	49,059	203	22	10.98505	2000	PG	1800	120	
2576	3120	CT	BULLS BRIDGE MOUNTAINS	SIGNIFICANT	HOUSATONIC RIVER	1902	22	3120	49,059	203	22	10.98505	150	PGMS	1800	120	
2576	218650	CT	ROCKY RIVER CANAL DIKE	HIGH	ROCKY RIVER	1902	20	218650	10,896	50	20	10.8955		RE	172000	5600	
2576	3120	CT	BULLS BRIDGE FOREBAY D	SIGNIFICANT	HOUSATONIC RIVER	1903	39	3120	121,397	265	39	11.746225	1250	RE	1800	120	784
2576	37200	CT	STEVENSON	HIGH	HOUSATONIC RIVER	1919	83	37200	1,423,069	1250	83	13.716325	70000	CNPG	26900	1063	1542
2576	218650	CT	ROCKY RIVER MAIN DAM	HIGH	ROCKY RIVER	1929	100	218650	1,378,256	952	100	14.4775		RE	172000	5600	40
2576	218650	CT	NORTH LANESVILLE DIKE	HIGH	ROCKY RIVER	1929	7	218650	13,067	181	7	10.313425		CNPG	172000	5600	40
2576	218650	CT	MIDDLE LANESVILLE DIKE	HIGH	ROCKY RIVER	1929	45	218650	90,292	167	45	12.014875		RE	172000	5600	40
2576	218650	CT	SOUTH LANESVILLE DIKE	HIGH	ROCKY RIVER	1929	17	218650	71,530	391	17	10.761175		CNPG	172000	5600	40
2576	218650	CT	DANBURY DIKE NO. 1	HIGH	ROCKY RIVER	1929	42	218650	435,612	873	42	11.88055		RE	172000	5600	40
2576	86100	CT	SHEPAUG	HIGH	HOUSATONIC RIVER	1955	140	86100	3,215,957	1412	140	16.2685	180000	CNPG	74000	1870	1391
2576	218650	CT	DANBURY DIKE NO. 2	HIGH	HOUSATONIC RIVER	1989	7	218650	9,385	130	7	10.313425		RE	172000	5600	
2597	3100	CT	FALLS VILLAGE	SIGNIFICANT	HOUSATONIC RIVER	1913	16	3100	54,868	320	16	10.7164	38000	CNPG	1135	100	634
2662	2000	CT	SCOTLAND	HIGH	SHETUCKET RIVER	1909	37	2000	207,454	481	37	11.656675	60000	CBCNPG	1300	134	429
3472	3480	CT	WYRE - WYND	LOW	QUINEBAUG RIVER	1913	14	3480	71,859	483	14	10.62685	46000	MSCNPG	2900	246	650
5062	340	CT	QUINEBAUG	LOW	QUINEBAUG RIVER	1855	14	340	37,194	250	14	10.62685	3640	MSPG	283	85	384
5062	312	CT	FIVE MILE POND	SIGNIFICANT	FIVE MILE RIVER	1855	17	312	26,526	145	17	10.761175	5283	MSPG	260	65	77
6066	4400	CT	LAKE HOUSATONIC	HIGH	HOUSATONIC RIVER	1870	25	4400	236,287	850	25	11.119375	160000	MSCNPG	4020	320	1574
6066	4400	CT	DERBY DIKE	LOW	HOUSATONIC RIVER	1870	10	4400	41,791	400	10	10.44775		RE	4020	320	1574
6066	4400	CT	DERBY CANAL WEIR	LOW	HOUSATONIC RIVER	1870	10	4400	6,269	60	10	10.44775	500	CNPG	4020	320	1574
6066	4400	CT	SHELTON CANAL DIKE	LOW	HOUSATONIC RIVER	1870	25	4400	489,253	1760	25	11.119375	448	RE	4020	320	25
11143	258	CT	BRUNSWICK	LOW	MOOSUP RIVER	1891	19	258	32,986	160	19	10.850725	3960	MSPG	215	43	77
11168	110	CT	DAYVILLE DIKE	LOW	FIVE MILE RIVER	1925	14	110	297,552	2000	14	10.62685		RE	93	31	
11168	110	CT	DAYVILLE EMERGENCY SPI	LOW	FIVE MILE RIVER	1925	8	110	3,066	37	8	10.3582		MSCN	93	31	
11168	110	CT	DAYVILLE WASTEWAY	LOW	FIVE MILE RIVER	1925	14	110	3,868	26	14	10.62685		STMS	93	31	
11547		CT	HALE	LOW	QUINEBAUG RIVER	1965	23	65	25,369	100	23	11.029825		OTCNPG	65	13	289
1889	28000	MA	TURNERS FALLS DIKE	LOW	CONNECTICUT CANAL	1905	10	28000	52,239	500	10	10.44775	15000	RE	16600	2000	7163
1889	28000	MA	MONTAGUE	SIGNIFICANT	CONNECTICUT RIVER	1915	62	28000	499,033	630	62	12.77605	280000	CNPG	16600	2000	7163
1889	28000	MA	CABOT SPILLWAY	LOW	CONNECTICUT CANAL	1915	35	28000	68,015	168	35	11.567125	15000	CNPG	16600	2000	7163
1889	28000	MA	CABOT STATION	LOW	CONNECTICUT CANAL	1916	35	28000	95,140	235	35	11.567125		PGMS	16600	2000	
1889	28000	MA	GILL	SIGNIFICANT	CONNECTICUT RIVER	1970	70	28000	453,263	493	70	13.13425	280000	CNPG	16600	2000	7163
2004	68900	MA	OVERFLOW NO. 1	LOW	CONNECTICUT RIVER	1850	30	68900	283,808	834	30	11.34325	3364	MSPGRE	26000	2550	
2004	68900	MA	OVERFLOW NO. 2	LOW	HOLYOKE CANAL	1860	20	68900	21,791	100	20	10.8955	2615	MSPG	26000	2550	8309
2004	68900	MA	OVERFLOW NO. 3	LOW	HOLYOKE CANAL	1860	18	68900	20,812	107	18	10.80595	1935	MSPG	26000	2550	8309
2004	68900	MA	OVERFLOW NO. 4	LOW	HOLYOKE CANAL	1891	26	68900	43,540	150	26	11.16415	950	MSPG	26000	2550	8309
2004	68900	MA	HOLYOKE DAM	HIGH	CONNECTICUT RIVER	1900	30	68900	347,103	1020	30	11.34325	300000	MSPG	26000	2550	8309
2004	68900	MA	CANAL GATE HOUSE	SIGNIFICANT	CONNECTICUT RIVER	1900	36	68900	75,245	180	36	11.6119		MS	26000	2550	
2323	818	MA	DEERFIELD NO. 5 - CANAL	LOW	DEERFIELD RIVER	1910	39	818	3,060,585	6681	39	11.746225		RE	248	38	237
2323	818	MA	DEERFIELD NO. 5 - CANAL	LOW	DEERFIELD RIVER	1910	33	818	541,627	1430	33	11.477575		RE	248	38	237
2323	818	MA	DEERFIELD NO. 5 - CANAL	LOW	DEERFIELD RIVER	1910	16	818	332,466	1939	16	10.7164		RE	248	38	237
2323	551	MA	DEERFIELD NO. 3	LOW	DEERFIELD RIVER	1912	21	551	109,129	475	21	10.940275	23300	CNPG	221	42	500
2323	551	MA	DEERFIELD NO. 3 - FOREBA	LOW	DEERFIELD RIVER	1912	23	551	253,686	1000	23	11.029825		RE	221	42	500
2323	1067	MA	DEERFIELD NO. 4	LOW	DEERFIELD RIVER	1912	48	1067	297,412	510	48	12.1492	19100	CNPGRE	467	75	404
2323	1067	MA	DEERFIELD NO. 4 - FOREBA	LOW	DEERFIELD RIVER	1912	20	1067	137,283	630	20	10.8955		RE	467	75	404
2323	589	MA	DEERFIELD NO. 2	SIGNIFICANT	DEERFIELD RIVER	1913	76	589	455,323	447	76	13.4029	31200	CNPG	350	63	508
2323	5480	MA	SHERMAN	HIGH	DEERFIELD RIVER	1927	110	5480	1,669,688	1017	110	14.92525	87000	RECNPG	3593	218	236
2323	818	MA	DEERFIELD NO. 5	LOW	DEERFIELD RIVER	1992	43	818	77,431	151	43	11.925325	35800	CNPG	248	38	237
2323	818	MA	DEERFIELD NO. 5 - DUNBA	LOW	DUNBAR BROOK	1993	29	818	52,425	160	29	11.298475	6800	CNPG	248	38	11
2334	510	MA	GARDNERS FALLS	LOW	DEERFIELD RIVER	1904	37	510	145,347	337	37	11.656675	65250	CNPG	50	21	501
2485	21500	MA	NORTHFIELD MOUNTAIN	HIGH	CONNECTICUT RIVER	1972	144	21500	26,526,689	11200	144	16.4476		ERRE	17240	278	1
2485	21500	MA	NORTHFIELD MT. - UPPER	LOW	CONNECTICUT RIVER	1972	9	21500	51,588	551	9	10.402975	11400	CNPG	17240	278	1

APPENDIX B Federal Energy Regulatory Commission Database 2 OF5

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
2485	21500	MA	NORTHFIELD MT. - UPPER	HIGH	CONNECTICUT RIVER	1973	20	21500	107,430	493	20	10.8955		CNPG	17240	278	1
2608	200	MA	WEST SPRINGFIELD	LOW	WESTFIELD RIVER	1840	18	200	106,979	550	18	10.80595	4800	TCCN	200	20	512
2631	2565	MA	WORONOCO	LOW	WESTFIELD RIVER	1938	53	2565	967,265	1475	53	12.373075	210000	CNPGRE	1830	46	346
2669	6800	MA	BEAR SWAMP - NORTH DIK	LOW	DEERFIELD RIVER	1974	155	6800	3,602,487	1372	155	16.940125	9900	ERRE	5100	118	1
2669	6800	MA	BEAR SWAMP - DIKE 'A'	LOW	DEERFIELD RIVER	1974	23	6800	89,297	352	23	11.029825		ERRE	5100	118	1
2669	6800	MA	BEAR SWAMP - EAST DIKE	HIGH	DEERFIELD RIVER	1974	50	6800	482,819	789	50	12.23875		ERRE	5100	118	1
2669	6800	MA	BEAR SWAMP - SOUTH DIK	HIGH	DEERFIELD RIVER	1974	140	6800	6,292,981	2763	140	16.2685		ERRE	5100	118	1
2669	7580	MA	FIFE BROOK	HIGH	DEERFIELD RIVER	1974	130	7580	1,851,028	900	130	15.82075	84200	ERREPG	5300	152	250
2800	19900	MA	GREAT STONE	LOW	MERRIMACK RIVER	1848	39	19900	431,991	943	39	11.746225	124600	MSPG	18000	655	4460
2801	570	MA	GLENDALE	LOW	HOUSATONIC RIVER	1906	26	570	52,248	180	26	11.16415	9000	PG	87	40	272
2985	50	MA	WILLOW MILL	SIGNIFICANT	HOUSATONIC RIVER	1872	12	50	22,761	180	12	10.5373	10000	MSPG	50	13	244
3127	145	MA	WARE LOWER	LOW	WARE RIVER	1890	18	145	22,563	116	18	10.80595	5770	MSPG	90	10	167
8093	210	MA	METHUEN FALLS	HIGH	SPICKETT RIVER	1895	23	210	47,693	188	23	11.029825	1800	MSPG	210	30	74
9100	173	MA	RIVERDALE MILLS	LOW	BLACKSTONE RIVER	1957	10	173	15,881	152	10	10.44775	5400	CNPG	89	12	142
2142	108000	ME	HARRIS	HIGH	KENNEBEC RIVER	1955	165	108000	5,781,034	2015	165	17.387875	22000	CNPGRE	72250	3666	1355
2194	2000	ME	BAR MILLS	LOW	SACO RIVER	1956	25	2000	111,194	400	25	11.119375	16320	CNPG	600	263	1595
2283	2280	ME	DEER RIPS	LOW	ANDROSCOGGIN RIVER	1903	54	2280	629,660	939	54	12.41785	2000	CNPG	1200	130	2865
2283	56100	ME	GULF ISLAND	HIGH	ANDROSCOGGIN RIVER	1926	99	56100	3,554,953	2488	99	14.432725	50000	CNPGRE	55100	2862	2863
2284	2000	ME	BRUNSWICK	LOW	ANDROSCOGGIN RIVER	1982	42	2000	301,885	605	42	11.88055	20000	CNPG	251	300	3430
2302	2800	ME	BATES WEIR	LOW	LEWISTON CROSS CA	1859	14	2800	10,563	71	14	10.62685	1054	MSPG	1600	200	2901
2302	2800	ME	RED SHOP WEIR	LOW	LEWISTON CROSS CA	1859	18	2800	11,670	60	18	10.80595	1573	MSPG	1600	200	2901
2302	2800	ME	GULLY BROOK LOWER	LOW	LEWISTON CANAL - GU	1859	9	2800	8,426	90	9	10.402975	1200	MSCNPG	1600	200	2901
2302	2800	ME	ANDROSCOGGIN WEIR	LOW	LEWISTON CANAL - GU	1859	9	2800	2,996	32	9	10.402975	480	MSCNPG	1600	200	2901
2302	2800	ME	GREAT STONE	HIGH	ANDROSCOGGIN RIVER	1865	27	2800	289,022	955	27	11.208925	8050	MSCNPG	1600	200	2901
2302	2800	ME	CONTINENTAL WEIR	LOW	LEWISTON CROSS CA	1920	14	2800	4,463	30	14	10.62685	1030	MSPG	1600	200	2901
2312	2244	ME	GREAT WORKS	LOW	PENOBSCOT RIVER	1914	20	2244	236,650	1086	20	10.8955	62200	TCERPG	1600	160	6670
2322	5100	ME	SHAWMUT	LOW	KENNEBEC RIVER	1912	40	5100	698,027	1480	40	11.791	12540	CNPG	5000	1310	4200
2325	22300	ME	WESTON NORTH CHANNEL	LOW	KENNEBEC RIVER	1921	38	22300	235,223	529	38	11.70145	143000	CNPGCB	18600	930	3894
2325	22300	ME	WESTON SOUTH CHANNEL	LOW	KENNEBEC RIVER	1921	51	22300	245,572	392	51	12.283525	51500	CNPGCB	18600	930	3894
2329	255000	ME	WYMAN	HIGH	KENNEBEC RIVER	1930	155	255000	8,018,947	3054	155	16.940125	59630	RECNPG	208910	3240	2619
2333	183	ME	RUMFORD FALLS MIDDLE	LOW	ANDROSCOGGIN RIVER	1892	20	183	93,265	428	20	10.8955	132500	TCER	141	21	2080
2333	3110	ME	RUMFORD FALLS UPPER D	SIGNIFICANT	ANDROSCOGGIN RIVER	1918	40	3110	247,139	524	40	11.791	121900	CNPG	2900	419	2069
2335	6700	ME	WILLIAMS	LOW	KENNEBEC RIVER	1939	45	6700	367,655	680	45	12.014875	48790	RECNPG	4575	446	2720
2364	425	ME	ABENAKI	LOW	KENNEBEC RIVER	1922	25	425	277,984	1000	25	11.119375	126000	CNPG	350	24	3148
2365	14500	ME	ANSON	LOW	KENNEBEC RIVER	1923	38	14500	380,180	855	38	11.70145	90000	CNPG	6000	650	3148
2367	2025	ME	CARIBOU	LOW	AROOSTOOK RIVER	1889	24	2025	133,427	502	24	11.0746	63000	TCERCN	1821	162	1943
2367	29033	ME	MILLINOCKET LAKE	LOW	MILLINOCKET STREAM	1943	11	29033	26,315	228	11	10.492525	2735	TCER	22900	2788	70
2368	89215	ME	SQUA PAN	HIGH	SQUA PAN STREAM	1928	35	89215	236,837	585	35	11.567125	5300	CNCBRE	64000	5043	69
2375	11560	ME	RILEY	LOW	ANDROSCOGGIN RIVER	1897	23	11560	202,949	800	23	11.029825	66000	TCER	3600	578	2440
2375	782	ME	LIVERMORE FALLS	LOW	ANDROSCOGGIN RIVER	1908	12	782	106,595	843	12	10.5373	65000	CNPG	300	46	2490
2375	2331	ME	JAY	LOW	ANDROSCOGGIN RIVER	1912	17	2331	145,803	797	17	10.761175	55000	CNPG	1800	206	2475
2389	25000	ME	EDWARDS	HIGH	KENNEBEC RIVER	1870	42	25000	520,938	1044	42	11.88055	87000	TCER	16985	1143	5550
2403	4800	ME	VEAZIE	LOW	PENOBSCOT RIVER	1913	30	4800	286,530	842	30	11.34325	100500	CNPGCB	3500	390	7800
2458	14520	ME	STONE DAM	HIGH	WEST BRANCH PENOB	1900	27	14520	381,933	1262	27	11.208925	109000	CNPGRE	8100	1344	1890
2458	56290	ME	DOLBY	HIGH	WEST BRANCH PENOB	1906	56	56290	977,078	1395	56	12.5074	75000	CNPGRE	41956	2048	2108
2458	2970	ME	EAST MILLINOCKET	LOW	WEST BRANCH PENOB	1907	24	2970	192,166	723	24	11.0746	75500	CNPGRE	1950	128	2111
2458	87670	ME	MILLINOCKET LAKE	HIGH	MILLINOCKET STREAM	1910	20	87670	138,373	635	20	10.8955	7000	CNPGRE	45370	8640	122
2458	392680	ME	NORTH TWIN	HIGH	WEST BRANCH PENOB	1934	35	392680	425,497	1051	35	11.567125	72000	RECNPG	346000	17790	1877
2519	1663	ME	NORTH GORHAM	HIGH	PRESUMPSCOT RIVER	1901	23	1663	229,078	903	23	11.029825	1320	CNPGMS	1300	98	444
2520	69100	ME	MATTACEUNK	HIGH	PENOBSCOT RIVER	1939	45	69100	632,583	1170	45	12.014875	125000	CNPGRE	55785	1664	3308
2527	33500	ME	SKELTON	HIGH	SACO RIVER	1948	75	33500	1,698,152	1695	75	13.358125	69600	CNPGRE	25250	488	1622
2528	266	ME	WEST CHANNEL DAM	LOW	SACO RIVER	1895	16	266	56,583	330	16	10.7164	2250	MSPG	28	14	1703
2528	2500	ME	SPRINGS	LOW	SACO RIVER	1925	12	2500	34,014	269	12	10.5373	3405	CNPG	711	359	1703
2528	2500	ME	BRADBURY	LOW	SACO RIVER	1929	12	2500	25,922	205	12	10.5373	2060	CNPG	711	359	1703

APPENDIX B Federal Energy Regulatory Commission Database 3 OF5

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
2528	266	ME	CATARACT	LOW	SACO RIVER	1938	49	266	98,588	165	49	12.193975	5625	CNPG	28	14	1703
2529	5440	ME	BONNY EAGLE	SIGNIFICANT	SACO RIVER	1911	67	5440	682,860	784	67	12.999925		CNPGRE	2320	347	1563
2529	5440	ME	NEW RIVER CHANNEL DAM	SIGNIFICANT	SACO RIVER	1911	13	5440	48,148	350	13	10.582075	17000	CNPGOT	2320	347	1563
2530	2530	ME	HIRAM	LOW	SACO RIVER	1917	30	2530	147,009	432	30	11.34325	16475	CNPG	1000	255	832
2531	13200	ME	WEST BUXTON	LOW	SACO RIVER	1907	30	13200	218,811	643	30	11.34325	4930	CNPGRE	12300	131	1572
2534	13300	ME	MILFORD	LOW	PENOBSCOT RIVER	1906	34	13300	548,464	1400	34	11.52235	70265	CNPG	9175	918	5300
2534	13300	ME	GILMAN FALLS	LOW	STILLWATER RIVER	1906	8	13300	39,361	475	8	10.3582	35132	CNPG	9175	918	5300
2552	5500	ME	FORT HALIFAX	LOW	SEBASTICOOK RIVER	1908	29	5500	154,981	473	29	11.298475	46500	CNCBPG	5000	417	946
2555	1440	ME	AUTOMATIC	LOW	MESSALONSKEE STRE	1924	33	1440	30,680	81	33	11.477575	1910	CNPG	900	68	205
2556	750	ME	UNION GAS	LOW	MESSALONSKEE STRE	1924	36	750	143,384	343	36	11.6119	2460	MSPG	600	25	207
2557	1500	ME	RICE RIPS	SIGNIFICANT	MESSALONSKEE STRE	1908	23	1500	55,811	220	23	11.029825	4945	CBPGRE	1000	87	185
2559	110	ME	OAKLAND	LOW	MESSALONSKEE STRE	1901	14	110	17,109	115	14	10.62685	200	CNPG	50	10	178
2559	118300	ME	MESSALONSKEE LAKE	HIGH	MESSALONSKEE STRE	1992	13	118300	22,836	166	13	10.582075	2400	CNPG	110000	3600	177
2572	977000	ME	RIPOGENUS	HIGH	WEST BRANCH PENOB	1916	73	977000	770,042	795	73	13.268575	92800	CNPGRE	710000	29270	1422
2574	1830	ME	LOCKWOOD	LOW	KENNEBEC RIVER	1919	20	1830	196,991	904	20	10.8955	123000	CNPG	600	82	4228
2600	17900	ME	RUN AROUND	LOW	MERRILL BROOK	1894	15	17900	32,015	200	15	10.671625	2000	RE	11250	1125	5100
2600	17900	ME	WEST ENFIELD	LOW	PENOBSCOT RIVER	1988	45	17900	359,004	664	45	12.014875	96000	CNPG	11250	1125	5100
2611	6150	ME	HYDRO - KENNEBEC	LOW	KENNEBEC RIVER	1989	40	6150	400,894	850	40	11.791	667000	CNPG	3900	250	4270
2615	275000	ME	BRASSUA	HIGH	MOOSE RIVER	1927	50	275000	1,094,756	1789	50	12.23875	27000	CNCBRE	207000	9700	722
2618	639580	ME	WEST GRAND LAKE	SIGNIFICANT	WEST BRANCH ST. CR	1836	13	639580	66,720	485	13	10.582075	5450	TCRE	556190	23825	224
2634	26740	ME	CANADA FALLS	LOW	WEST BRANCH PENOB	1921	50	26740	467,520	764	50	12.23875	10060	CNPG	21700	2521	164
2634	159000	ME	SEBOOMOOK	LOW	WEST BRANCH PENOB	1936	60	159000	472,699	621	60	12.6865	45000	CNPGRE	117800	6838	526
2634	40170	ME	RAGGED LAKE	LOW	RAGGED STREAM	1937	30	40170	409,718	1204	30	11.34325	6680	RECNPG	30490	2786	40
2634	103800	ME	CAUCOMGOMOC	LOW	CAUCOMGOMOC STRE	1981	12	103800	339,006	2681	12	10.5373	14750	RECNPG	42516	5728	178
2660	113330	ME	FOREST CITY	LOW	EAST BRANCH ST. CRO	1949	16	113330	85,731	500	16	10.7164		TCRE	105300	16070	138
2666	1980	ME	MEDWAY	LOW	WEST BRANCH PENOB	1922	35	1980	207,688	513	35	11.567125	18700	CNPG	1500	120	2120
2671	1400000	ME	MOOSEHEAD - EAST OUTL	SIGNIFICANT	KENNEBEC RIVER	1835	20	1400000	218,782	1004	20	10.8955	25100	CNPGRE	1080000	74200	1268
2671	1400000	ME	MOOSEHEAD - WEST OUTL	SIGNIFICANT	KENNEBEC RIVER	1835	18	1400000	161,441	830	18	10.80595	3900	CNPGRE	1080000	74200	1268
2710	1300	ME	ORONO	LOW	STILLWATER RIVER	1917	15	1300	188,888	1180	15	10.671625	43500	CNPGCB	812	140	2300
2712	3830	ME	STILLWATER	LOW	STILLWATER RIVER	1902	25	3830	475,909	1712	25	11.119375	25000	CNPG	3040	300	7602
2721	4370	ME	HOWLAND	LOW	PISCATAQUIS RIVER	1916	17	4370	120,740	660	17	10.761175	42525	CNPG	3400	270	1500
2727	3040	ME	ELLSWORTH	HIGH	UNION RIVER	1907	62	3040	298,627	377	62	12.77605	17000	CNCB	2500	125	613
2727	145000	ME	GRAHAM	HIGH	UNION RIVER	1924	43	145000	384,592	750	43	11.925325	19000	CNPGRE	144670	12200	452
2804	1800	ME	MASONS	LOW	GOOSE RIVER	1835	15	1800	13,766	86	15	10.671625		MSPG	1620	70	19
2804	270	ME	KELLY	LOW	GOOSE RIVER	1835	15	270	21,610	135	15	10.671625		MSPG	200	16	18
2804	11270	ME	SWAN LAKE	LOW	GOOSE RIVER	1900	10	11270	26,119	250	10	10.44775	90	CNMSPG	7500	1510	10
2804	82	ME	CMP	LOW	GOOSE RIVER	1908	21	82	53,071	231	21	10.940275		CNPGCB	72	5	19
2808	210	ME	BARKER'S MILL	LOW	LITTLE ANDROSCOGGI	1874	30	210	78,268	230	30	11.34325	9400	CNCBPG	150	12	353
2809	120	ME	AMERICAN TISSUE	HIGH	COBBOSSEECONTEE S	1900	24	120	60,334	227	24	11.0746	5392	MSCNPG	108	3	220
2897	100	ME	SACCARAPPA WEST	LOW	PRESUMPSCOT RIVER	1911	12	100	12,898	102	12	10.5373	10000	CNPG	11	10	569
2897	100	ME	SACCARAPPA EAST	LOW	PRESUMPSCOT RIVER	1911	9	100	20,598	220	9	10.402975	14000	CNPG	11	10	569
2931	1261	ME	GAMBO	LOW	PRESUMPSCOT RIVER	1911	24	1261	93,027	350	24	11.0746	14600	CNPG	1000	71	497
2932	56	ME	MALLISON FALLS	LOW	PRESUMPSCOT RIVER	1900	14	56	42,847	288	14	10.62685	5682	MSCNPG	31	7	503
2942	3337	ME	DUNDEE	HIGH	PRESUMPSCOT RIVER	1913	44	3337	724,191	1375	44	11.9701	22800	CNPGRE	2900	190	443
2984	383990	ME	EEL WEIR	HIGH	PRESUMPSCOT RIVER	1879	23	383990	111,622	440	23	11.029825	29800	MSPGRE	330000	29184	436
3428	2960	ME	WORUMBO	LOW	ANDROSCOGGIN RIVER	1988	17	2960	159,158	870	17	10.761175	136735	TCERPG	1700	180	3370
3562	665	ME	BARKER MILL UPPER	LOW	LITTLE ANDROSCOGGI	1987	24	665	61,132	230	24	11.0746	19900	MSPG	255	41	350
4026	321195	ME	AZISCOHOS	HIGH	MAGALLOWAY RIVER	1911	74	321195	867,951	881	74	13.31335	7746	CBPGRE	221355	8320	214
4026	321195	ME	ABBOTT BROOK DIKE	HIGH	ABBOTT BROOK	1911	27	321195	272,377	900	27	11.208925		RE	221355	8320	214
4202	820	ME	LOWELL TANNERY	LOW	PASSADUMKEAG RIVE	1987	27	820	69,607	230	27	11.208925	9623	CNPG	680	69	301
4784	5191	ME	PEJEPSCOT	LOW	ANDROSCOGGIN RIVER	1896	48	5191	326,570	560	48	12.1492	95000	TCERCN	3278	225	3420
5073	1536	ME	BENTON FALLS	LOW	SEBASTICOOK RIVER	1987	27	1536	151,320	500	27	11.208925	23000	CNPGRE	955	83	860
5362	351	ME	KESSLEN	LOW	MOUSAM RIVER	1954	18	351	27,231	140	18	10.80595	6200	CNPG	224	20	125
5362	240	ME	DANE PERKINS	LOW	MOUSAM RIVER	1979	12	240	8,219	65	12	10.5373	1150	CNPG	150	25	125

APPENDIX B Federal Energy Regulatory Commission Database 4 OF5

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
5362	146	ME	TWINE MILL	LOW	MOUSAM RIVER	1980	18	146	35,011	180	18	10.80595	2400	CNPG	104	12	125
6398	774	ME	HACKETT MILLS	LOW	LITTLE ANDROSCOGGI	1986	8	774	18,230	220	8	10.3582	474	TCERCN	480	60	313
7189	113000	ME	GREEN LAKE	LOW	REEDS BROOK	1911	8	113000	22,622	273	8	10.3582	2500	MSOT	107000	2989	58
8277	2620	ME	OTIS	LOW	ANDROSCOGGIN RIVEF	1898	17	2620	153,670	840	17	10.761175	68000	CNPG	1700	115	2490
9340	145	ME	UPPER KEZAR FALLS #2	LOW	OSSIPEE RIVER	1860	8	145	22,374	270	8	10.3582	16600	TCER	130	10	416
9340	175	ME	LOWER KEZAR FALLS	LOW	OSSIPEE RIVER	1910	9	175	41,196	440	9	10.402975	17180	TCERCN	150	5	417
9340	145	ME	UPPER KEZAR FALLS #1	LOW	OSSIPEE RIVER	1910	11	145	22,622	196	11	10.492525	3360	CNPG	130	10	416
11132	720	ME	EUSTIS	LOW	NORTH BRANCH DEAC	1952	17	720	43,906	240	17	10.761175	11345	CNPGRE	570	74	236
11433	1400	ME	SANDY RIVER	LOW	SANDY RIVER	1902	18	1400	77,803	400	18	10.80595	12000	CNMSPG	1050	150	578
11482	240	ME	MECHANIC FALLS	LOW	LITTLE ANDROSCOGGI	1866	15	240	27,533	172	15	10.671625	1000	MSCNPG	103	27	250
1855	55560	NH	BELLOWS FALLS	LOW	CONNECTICUT RIVER	1907	48	55560	374,973	643	48	12.1492	157600	CNPG	30000	2804	5414
1892	79800	NH	WILDER	HIGH	CONNECTICUT RIVER	1950	59	79800	2,162,999	2900	59	12.641725	213300	CNPGRE	55000	3100	3375
1893	5700	NH	GARVINS FALLS	LOW	MERRIMACK RIVER	1901	18	5700	125,457	645	18	10.80595	113000	MSCNPG	2700	250	2427
1893	8100	NH	AMOSKEAG	LOW	MERRIMACK RIVER	1921	29	8100	352,230	1075	29	11.298475	87000	CNPG	4320	478	2854
1893	4180	NH	HOOKSETT	LOW	MERRIMACK RIVER	1927	11	4180	76,984	667	11	10.492525	78500	MSPG	1650	405	2805
1904	54000	NH	VERNON	LOW	CONNECTICUT RIVER	1909	58	54000	698,476	956	58	12.59695	224700	CNPG	18300	2550	6266
2077	57700	NH	COMERFORD	HIGH	CONNECTICUT RIVER	1930	170	57700	6,745,476	2253	170	17.61175	288200	CNPGRE	46800	1093	1635
2077	14100	NH	MCINDOES	SIGNIFICANT	CONNECTICUT RIVER	1931	25	14100	202,929	730	25	11.119375	138500	CNPG	9800	543	2200
2077	223722	NH	MOORE	HIGH	CONNECTICUT RIVER	1957	144	223722	6,915,887	2920	144	16.4476	211300	CNPGRE	200000	3490	1600
2287	94	NH	J. BRODIE SMITH	HIGH	ANDROSCOGGIN RIVEF	1948	31	94	194,166	550	31	11.368025	56000	CNPG	60	8	1372
2288		NH	GORHAM	LOW	ANDROSCOGGIN RIVEF	1958	20	258	93,701	430	20	10.8955	43000	TCERPG	258	32	1431
2300	2000	NH	SHELBURNE	LOW	ANDROSCOGGIN RIVEF	1906	16	2000	120,195	701	16	10.7164	23000	CNTC	960	210	1494
2311	685	NH	GORHAM	LOW	ANDROSCOGGIN RIVEF	1904	24	685	205,988	775	24	11.0746	47500	TCERRE	370	45	1384
2326	195	NH	CROSS	HIGH	ANDROSCOGGIN RIVEF	1903	30	195	201,796	593	30	11.34325	21000	CNPG	120	22	1350
2327	400	NH	CASCADE	HIGH	ANDROSCOGGIN RIVEF	1903	58	400	425,953	583	58	12.59695	40000	CNPG	200	28	1361
2392	1030	NH	GILMAN	LOW	CONNECTICUT RIVER	1920	30	1030	94,603	278	30	11.34325	3538	PGTCER	705	130	1514
2422	830	NH	SAWMILL	LOW	ANDROSCOGGIN RIVEF	1965	20	830	181,955	835	20	10.8955	33000	CNPG	620	73	1338
2423	95	NH	RIVERSIDE	LOW	ANDROSCOGGIN RIVEF	1970	23	95	209,291	825	23	11.029825	37800	PGTCER	60	7	1338
2456	16000	NH	AYERS ISLAND	SIGNIFICANT	PEMIGEWASSET RIVER	1924	80	16000	759,505	699	80	13.582	72000	CNCB	10000	600	746
2457	9340	NH	EASTMAN FALLS	SIGNIFICANT	PEMIGEWASSET RIVER	1937	37	9340	178,557	414	37	11.656675	75000	CNPG	4570	530	1003
2861	2283	NH	PONTOOK	LOW	ANDROSCOGGIN RIVEF	1909	15	2283	63,870	399	15	10.671625	20500	TCER	883	280	1214
2966	60	NH	CLEMENT	LOW	WINNIPESAUKEE RIVEF	1984	24	60	31,895	120	24	11.0746	7750	CNPG	20	5	482
3025	2290	NH	KELLEY'S FALLS	HIGH	PISCATAQUOG RIVER	1916	24	2290	58,474	220	24	11.0746	21300	CNPG	1350	129	214
3133	119250	NH	ERROL	LOW	ANDROSCOGGIN RIVEF	1887	25	119250	56,987	205	25	11.119375	19700	OTERCN	80000	7850	1045
3342	94	NH	ALLIED LEATHER FOREBAY	LOW	CONTOOCOOK RIVER	1982	15	94	16,968	106	15	10.671625		CNOT	54	8	766
3342	94	NH	PENACOOK LOWER FALLS	LOW	CONTOOCOOK RIVER	1982	15	94	21,450	134	15	10.671625		CNOT	54	8	766
3342	94	NH	ALLIED LEATHER AUXILIAR	LOW	CONTOOCOOK RIVER	1982	15	94	50,584	316	15	10.671625	40000	CNPG	54	8	766
3442	2938	NH	MINE FALLS	LOW	NASHUA RIVER	1889	20	2938	70,821	325	20	10.8955	1700	MSCNPG	1970	242	405
3777	527	NH	ROLLINSFORD	LOW	SALMON FALLS RIVER	1910	20	527	83,895	385	20	10.8955	7000	CNMSPG	456	57	230
3820	633	NH	SOMERSWORTH	LOW	SALMON FALLS RIVER	1929	12	633	37,934	300	12	10.5373	8000	MSPG	377	55	218
4451	464	NH	LOWER GREAT FALLS	SIGNIFICANT	SALMON FALLS RIVER	1984	36	464	112,868	270	36	11.6119	7850	MSCNPG	272	32	220
4718	330	NH	COCHECO FALLS	LOW	COCHECO RIVER	1930	9	330	14,044	150	9	10.402975	2900	CNPG	110	55	187
6440	208000	NH	LAKEPORT	LOW	WINNIPESAUKEE RIVEF	1958	10	208000	23,507	225	10	10.44775	4080	CNOT	165800	46720	363
6597	51	NH	PIERCE	LOW	CONTOOCOOK RIVER	1921	12	51	53,108	420	12	10.5373	13400	CBCNPG	33	7	191
6597	50	NH	PAPER MILL	LOW	CONTOOCOOK RIVER	1922	9	50	26,215	280	9	10.402975	13400	CNPG	25	5	191
6597	240	NH	MONADNOCK	LOW	CONTOOCOOK RIVER	1923	22	240	120,836	500	22	10.98505	13400	CNPGRE	217	4	190
6597	8600	NH	POWDER MILL	LOW	CONTOOCOOK RIVER	1924	21	8600	84,087	366	21	10.940275	18200	CNPGRE	2400	435	184
6689	114	NH	PENACOOK UPPER FALLS	LOW	CONTOOCOOK RIVER	1987	16	114	45,780	267	16	10.7164	35000	CNOT	70	11	766
7528	400	NH	CANAAN	LOW	CONNECTICUT RIVER	1943	18	400	53,489	275	18	10.80595	37000	CNPG	200	20	381
7883	320	NH	WESTON	LOW	UPPER AMMONOOSUC	1987	20	320	45,761	210	20	10.8955	14250	TCER	275	30	263
7887	160	NH	MINNEWAWA	HIGH	MINNEWAWA BROOK	1932	63	160	214,044	265	63	12.820825	1700	CNVA	120	10	23
8405	28	NH	GLEN ROAD	SIGNIFICANT	MASCOMA RIVER	1988	16	28	30,006	175	16	10.7164	8600	CNPG	10	2	194
8924	83	NH	MCLANE	LOW	SOUHEGAN RIVER	1929	18	83	44,737	230	18	10.80595	9400	CNMSPG	47	6	138
9282	98	NH	HILLSBOROUGH MILL	LOW	SOUHEGAN RIVER	1925	27	98	60,528	200	27	11.208925	3300	CNMSPG	70	7	97

APPENDIX B Federal Energy Regulatory Commission Database 5 OF5

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
10898	300	NH	COY PAPER MILL	SIGNIFICANT	SUGAR RIVER	1922	33	300	118,931	314	33	11.477575	14000	CNPG	150	30	270
11128	725	NH	RED	LOW	UPPER AMMONOOSUC	1900	10	725	28,731	275	10	10.44775	12500	TCER	200	75	247
11128	240	NH	BROOKLYN	LOW	UPPER AMMONOOSUC	1910	19	240	56,695	275	19	10.850725	12500	TCER	50	26	254
11163	641	NH	SOUTH BERWICK	LOW	SALMON FALLS RIVER	1916	18	641	56,407	290	18	10.80595	14747	CNPG	525	58	235
11313	280	NH	APTHORP	SIGNIFICANT	AMMONOOSUC RIVER	1936	24	280	62,461	235	24	11.0746	14800	CNPG	210	20	205
2972	360	RI	WOONSOCKET FALLS	LOW	BLACKSTONE RIVER	1960	23	360	67,988	268	23	11.029825	33000	CNPG	300	32	369
3011	530	RI	ARCTIC	LOW	SOUTH BRANCH PAWT	1885	30	530	40,836	120	30	11.34325	4000	MSPG	442	45	73
3023	366	RI	TUPPERWARE	LOW	BLACKSTONE RIVER	1904	13	366	28,889	210	13	10.582075	12750	MSPG	305	40	261
3037	180	RI	ELIZABETH WEBBING MILLS	LOW	BLACKSTONE RIVER	1891	11	180	18,005	156	11	10.492525	8900	MSPG	150	26	473
3063	96	RI	VALLEY FALLS	LOW	BLACKSTONE RIVER	1859	10	96	20,896	200	10	10.44775	19310	MSPG	80	15	446
2205	3725	VT	FAIRFAX FALLS	LOW	LAMOILLE RIVER	1919	45	3725	185,990	344	45	12.014875	66900	CNPG	1080	152	529
2205	2025	VT	MILTON	LOW	LAMOILLE RIVER	1929	25	2025	40,030	144	25	11.119375	83000	CNPG	93	11	690
2205	11520	VT	CLARK FALLS	HIGH	LAMOILLE RIVER	1937	40	11520	400,894	850	40	11.791	85000	CNPGRE	6000	740	690
2205	6340	VT	PETERSON	HIGH	LAMOILLE RIVER	1949	75	6340	347,645	347	75	13.358125	93000	CNPG	2840	136	700
2306	6060	VT	ECHO	LOW	CLYDE RIVER	1922	16	6060	20,575	120	16	10.7164	693	PG	5000	530	24
2306	420	VT	WEST CHARLESTON	LOW	CLYDE RIVER	1928	30	420	66,698	196	30	11.34325	1049	OT	220	100	107
2306	3400	VT	NEWPORT NO. 1	HIGH	CLYDE RIVER	1936	23	3400	92,595	365	23	11.029825	3209	PG	3000	200	142
2323	190000	VT	SOMERSET	HIGH	EAST BRANCH DEERFI	1913	110	190000	3,449,375	2101	110	14.92525	27000	RECNPG	57345	1514	30
2323	600	VT	SEARSBURG	LOW	DEERFIELD RIVER	1922	50	600	374,506	612	50	12.23875	12200	RECNPG	412	30	90
2323	318000	VT	HARRIMAN	HIGH	DEERFIELD RIVER	1924	216	318000	5,311,278	1250	216	19.6714	35200	RE	117300	2039	184
2396	524	VT	PIERCE MILLS	LOW	PASSUMPSIC RIVER	1928	18	524	27,231	140	18	10.80595	6430	CNPG	50	25	237
2397	2548	VT	GAGE	LOW	PASSUMPSIC RIVER	1928	18	2548	62,437	321	18	10.80595	27700	CNPG	70	15	413
2399	427	VT	ARNOLD FALLS	LOW	PASSUMPSIC RIVER	1928	20	427	91,522	420	20	10.8955	10300	TCER	46	7	254
2400	494	VT	PASSUMPSIC	LOW	PASSUMPSIC RIVER	1929	11	494	29,778	258	11	10.492525	21400	CNPG	70	18	424
2445	490	VT	CENTER RUTLAND	LOW	OTTER CREEK	1898	14	490	25,887	174	14	10.62685	1120	CN	30	13	307
2489	592	VT	CAVENDISH	LOW	BLACK RIVER	1907	39	592	59,553	130	39	11.746225	18400	CNPG	100	10	82
2490	385	VT	TAFTSVILLE	LOW	OTTAUQUECHEE RIVEF	1910	18	385	42,792	220	18	10.80595	15300	CNPG	100	21	190
2513	6085	VT	ESSEX NO. 19	SIGNIFICANT	WINOOSKI RIVER	1917	53	6085	252,473	385	53	12.373075	150000	PG	1950	352	1043
2547	24278	VT	HIGHGATE FALLS	SIGNIFICANT	MISSISQUOI RIVER	1918	46	24278	133,139	240	46	12.05965	8200	PG	7000	65	815
2558	2122	VT	HUNTINGTON FALLS	LOW	OTTER CREEK	1910	34	2122	73,259	187	34	11.52235	2587	CN	250	23	749
2558	3369	VT	PROCTOR	LOW	OTTER CREEK	1910	16	3369	21,947	128	16	10.7164	2328	ST	460	92	347
2558	1730	VT	BELDENS EAST	LOW	OTTER CREEK	1913	27	1730	16,948	56	27	11.208925	775	PG	150	22	632
2558	1730	VT	BELDENS WEST	LOW	OTTER CREEK	1913	15	1730	9,124	57	15	10.671625	788	PG	150	22	632
2629	1000	VT	CADYS FALLS	LOW	LAMOILLE RIVER	1894	29	1000	121,560	371	29	11.298475	140000	PG	1000	150	250
2629	1038	VT	MORRISVILLE DAM	LOW	LAMOILLE RIVER	1924	37	1038	107,824	250	37	11.656675	140000	PG	150	15	222
2629	1038	VT	MORRISVILLE BACK SPILLV	LOW	LAMOILLE RIVER	1924	8	1038	12,430	150	8	10.3582	35000	PG	150	15	
2629	17000	VT	GREEN RIVER DAM	HIGH	GREEN RIVER	1947	110	17000	525,369	320	110	14.92525	2535	VA	16900	625	14
2629	17000	VT	GREEN RIVER DIKE	SIGNIFICANT	GREEN RIVER	1947	22	17000	60,418	250	22	10.98505		RE	16900	625	
2674	1649	VT	VERGENNES NO. 9	LOW	OTTER CREEK	1912	12	1649	68,029	538	12	10.5373	3459	PG	350	70	866
2731	5100	VT	WEYBRIDGE WEST	LOW	OTTER CREEK	1944	30	5100	51,045	150	30	11.34325	46000	CNPG	600	59	750
2731	5100	VT	WEYBRIDGE EAST	LOW	OTTER CREEK	1951	30	5100	37,433	110	30	11.34325	46000	PG	600	59	750
2737	677	VT	MIDDLEBURY LOWER EAST	LOW	OTTER CREEK	1917	15	677	49,623	310	15	10.671625	13700	CNPG	45	16	632
2737	677	VT	MIDDLEBURY LOWER WEST	LOW	OTTER CREEK	1917	15	677	12,806	80	15	10.671625	1275	PG	45	16	632
2756	400	VT	CHACE MILL	LOW	WINOOSKI RIVER	1876	29	400	78,637	240	29	11.298475	30000	PG	34	50	1060
2839	160	VT	GREAT FALLS	HIGH	PASSUMPSIC RIVER	1915	34	160	62,682	160	34	11.52235	1550	PG	135	12	220
2879	18558	VT	BOLTON FALLS	LOW	WINOOSKI RIVER	1898	75	18558	190,353	190	75	13.358125	68000	TCER	355	70	835
2905	7471	VT	ENOSBERG FALLS	LOW	MISSISQUOI RIVER	1928	21	7471	44,800	195	21	10.940275	26443	PG	750	120	587
5261	14	VT	NEWBURY	SIGNIFICANT	WELLS RIVER	1912	20	14	19,612	90	20	10.8955	3200	PG	12	12	90
5944	209	VT	MORETOWN NO. 8	SIGNIFICANT	MAD RIVER	1910	31	209	117,559	333	31	11.388025	122000	PG	209	36	143
6470	69	VT	WINOOSKI NO. 8	LOW	WINOOSKI RIVER	1985	29	69	74,378	227	29	11.298475	14500	PG	34	7	199
7186	2250	VT	SHELDON SPRINGS	LOW	MISSISQUOI RIVER	1920	38	2250	125,837	283	38	11.70145	3822	CB	750	175	794
7725	793	VT	BARTON VILLAGE	LOW	CLYDE RIVER	1949	9	793	7,209	77	9	10.402975	762	OT	560	187	108
9648	90	VT	FELLOWS	LOW	BLACK RIVER	1990	10	90	20,896	200	10	10.44775	1780	PG	60	21	190

APPENDIX C National Inventory of Dams Database 1 of 10

FERC#	FERC#	NID #	STATE	DAM_NAME	HAZARD	EAP	STATE_NAME	CONG_DIST	COUNTY	NEAR_CITY	DIST_CIT	RIVER	PRM_PURPOSE	NID_DAMTYP	YEAR_C	NID_HEIGHT	NID_STOR	DAM_LENGTH	MAX_DISCH	OWNER
1855.0101	1855	NH00112	NH	BELLOWS FALLS	LOW	NO	NEW HAMPSHIRE	NH-02	CHESHIRE	BELLOWS FALLS, VT.		CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1907	48	55560	643	157600	NEW ENGLAND POWER CO.
1889.0101	1889	MA00849	MA	GILL	SIGNIFICANT	YES	MASSACHUSETTS	MA-01	FRANKLIN	TURNERS FALLS	1	CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1970	70	28000	493	280000	WESTERN MASSACHUSETTS ELE
1889.0102	1889	MA00848	MA	MONTAGUE	SIGNIFICANT	YES	MASSACHUSETTS	MA-01	FRANKLIN	TURNERS FALLS	1	CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1915	62	28000	630	280000	WESTERN MASSACHUSETTS ELE
1889.0103	1889	MA00847	MA	CABOT SPILLWAY	LOW	NO	MASSACHUSETTS	MA-01	FRANKLIN	GREENFIELD	2	CONNECTICUT CANAL	HYDROELECTRIC	GRAVITY	1915	35	28000	168	15000	WESTERN MASSACHUSETTS ELE
1889.0105	1889	MA83030	MA	CABOT STATION	LOW	NO	MASSACHUSETTS	MA-01	FRANKLIN	GREENFIELD	2	CONNECTICUT CANAL	HYDROELECTRIC	GRAVITY	1916	35	28000	235		WESTERN MASSACHUSETTS ELE
1892.0101	1892	NH00259	NH	WILDER	HIGH	YES	NEW HAMPSHIRE	NH-02	GRAFTON	WEST LEBANON	3	CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1950	59	79800	2900	213300	NEW ENGLAND POWER CO.
1893.0101	1893	NH00102	NH	AMOSKEAG	LOW	YES	NEW HAMPSHIRE	NH-01	HILLSBOROUGH	MANCHESTER		MERRIMACK RIVER	HYDROELECTRIC	GRAVITY	1921	29	8100	1075	87000	PUBLIC SERVICE COMPANY OF NE
1893.0301	1893	NH00090	NH	GARVINS FALLS	LOW	YES	NEW HAMPSHIRE	NH-02	MERRIMACK	BOW		MERRIMACK RIVER	HYDROELECTRIC	GRAVITY	1901	18	5700	645	113000	PUBLIC SERVICE COMPANY OF NE
1893.0201	1893	NH00239	NH	HOOKSETT	LOW	NO	NEW HAMPSHIRE	NH-01	MERRIMACK	HOOKSETT		MERRIMACK RIVER	HYDROELECTRIC	GRAVITY	1927	11	4180	667	78500	PUBLIC SERVICE COMPANY OF NE
1904.0101	1904	NH00097	NH	VERNON	LOW	NO	NEW HAMPSHIRE	NH-02	CHESHIRE	VERNON, VT.		CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1909	58	54000	956	224700	NEW ENGLAND POWER CO.
2004.0106	2004	MA83056	MA	CANAL GATE HOUSE	SIGNIFICANT	YES	MASSACHUSETTS		HAMPDEN			CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1900	36	68900	180		HOLYOKE WATER POWER CO.
2004.0101	2004	MA00973	MA	HOLYOKE DAM	HIGH	YES	MASSACHUSETTS		HAMPDEN	HOLYOKE		CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1900	30	68900	1020	300000	HOLYOKE WATER POWER CO.
2004.0103	2004	MA83004	MA	OVERFLOW NO. 2	LOW	NO	MASSACHUSETTS	MA-01	HAMPDEN	HOLYOKE		HOLYOKE CANAL	HYDROELECTRIC	GRAVITY	1860	20	68900	100	2615	HOLYOKE WATER POWER CO.
2004.0104	2004	MA83005	MA	OVERFLOW NO. 3	LOW	NO	MASSACHUSETTS	MA-01	HAMPDEN	HOLYOKE		HOLYOKE CANAL	HYDROELECTRIC	GRAVITY	1860	18	68900	107	1935	HOLYOKE WATER POWER CO.
2004.0105	2004	MA83002	MA	OVERFLOW NO. 4	LOW	NO	MASSACHUSETTS	MA-01	HAMPDEN	HOLYOKE		HOLYOKE CANAL	HYDROELECTRIC	GRAVITY	1891	26	68900	150	950	HOLYOKE WATER POWER CO.
2077.0101	2077	NH00166	NH	MCINDOES	SIGNIFICANT	YES	NEW HAMPSHIRE		GRAFTON	EAST RYEGATE, VT	4	CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1931	25	14100	730	138500	NEW ENGLAND POWER CO.
2077.0201	2077	NH00165	NH	COMERFORD	HIGH	YES	NEW HAMPSHIRE	NH-02	GRAFTON	BARNET, VT.	3	CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1930	170	57700	2253	288200	NEW ENGLAND POWER CO.
2077.0301	2077	NH00414	NH	MOORE	HIGH	YES	NEW HAMPSHIRE	NH-02	GRAFTON	BARNET, VT.	9	CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1957	144	223722	2920	211300	NEW ENGLAND POWER CO.
2142.0101	2142	ME00090	ME	HARRIS	HIGH	YES	MAINE	ME-02	SOMERSET	THE FORKS	10	KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1955	165	108000	2015	22000	CENTRAL MAINE POWER CO.
2194.0101	2194	ME00034	ME	BAR MILLS	LOW	NO	MAINE	ME-01	YORK	BUXTON	1	SACO RIVER	HYDROELECTRIC	GRAVITY	1956	25	2000	400	16320	CENTRAL MAINE POWER CO.
2205.0101	2205	VT00031	VT	PETERSON	HIGH	YES	VERMONT	VT-01	CHITTENDEN	WEST MILTON	1	LAMOILLE RIVER	HYDROELECTRIC	GRAVITY	1949	75	6340	347	93000	CENTRAL VERMONT PUBLIC SERV
2205.0201	2205	VT00032	VT	MILTON	LOW	NO	VERMONT	VT-01	CHITTENDEN	WEST MILTON	3	LAMOILLE RIVER	HYDROELECTRIC	GRAVITY	1929	25	2025	144	83000	CENTRAL VERMONT PUBLIC SERV
2205.0401	2205	VT00034	VT	FAIRFAX FALLS	LOW	NO	VERMONT	VT-01	FRANKLIN	FAIRFAX	1	LAMOILLE RIVER	HYDROELECTRIC	GRAVITY	1919	45	3725	344	66900	CENTRAL VERMONT PUBLIC SERV
2205.0301	2205	VT00033	VT	CLARK FALLS	HIGH	YES	VERMONT	VT-01	CHITTENDEN	MILTON		LAMOILLE RIVER	HYDROELECTRIC	GRAVITY	1937	40	11520	850	85000	CENTRAL VERMONT PUBLIC SERV
2283.0101	2283	ME00006	ME	DEER RIPS	LOW	YES	MAINE	ME-02	ANDROSCOGGIN	LEWISTON - AUBURN	2	ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1903	54	2280	939	2000	CENTRAL MAINE POWER CO.
2283.0301	2283	ME00007	ME	GULF ISLAND	HIGH	YES	MAINE	ME-02	ANDROSCOGGIN	LEWISTON - AUBURN	3	ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1926	89	56100	2488	50000	CENTRAL MAINE POWER CO.
2284.0101	2284	ME00001	ME	BRUNSWICK	LOW	NO	MAINE	ME-01	CUMBERLAND	BRUNSWICK		ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1982	42	2000	605	20000	CENTRAL MAINE POWER CO.
2287.0101	2287	NH00157	NH	J. BRODIE SMITH	HIGH	YES	NEW HAMPSHIRE	NH-02	COOS	BERLIN		ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1948	31	94	550	56000	PUBLIC SERVICE COMPANY OF NE
2300.0101	2300	NH00052	NH	SHELBURNE	LOW	NO	NEW HAMPSHIRE	NH-02	COOS	SHELBURNE	3	ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1906	16	2000	701	23000	JAMES RIVER - NEW HAMPSHIRE
2302.0101	2302	ME00005	ME	GREAT STONE	HIGH	YES	MAINE	ME-02	ANDROSCOGGIN	LEWISTON - AUBURN		ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1865	27	2800	955	8050	CENTRAL MAINE POWER CO. & U
2302.0105	2302	ME83003	ME	GULLY BROOK LOWER	LOW	NO	MAINE	ME-02	ANDROSCOGGIN	LEWISTON - AUBURN		LEWISTON CANAL - GULL	HYDROELECTRIC	GRAVITY	1859	9	2800	90	1200	CENTRAL MAINE POWER CO. & U
2302.0106	2302	ME83004	ME	ANDROSCOGGIN WEIR	LOW	NO	MAINE	ME-02	ANDROSCOGGIN	LEWISTON - AUBURN		LEWISTON CANAL - GULL	HYDROELECTRIC	GRAVITY	1859	9	2800	32	480	CENTRAL MAINE POWER CO. & U
2302.0102	2302	ME83001	ME	BATES WEIR	LOW	NO	MAINE		ANDROSCOGGIN	LEWISTON - AUBURN		LEWISTON CROSS CANA	HYDROELECTRIC	GRAVITY	1859	14	2800	71	1054	CENTRAL MAINE POWER CO. & U
2302.0103	2302	ME83002	ME	RED SHOP WEIR	LOW	NO	MAINE		ANDROSCOGGIN	LEWISTON - AUBURN		LEWISTON CROSS CANA	HYDROELECTRIC	GRAVITY	1859	18	2800	60	1573	CENTRAL MAINE POWER CO. & U
2302.0107	2302	ME83005	ME	CONTINENTAL WEIR	LOW	NO	MAINE	ME-02	ANDROSCOGGIN	LEWISTON - AUBURN		LEWISTON CROSS CANA	HYDROELECTRIC	GRAVITY	1920	14	2800	30	1030	CENTRAL MAINE POWER CO. & U
2322.0101	2322	ME00084	ME	SHAWMUT	LOW	NO	MAINE	ME-01	KENNEBEC	FAIRFIELD	3	KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1912	40	5100	1480	12540	CENTRAL MAINE POWER CO.
2323.0101	2323	MA00840	MA	DEERFIELD NO. 5	LOW	NO	MASSACHUSETTS	MA-01	FRANKLIN	MONROE BRIDGE		DEERFIELD RIVER	HYDROELECTRIC	GRAVITY	1992	43	818	151	35800	NEW ENGLAND POWER CO.
2323.0105	2323	MA00222	MA	DEERFIELD NO. 5 - DUNE	LOW	NO	MASSACHUSETTS		BERKSHIRE	FLORIDA		DUNBAR BROOK	HYDROELECTRIC	GRAVITY	1993	29	818	160	6800	NEW ENGLAND POWER CO.
2323.0201	2323	MA00464	MA	DEERFIELD NO. 2	SIGNIFICANT	YES	MASSACHUSETTS	MA-01	FRANKLIN	CONWAY		DEERFIELD RIVER	HYDROELECTRIC	GRAVITY	1913	76	589	447	31200	NEW ENGLAND POWER CO.
2323.0301	2323	MA00461	MA	DEERFIELD NO. 3	LOW	NO	MASSACHUSETTS	MA-01	FRANKLIN	SHELBURNE FALLS		DEERFIELD RIVER	HYDROELECTRIC	GRAVITY	1912	21	551	475	23300	NEW ENGLAND POWER CO.
2323.0401	2323	MA00460	MA	DEERFIELD NO. 4	LOW	NO	MASSACHUSETTS	MA-01	FRANKLIN	SHELBURNE FALLS	3	DEERFIELD RIVER	HYDROELECTRIC	GRAVITY	1912	48	1067	510	19100	NEW ENGLAND POWER CO.
2323.0501	2323	MA00043	MA	SHERMAN	HIGH	YES	MASSACHUSETTS	MA-01	FRANKLIN	MONROE BRIDGE	1	DEERFIELD RIVER	HYDROELECTRIC	GRAVITY	1927	110	5480	1017	87000	NEW ENGLAND POWER CO.
2323.0701	2323	VT00026	VT	SEARSBURG	LOW	NO	VERMONT	VT-01	BENNINGTON	WILMINGTON	7	DEERFIELD RIVER	HYDROELECTRIC	GRAVITY	1922	50	600	612	12200	NEW ENGLAND POWER CO.
2323.0801	2323	VT00018	VT	SOMERSET	HIGH	YES	VERMONT	VT-01	WINDHAM	SEARSBURG	6	EAST BRANCH DEERFIELD	HYDROELECTRIC	GRAVITY	1913	110	190000	2101	27000	NEW ENGLAND POWER CO.
2325.0101	2325	ME00085	ME	WESTON NORTH CHANN	LOW	NO	MAINE	ME-02	SOMERSET	SKOWHEGAN		KENNEBEC RIVER	HYDROELECTRIC	BUTTRESS	1921	38	22300	529	143000	CENTRAL MAINE POWER CO.
2325.0102	2325	ME83033	ME	WESTON SOUTH CHANN	LOW	NO	MAINE	ME-02	SOMERSET	SKOWHEGAN		KENNEBEC RIVER	HYDROELECTRIC	BUTTRESS	1921	51	22300	392	51500	CENTRAL MAINE POWER CO.
2326.0101	2326	NH00088	NH	CROSS	HIGH	YES	NEW HAMPSHIRE	NH-02	COOS	BERLIN		ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1903	30	195	593	21000	JAMES RIVER - NEW HAMPSHIRE
2327.0101	2327	NH00163	NH	CASCADE	HIGH	YES	NEW HAMPSHIRE	NH-02	COOS	GORHAM		ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1903	58	400	583	40000	JAMES RIVER - NEW HAMPSHIRE
2329.0101	2329	ME00089	ME	WYMAN	HIGH	YES	MAINE	ME-02	SOMERSET	BINGHAM	1	KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1930	155	255000	3054	59630	CENTRAL MAINE POWER CO.
2333.0201	2333	ME00013	ME	RUMFORD FALLS UPPER	SIGNIFICANT	YES	MAINE	ME-02	OXFORD	RUMFORD	1	ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1918	40	3110	524	121900	RUMFORD FALLS POWER CO.
2334.0101	2334	MA00853	MA	GARDNERS FALLS	LOW	YES	MASSACHUSETTS	MA-01	FRANKLIN	BUCKLAND	1	DEERFIELD RIVER	HYDROELECTRIC	GRAVITY	1904	37	510	337	65250	WESTERN MASSACHUSETTS ELE
2335.0101	2335	ME00088	ME	WILLIAMS	LOW	NO	MAINE	ME-02	SOMERSET	SOLON	1	KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1939	45	6700	680	48790	CENTRAL MAINE POWER CO.
2364.0101	2364	ME00086	ME	ABENAKI	LOW	NO	MAINE	ME-02	SOMERSET	MADISON		KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1922	25	425	1000	126000	MADISON PAPER INDUSTRIES
2365.0101	2365	ME00087	ME	ANSON	LOW	NO	MAINE	ME-02	SOMERSET	MADISON		KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1923	38	14500	855	90000	MADISON PAPER INDUSTRIES
2368.0101	2368	ME00234	ME	SQUA PAN	HIGH	YES	MAINE	ME-02	AROOSTOOK	ASHLAND	10	SQUA PAN STREAM	HYDROELECTRIC	BUTTRESS	1928	35	89215	585	5300	MAINE PUBLIC SERVICE CO.
2375.0101	2375	ME00008	ME	LIVERMORE FALLS	LOW	NO	MAINE	ME-02	ANDROSCOGGIN	LIVERMORE FALLS		ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1908	12	782	843	65000	INTERNATIONAL PAPER CO.
2375.0301	2375	ME00010	ME	JAY	LOW	NO	MAINE	ME-02	FRANKLIN	JAY		ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1912	17	2331	797	55000	INTERNATIONAL PAPER CO.
2396.0101	2396	VT00250	VT	PIERCE MILLS	LOW	NO	VERMONT	VT-01	CALEDONIA			PASSUMPSIC RIVER	HYDROELECTRIC	GRAVITY	1928	18	524	140	6430	CENTRAL VERMONT PUBLIC SERV
2397.0101	2397	VT00192	VT	GAGE	LOW	NO	VERMONT	VT-01	CALEDONIA	PASSUMPSIC	2	PASSUMPSIC RIVER	HYDROELECTRIC	GRAVITY	1928	18	2548	321	27700	CENTRAL VERMONT PUBLIC SERV
2400.0101	2400	VT00195	VT	PASSUMPSIC	LOW	NO	VERMONT	VT-01	CALEDONIA	EAST BARNET	4	PASSUMPSIC RIVER	HYDROELECTRIC	GRAVITY	1929	11	494	258	21400	CENTRAL VERMONT PUBLIC SERV
2403.0101	2403	ME00137	ME	VEAZIE	LOW	NO	MAINE	ME-02	PENOBSCOT	EDDINGTON	1	PENOBSCOT RIVER	HYDROELECTRIC	BUTTRESS	1913	30	4800	842	100500	BANGOR HYDRO-ELECTRIC CO.
2422.0101	2422	NH00089	NH	SAWMILL	LOW	NO	NEW HAMPSHIRE	NH-02	COOS	BERLIN		ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1965	20	830	835	33000	JAMES RIVER - NEW HAMPSHIRE
2445.0101	2445	VT00208	VT	CENTER RUTLAND	LOW	NO	VERMONT	VT-01	RUTLAND	CENTER RUTLAND		OTTER CREEK	HYDROELECTRIC	GRAVITY	1898	14	490	174	1120	VERMONT MARBLE CO.
2456.0101	2456	NH00160	NH	AYERS ISLAND	SIGNIFICANT	YES	NEW HAMPSHIRE	NH-02	GRAFTON	BRISTOL		PEMIGEWASSET RIVER	HYDROELECTRIC	BUTTRESS	1924	80	16000	699	72000	PUBLIC SERVICE COMPANY OF NE
2457.0101	2457	NH00164	NH	EASTMAN FALLS	SIGNIFICANT	YES	NEW HAMPSHIRE	NH-02	MERRIMACK	FRANKLIN		PEMIGEWASSET RIVER	HYDROELECTRIC	GRAVITY	1937	37	9340	414	75000	PUBLIC SERVICE COMPANY OF NE
2458.0101	2458	ME00200	ME	EAST MILLINOCKET	LOW	YES	MAINE	ME-02	PENOBSCOT	EAST MILLINOCKET		WEST BRANCH PENOBSC	HYDROELECTRIC	GRAVITY	1907	24	2970	723	75500	GREAT NORTHERN PAPER, INC.

APPENDIX C National Inventory of Dams Database 2 of 10

FERC#	FERC#	NID #	STATE	DAM_NAME	HAZARD	EAP	STATE_NAME	CONG_DIST	COUNTY	NEAR_CITY	DIST_CIT	RIVER	PRM_PURPOSE	NID_DAMTYP	YEAR_C	NID_HEIGHT	NID_STOR	DAM_LENGTH	MAX_DISCH	OWNER
2458.0201	2458	ME00201	ME	DOLBY	HIGH	YES	MAINE	ME-02	PENOBSCOT	EAST MILLINOCKET	2	WEST BRANCH PENOBSC	HYDROELECTRIC	GRAVITY	1906	56	56290	1395	75000	GREAT NORTHERN PAPER, INC.
2458.0301	2458	ME00202	ME	STONE DAM	HIGH	YES	MAINE	ME-02	PENOBSCOT	EAST MILLINOCKET	4	WEST BRANCH PENOBSC	HYDROELECTRIC	GRAVITY	1900	27	14520	1262	109000	GREAT NORTHERN PAPER, INC.
2458.0501	2458	ME00205	ME	MILLINOCKET LAKE	HIGH	YES	MAINE	ME-02	PENOBSCOT	MILLINOCKET	6	MILLINOCKET STREAM	HYDROELECTRIC	GRAVITY	1910	20	87670	635	7000	GREAT NORTHERN PAPER, INC.
2458.0401	2458	ME00203	ME	NORTH TWIN	HIGH	YES	MAINE	ME-02	PENOBSCOT	MILLINOCKET	4	WEST BRANCH PENOBSC	HYDROELECTRIC	GRAVITY	1934	35	392680	1051	72000	GREAT NORTHERN PAPER, INC.
2485.0102	2485	MA83021	MA	NORTHFIELD MT. - UPPE	HIGH	YES	MASSACHUSETTS	MA-01	FRANKLIN	FARLEY	1	CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1973	20	21500	493		WESTERN MASSACHESETTS EL
2485.0103	2485	MA83022	MA	NORTHFIELD MT. - UPPE	LOW	YES	MASSACHUSETTS	MA-01	FRANKLIN	FARLEY	1	CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1972	9	21500	551	11400	WESTERN MASSACHUSETTS EL
2488.0101	2488	VT00044	VT	BRADFORD	HIGH	YES	VERMONT	VT-01	ORANGE	BRADFORD		WAITS RIVER	HYDROELECTRIC	ARCH	1908	50	551	255	20000	CENTRAL VERMONT PUBLIC SER
2489.0101	2489	VT00037	VT	CAVENDISH	LOW	NO	VERMONT	VT-01	WINDSOR	WHITESVILLE	1	BLACK RIVER	HYDROELECTRIC	GRAVITY	1907	39	592	130	18400	CENTRAL VERMONT PUBLIC SER
2490.0101	2490	VT00207	VT	TAFTSVILLE	LOW	NO	VERMONT	VT-01	WINDSOR	QUECHEE	4	OTTAUQUECHEE RIVER	HYDROELECTRIC	GRAVITY	1910	18	385	220	15300	CENTRAL VERMONT PUBLIC SER
2492.0101	2492	ME00220	ME	VANCEBORO	SIGNIFICANT	YES	MAINE	ME-02	WASHINGTON	VANCEBORO		ST. CROIX RIVER	HYDROELECTRIC	GRAVITY	1967	16	214470	469	13400	GEORGIA PACIFIC CORP.
2519.0101	2519	ME00069	ME	NORTH GORHAM	HIGH	YES	MAINE	ME-01	CUMBERLAND	GORHAM	2	PRESUMPSCOT RIVER	HYDROELECTRIC	GRAVITY	1901	23	1663	903	1320	CENTRAL MAINE POWER CO.
2520.0101	2520	ME00143	ME	MATTACEUNK	HIGH	YES	MAINE	ME-02	PENOBSCOT	MATTAWAMKEAG	5	PENOBSCOT RIVER	HYDROELECTRIC	GRAVITY	1939	45	69100	1170	125000	GREAT NORTHERN PAPER, INC.
2527.0101	2527	ME00033	ME	SKELTON	HIGH	YES	MAINE	ME-01	YORK	BIDDEFORD		SACO RIVER	HYDROELECTRIC	GRAVITY	1948	75	33500	1695	69600	CENTRAL MAINE POWER CO.
2528.0101	2528	ME00030	ME	CATARACT	LOW	NO	MAINE	ME-01	YORK	BIDDEFORD		SACO RIVER	HYDROELECTRIC	GRAVITY	1938	49	266	165	5625	CENTRAL MAINE POWER CO.
2528.0201	2528	ME83030	ME	SPRINGS	LOW	NO	MAINE	ME-01	YORK	BIDDEFORD		SACO RIVER	HYDROELECTRIC	GRAVITY	1925	12	2500	269	3405	CENTRAL MAINE POWER CO.
2528.0202	2528	ME00546	ME	BRADBURY	LOW	NO	MAINE	ME-01	YORK	BIDDEFORD		SACO RIVER	HYDROELECTRIC	GRAVITY	1929	12	2500	205	2060	CENTRAL MAINE POWER CO.
2528.0104	2528	ME00032	ME	WEST CHANNEL DAM	LOW	NO	MAINE	ME-01	YORK	BIDDEFORD		SACO RIVER	HYDROELECTRIC	GRAVITY	1895	16	266	330	2250	CENTRAL MAINE POWER CO.
2529.0102	2529	ME83031	ME	NEW RIVER CHANNEL DA	SIGNIFICANT	YES	MAINE	ME-01	YORK	HOLLIS	1	SACO RIVER	HYDROELECTRIC	GRAVITY	1911	13	5440	350	17000	CENTRAL MAINE POWER CO.
2529.0101	2529	ME00036	ME	BONNY EAGLE	SIGNIFICANT	YES	MAINE	ME-01	YORK	HOLLIS	1	SACO RIVER	HYDROELECTRIC	GRAVITY	1911	67	5440	784		CENTRAL MAINE POWER CO.
2530.0101	2530	ME00037	ME	HIRAM	LOW	NO	MAINE		OXFORD	BALDWIN	4	SACO RIVER	HYDROELECTRIC	GRAVITY	1917	30	2530	432	16475	CENTRAL MAINE POWER CO.
2531.0101	2531	ME00035	ME	WEST BUXTON	LOW	NO	MAINE	ME-01	YORK	BUXTON	5	SACO RIVER	HYDROELECTRIC	GRAVITY	1907	30	13200	643	4930	CENTRAL MAINE POWER CO.
2534.0101	2534	ME00141	ME	MILFORD	LOW	NO	MAINE	ME-02	PENOBSCOT	OLD TOWN		PENOBSCOT RIVER	HYDROELECTRIC	GRAVITY	1906	34	13300	1400	70265	BANGOR HYDRO-ELECTRIC CO.
2534.0102	2534	ME83006	ME	GILMAN FALLS	LOW	NO	MAINE	ME-02	PENOBSCOT	OLD TOWN		STILLWATER RIVER	HYDROELECTRIC	GRAVITY	1906	8	13300	475	35132	BANGOR HYDRO-ELECTRIC CO.
2552.0101	2552	ME00108	ME	FORT HALIFAX	LOW	NO	MAINE	ME-01	KENNEBEC	WATERVILLE		SEBASTICOOK RIVER	HYDROELECTRIC	BUTTRESS	1908	29	5500	473	46500	CENTRAL MAINE POWER CO.
2555.0101	2555	ME00103	ME	AUTOMATIC	LOW	NO	MAINE	ME-01	KENNEBEC	WATERVILLE		MESSALONSKEE STREAM	HYDROELECTRIC	GRAVITY	1924	33	1440	81	1910	KENNEBEC WATER DISTRICT
2556.0101	2556	ME00102	ME	UNION GAS	LOW	NO	MAINE	ME-01	KENNEBEC	SIDNEY	5	MESSALONSKEE STREAM	HYDROELECTRIC	GRAVITY	1924	36	750	343	2460	CENTRAL MAINE POWER CO.
2558.0101	2558	VT00042	VT	HUNTINGTON FALLS	LOW	NO	VERMONT	VT-01	ADDISON	WEYBRIDGE	1	OTTER CREEK	HYDROELECTRIC	GRAVITY	1910	34	2122	187	2587	VERMONT MARBLE CO.
2559.0101	2559	ME00105	ME	OAKLAND	LOW	YES	MAINE	ME-01	KENNEBEC	WATERVILLE	6	MESSALONSKEE STREAM	HYDROELECTRIC	GRAVITY	1901	14	110	115	200	CENTRAL MAINE POWER CO.
2559.0201	2559	ME00106	ME	MESSALONSKEE LAKE	HIGH	YES	MAINE	ME-01	KENNEBEC	OAKLAND		MESSALONSKEE STREAM	HYDROELECTRIC	GRAVITY	1992	13	118300	166	2400	CENTRAL MAINE POWER CO.
2572.0101	2572	ME00204	ME	RIPOGENUS	HIGH	YES	MAINE	ME-02	PISCATAQUIS	MILLINOCKET	37	WEST BRANCH PENOBSC	HYDROELECTRIC	GRAVITY	1916	73	977000	795	92800	GREAT NORTHERN PAPER, INC.
2574.0101	2574	ME00082	ME	LOCKWOOD	LOW	NO	MAINE	ME-01	KENNEBEC	WATERVILLE		KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1919	20	1830	904	123000	MERIMIL LIMITED PARTNERSHIP
2576.0101	2576	CT00232	CT	SHEPAUG	HIGH	YES	CONNECTICUT	CT-06	NEW HAVEN	BERKSHIRE ESTATE	1	HOUSATONIC RIVER	HYDROELECTRIC	GRAVITY	1955	140	86100	1412	180000	CONNECTICUT LIGHT & POWER C
2576.0201	2576	CT00548	CT	BULLS BRIDGE	SIGNIFICANT	YES	CONNECTICUT	CT-06	LITCHFIELD	GAYLORDSVILLE	2	HOUSATONIC RIVER	HYDROELECTRIC	GRAVITY	1902	22	3120	203	45000	CONNECTICUT LIGHT & POWER C
2576.0303	2576	CT83002	CT	NORTH LANESVILLE DIK	HIGH	YES	CONNECTICUT	CT-06	LITCHFIELD	NEW MILFORD	2	ROCKY RIVER	HYDROELECTRIC	GRAVITY	1929	7	218650	181		CONNECTICUT LIGHT & POWER C
2576.0305	2576	CT83004	CT	SOUTH LANESVILLE DIK	HIGH	YES	CONNECTICUT	CT-06	LITCHFIELD	NEW MILFORD	2	ROCKY RIVER	HYDROELECTRIC	GRAVITY	1929	17	218650	391		CONNECTICUT LIGHT & POWER C
2576.0401	2576	CT00023	CT	STEVENSON	HIGH	YES	CONNECTICUT		FAIRFIELD	OXFORD		HOUSATONIC RIVER	HYDROELECTRIC	GRAVITY	1919	83	37200	1250	70000	CONNECTICUT LIGHT & POWER C
2576.0202	2576	CT00549	CT	SPOONER	SIGNIFICANT	YES	CONNECTICUT	CT-06	LITCHFIELD	GAYLORDSVILLE	2	HOUSATONIC RIVER	HYDROELECTRIC	GRAVITY	1902	20	3120	156	45000	CONNECTICUT LIGHT & POWER C
2576.0204	2576	CT83021	CT	BULLS BRIDGE MOUNTA	SIGNIFICANT	YES	CONNECTICUT	CT-06	LITCHFIELD	NEW MILFORD	9	HOUSATONIC RIVER	HYDROELECTRIC	GRAVITY	1902	22	3120	203	150	CONNECTICUT LIGHT & POWER C
2597.0101	2597	CT00514	CT	FALLS VILLAGE	SIGNIFICANT	YES	CONNECTICUT	CT-06	LITCHFIELD	FALLS VILLAGE	1	HOUSATONIC RIVER	HYDROELECTRIC	GRAVITY	1913	16	3100	320	38000	CONNECTICUT LIGHT & POWER C
2600.0101	2600	ME00142	ME	WEST ENFIELD	LOW	NO	MAINE	ME-02	PENOBSCOT	HOWLAND	1	PENOBSCOT RIVER	HYDROELECTRIC	GRAVITY	1988	45	17900	664	96000	BANGOR - PACIFIC HYDRO ASSO
2611.0101	2611	ME00083	ME	HYDRO - KENNEBEC	LOW	NO	MAINE	ME-01	KENNEBEC	WATERVILLE		KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1989	40	6150	850	667000	SCOTT PAPER CO. & UAH - HYDR
2612.0101	2612	ME00127	ME	FLAGSTAFF	HIGH	YES	MAINE	ME-02	SOMERSET	THE FORKS	17	DEAD RIVER	HYDROELECTRIC	GRAVITY	1948	43	435000	1347	20000	CENTRAL MAINE POWER CO.
2613.0101	2613	ME00132	ME	MOXIE	LOW	NO	MAINE	ME-02	SOMERSET	THE FORKS	8	MOXIE STREAM	HYDROELECTRIC	GRAVITY	1925	17	39400	570	1850	CENTRAL MAINE POWER CO., ET
2615.0101	2615	ME00133	ME	BRASSUA	HIGH	YES	MAINE	ME-02	SOMERSET	ROCKWOOD	4	MOOSE RIVER	HYDROELECTRIC	BUTTRESS	1927	50	275000	1789	27000	CENTRAL MAINE POWER CO., ET
2631.0101	2631	MA00737	MA	WORONOCO	LOW	NO	MASSACHUSETTS	MA-01	HAMPDEN	WESTFIELD	8	WESTFIELD RIVER	HYDROELECTRIC	GRAVITY	1938	53	2565	1475	210000	INTERNATIONAL PAPER CO.
2634.0101	2634	ME00215	ME	CANADA FALLS	LOW	YES	MAINE	ME-02	SOMERSET	PITTSTON FARM		WEST BRANCH PENOBSC	HYDROELECTRIC	GRAVITY	1921	50	26740	764	10060	GREAT NORTHERN PAPER, INC.
2634.0401	2634	ME00206	ME	SEBOOMOOK	LOW	YES	MAINE	ME-02	SOMERSET	SEBOOMOOK		WEST BRANCH PENOBSC	HYDROELECTRIC	GRAVITY	1936	60	159000	621	45000	GREAT NORTHERN PAPER, INC.
2634.0201	2634	ME00211	ME	CAUCOMGOMOC	LOW	YES	MAINE	ME-02	PISCATAQUIS	CHESUNCOOK		CAUCOMGOMOC STREAM	HYDROELECTRIC	GRAVITY	1981	12	103800	2681	14750	GREAT NORTHERN PAPER, INC.
2634.0301	2634	ME00209	ME	RAGGED LAKE	LOW	YES	MAINE	ME-02	PISCATAQUIS	MILLINOCKET		RAGGED STREAM	HYDROELECTRIC	GRAVITY	1937	30	40170	1204	6880	GREAT NORTHERN PAPER, INC.
2662.0101	2662	CT00192	CT	SCOTLAND	HIGH	YES	CONNECTICUT	CT-02	WINDHAM	BALTIC	4	SHETUCKET RIVER	HYDROELECTRIC	BUTTRESS	1909	37	2000	481	60000	CONNECTICUT LIGHT & POWER C
2666.0101	2666	ME00199	ME	MEDWAY	LOW	NO	MAINE	ME-02	PENOBSCOT	MEDWAY		WEST BRANCH PENOBSC	HYDROELECTRIC	GRAVITY	1922	35	1980	513	18700	BANGOR HYDRO-ELECTRIC CO.
2671.0101	2671	ME00091	ME	MOOSEHEAD - EAST OU	SIGNIFICANT	NO	MAINE		PISCATAQUIS	THE FORKS	24	KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1835	20	1400000	1004	25100	KENNEBEC WATER POWER CO.
2671.0102	2671	ME00092	ME	MOOSEHEAD - WEST OU	SIGNIFICANT	NO	MAINE	ME-02	SOMERSET	THE FORKS	29	KENNEBEC RIVER	HYDROELECTRIC	GRAVITY	1835	18	1400000	830	3900	KENNEBEC WATER POWER CO.
2710.0101	2710	ME00138	ME	ORONO	LOW	NO	MAINE	ME-02	PENOBSCOT	ORONO		STILLWATER RIVER	HYDROELECTRIC	BUTTRESS	1917	15	1300	1180	43500	BANGOR HYDRO-ELECTRIC CO.
2712.0101	2712	ME00139	ME	STILLWATER	LOW	NO	MAINE	ME-02	PENOBSCOT	ORONO	3	STILLWATER RIVER	HYDROELECTRIC	GRAVITY	1902	25	3830	1712	25000	BANGOR HYDRO-ELECTRIC CO.
2721.0101	2721	ME00155	ME	HOWLAND	LOW	NO	MAINE	ME-02	PENOBSCOT	HOWLAND		PISCATAQUIS RIVER	HYDROELECTRIC	GRAVITY	1916	17	4370	660	42525	BANGOR HYDRO-ELECTRIC CO.
2727.0101	2727	ME00263	ME	ELLSWORTH	HIGH	YES	MAINE	ME-02	HANCOCK	ELLSWORTH		UNION RIVER	HYDROELECTRIC	BUTTRESS	1907	62	3040	377	17000	BANGOR HYDRO-ELECTRIC CO.
2727.0201	2727	ME00264	ME	GRAHAM	HIGH	YES	MAINE	ME-02	HANCOCK	ELLSWORTH	4	UNION RIVER	HYDROELECTRIC	GRAVITY	1924	43	145000	750	19000	BANGOR HYDRO-ELECTRIC CO.
2731.0101	2731	VT00047	VT	WEYBRIDGE WEST	LOW	NO	VERMONT	VT-01	ADDISON	WEYBRIDGE		OTTER CREEK	HYDROELECTRIC	GRAVITY	1944	30	5100	150	46000	CENTRAL VERMONT PUBLIC SER
2737.0101	2737	VT00194	VT	MIDDLEBURY LOWER EA	LOW	NO	VERMONT	VT-01	ADDISON	WEYBRIDGE	5	OTTER CREEK	HYDROELECTRIC	GRAVITY	1917	15	677	310	13700	CENTRAL VERMONT PUBLIC SER
2790.0102	2790	MA83042	MA	FISH LADDER	LOW	NO	MASSACHUSETTS		MIDDLESEX			MERRIMACK RIVER	HYDROELECTRIC	GRAVITY		23	4500	85		
2790.0108	2790	MA83048	MA	ELF FOREBAY WALL	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		NORTHERN CANAL	HYDROELECTRIC	GRAVITY	1848	20	4500	120		US NATIONAL PARK SERVICE
2790.0109	2790	MA83049	MA	ELF FISH PASSAGE	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		NORTHERN CANAL	HYDROELECTRIC	GRAVITY		15	4500	100		US NATIONAL PARK SERVICE
2790.0112	2790	MA00836	MA	SWAMP LOCKS	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		UPPER PAWTUCKET CAN	HYDROELECTRIC	GRAVITY	1823	15	4500	105	3367	BOOTT HYDROPOWER & GE CRE
2790.0121	2790	MA83054	MA	EAST CANAL SYPHON S	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		EASTERN CANAL	HYDROELECTRIC	GRAVITY		19	4500	36	500	US NATIONAL PARK SERVICE
2790.0119	2790	MA83006	MA	LAWRENCE STREET	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		WESTERN CANAL	HYDROELECTRIC	GRAVITY	1831	12	4500	100	1654	BOOTT HYDROPOWER & GE CRE

APPENDIX C National Inventory of Dams Database 3 of 10

FERC#	FERC#	NID #	STATE	DAM_NAME	HAZARD	EAP	STATE_NAME	CONG_DIST	COUNTY	NEAR_CITY	DIST_CIT	RIVER	PRM_PURPOSE	NID_DAMTYP	YEAR_C	NID_HEIGHT	NID_STOR	DAM_LENGTH	MAX_DISCH	OWNER
2790.0120	2790	MA00835	MA	LOWER PAWTUCKET LO	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		LOWER PAWTUCKET CAN	HYDROELECTRIC	GRAVITY	1822	20	4500	100	3400	BOOTT HYDROPOWER & GE CRE
2790.0101	2790	MA00837	MA	PAWTUCKET	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		MERRIMACK RIVER	HYDROELECTRIC	GRAVITY	1848	16	4500	1093	138000	BOOTT HYDROPOWER & GE CRE
2790.0103	2790	MA83043	MA	NORTH CANAL GATEHOU	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		MERRIMACK RIVER	HYDROELECTRIC	GRAVITY	1848	16	4500	1093		US NATIONAL PARK SERVICE
2790.0115	2790	MA83008	MA	MERRIMACK	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		MERRIMACK CANAL	HYDROELECTRIC	GRAVITY	1847	8	4500	18	440	BOOTT HYDROPOWER & GE CRE
2790.0118	2790	MA83007	MA	HALL STREET	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		WESTERN CANAL	HYDROELECTRIC	GRAVITY	1831	15	4500	115	1350	BOOTT HYDROPOWER & GE CRE
2790.0123	2790	MA83010	MA	BOOTT	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		EASTERN CANAL	HYDROELECTRIC	GRAVITY	1835	7	4500	40	1307	BOOTT HYDROPOWER & GE CRE
2790.0111	2790	MA00834	MA	GUARD LOCK & GATES	SIGNIFICANT	YES	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		MERRIMACK RIVER	HYDROELECTRIC	GRAVITY	1848	13	4500	160	3970	BOOTT HYDROPOWER & GE CRE
2790.0117	2790	MA83009	MA	ROLLING	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		MERRIMACK CANAL	HYDROELECTRIC	GRAVITY	1835	19	4500	18	226	BOOTT HYDROPOWER & GE CRE
2790.0104	2790	MA83044	MA	GRW - ISLAND SECTION	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		NORTHERN CANAL	HYDROELECTRIC	GRAVITY	1848	31	4500	1200		US NATIONAL PARK SERVICE
2790.0105	2790	MA83045	MA	GREAT RIVER WALL (GR	LOW	NO	MASSACHUSETTS		MIDDLESEX	LOWELL		NORTHERN CANAL	HYDROELECTRIC	GRAVITY	1848	28	4500	900		US NATIONAL PARK SERVICE
2790.0106	2790	MA83046	MA	GRW - WASTE GATE SEC	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		NORTHERN CANAL	HYDROELECTRIC	GRAVITY	1848	32	4500	65	2000	US NATIONAL PARK SERVICE
2790.0113	2790	MA83051	MA	HAMILTON WASTE GATE	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	LOWELL		UPPER PAWTUCKET CAN	HYDROELECTRIC	GRAVITY	1848	120	4500	10		US NATIONAL PARK SERVICE
2800.0101	2800	MA00234	MA	GREAT STONE	LOW	NO	MASSACHUSETTS	MA-05	ESSEX	LAWRENCE		MERRIMACK RIVER	HYDROELECTRIC	GRAVITY	1848	39	19900	943	124600	LAWRENCE HYDROELECTRIC ASS
2804.0101	2804	ME00287	ME	SWAN LAKE	LOW	NO	MAINE	ME-02	WALDO	SWANVILLE		GOOSE RIVER	HYDROELECTRIC	GRAVITY	1900	10	11270	250	90	GOOSE RIVER HYDRO, INC.
2804.0501	2804	ME00594	ME	CMP	LOW	NO	MAINE		WALDO	BELFAST	1	GOOSE RIVER	HYDROELECTRIC	BUTTRESS	1908	21	82	231		GOOSE RIVER HYDRO, INC.
2804.0201	2804	ME00286	ME	MASONS	LOW	NO	MAINE	ME-02	WALDO	BELFAST	3	GOOSE RIVER	HYDROELECTRIC	GRAVITY	1835	15	1800	86		GOOSE RIVER HYDRO, INC.
2804.0301	2804	ME00285	ME	KELLY	LOW	NO	MAINE	ME-02	WALDO	BELFAST	2	GOOSE RIVER	HYDROELECTRIC	GRAVITY	1835	15	270	135		GOOSE RIVER HYDRO, INC.
2808.0101	2808	ME00551	ME	BARKER'S MILL	LOW	NO	MAINE	ME-02	ANDROSCOGGIN	AUBURN		LITTLE ANDROSCOGGIN F	HYDROELECTRIC	BUTTRESS	1874	30	210	230	9400	CONSOLIDATED HYDRO MAINE, I
2809.0101	2809	ME00094	ME	AMERICAN TISSUE	HIGH	YES	MAINE	ME-01	KENNEBEC	GARDINER	1	COBBOSSEECONTEE STR	HYDROELECTRIC	GRAVITY	1900	24	120	227	5392	CONSOLIDATED HYDRO MAINE, I
2897.0101	2897	ME00066	ME	SACCARAPPA WEST	LOW	NO	MAINE	ME-01	CUMBERLAND	WESTBROOK		PRESUMPSCOT RIVER	HYDROELECTRIC	GRAVITY	1911	12	100	102	10000	S. D. WARREN COMPANY
2897.0102	2897	ME83037	ME	SACCARAPPA EAST	LOW	NO	MAINE	ME-01	CUMBERLAND	WESTBROOK		PRESUMPSCOT RIVER	HYDROELECTRIC	GRAVITY	1911	9	100	220	14000	S. D. WARREN COMPANY
2931.0101	2931	ME00067	ME	GAMBO	LOW	NO	MAINE	ME-01	CUMBERLAND	WINDHAM	2	PRESUMPSCOT RIVER	HYDROELECTRIC	GRAVITY	1911	24	1261	350	14600	S. D. WARREN COMPANY
2932.0101	2932	ME00325	ME	MALLISON FALLS	LOW	NO	MAINE	ME-01	CUMBERLAND	WESTBROOK	4	PRESUMPSCOT RIVER	HYDROELECTRIC	GRAVITY	1900	14	56	288	5682	S. D. WARREN COMPANY
2942.0101	2942	ME00068	ME	DUNDEE	HIGH	YES	MAINE	ME-01	CUMBERLAND	SOUTH WINDHAM	3	PRESUMPSCOT RIVER	HYDROELECTRIC	GRAVITY	1913	44	3337	1375	22800	S. D. WARREN COMPANY
2966.0101	2966	NH83001	NH	CLEMENT	LOW	NO	NEW HAMPSHIRE	NH-02	BELKNAP	FRANKLIN		WINNIPESAUKEE RIVER	HYDROELECTRIC	GRAVITY	1984	24	60	120	7750	KATSEKAS, J. & DIMOS, Z. & CLE
2972.0101	2972	RI03902	RI	WOONSOCKET FALLS	LOW	YES	RHODE ISLAND	RI-01	PROVIDENCE	WOONSOCKET		BLACKSTONE RIVER	HYDROELECTRIC	GRAVITY	1960	23	360	268	33000	WOONSOCKET, CITY OF
2985.0101	2985	MA00262	MA	WILLOW MILL	SIGNIFICANT	YES	MASSACHUSETTS	MA-01	BERKSHIRE	STOCKBRIDGE	1	HOUSATONIC RIVER	HYDROELECTRIC	GRAVITY	1872	12	50	180	10000	MEAD PAPER CORP.
2998.0101	2998	MA83011	MA	LAWRENCE STREET	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX			CONCORD RIVER	HYDROELECTRIC	GRAVITY		15	75	320	5640	CENTENNIAL ISLAND HYDROELEC
3011.0101	3011	RI03802	RI	ARCTIC	LOW	YES	RHODE ISLAND	RI-02	KENT	ARCTIC		SOUTH BRANCH PAWTUX	HYDROELECTRIC	GRAVITY	1885	30	530	120	4000	NATCO PRODUCTS CORP.
3023.0101	3023	RI83001	RI	TUPPERWARE	LOW	NO	RHODE ISLAND		PROVIDENCE	NORTH SMITHFIELD		BLACKSTONE RIVER	HYDROELECTRIC	GRAVITY	1904	13	366	210	12750	BLACKSTONE HYDRO INC.
3025.0101	3025	NH00299	NH	KELLEY'S FALLS	HIGH	YES	NEW HAMPSHIRE	NH-01	HILLSBOROUGH	MANCHESTER		PISCATAQUOG RIVER	HYDROELECTRIC	GRAVITY	1916	24	2290	220	21300	NH DEPT. OF ENVIR. SERV. - WAT
3037.0101	3037	RI83002	RI	ELIZABETH WEBBING MIL	LOW	NO	RHODE ISLAND	RI-01	PROVIDENCE	CENTRAL FALLS		BLACKSTONE RIVER	HYDROELECTRIC	GRAVITY	1891	11	180	156	8900	ROOSEVELT HYDRO ELECTRIC CO
3051.0101	3051	VT83006	VT	EAST BARNET	LOW	NO	VERMONT	VT-01	CALEDONIA			PASSUMPSIC RIVER	HYDROELECTRIC	GRAVITY	1984	12	400	290	8200	CENTRAL VERMONT PUBLIC SERV
3063.0101	3063	RI00401	RI	VALLEY FALLS	LOW	NO	RHODE ISLAND	RI-01	PROVIDENCE	CENTRAL FALLS		BLACKSTONE RIVER	HYDROELECTRIC	GRAVITY	1859	10	96	200	19310	BLACKSTONE FALLS ASSOCIATE
3127.0101	3127	MA83012	MA	WARE LOWER	LOW	NO	MASSACHUSETTS	MA-02	HAMPSHIRE	WARE		WARE RIVER	HYDROELECTRIC	GRAVITY	1890	18	145	116	5770	PIONEER HYDROPOWER, INC.
3127.0201	3127	MA00594	MA	WARE UPPER	LOW	NO	MASSACHUSETTS	MA-02	HAMPSHIRE	WARE		WARE RIVER	HYDROELECTRIC	GRAVITY	1890	34	985	250	5900	PIONEER HYDROPOWER, INC.
3128.0101	3128	NH00015	NH	LOCHMERE	LOW	NO	NEW HAMPSHIRE	NH-02	BELKNAP	EAST TILTON	1	WINNIPESAUKEE RIVER	HYDROELECTRIC	GRAVITY	1910	11	33280	223	2400	NH DEPT. OF ENVIR. SERV. - WAT
3133.0101	3133	NH00161	NH	ERROL	LOW	NO	NEW HAMPSHIRE	NH-02	COOS	ERROL	1	ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1887	25	119250	205	19700	UNION WATER POWER CO.
3180.0101	3180	NH00093	NH	GREGG'S FALLS	HIGH	YES	NEW HAMPSHIRE	NH-01	HILLSBOROUGH	PINARDVILLE	3	PISCATAQUOG RIVER	HYDROELECTRIC	GRAVITY	1917	60	4695	1360	32150	NH DEPT. OF ENVIR. SERV. - WAT
3185.0101	3185	NH00378	NH	WEBSTER	LOW	NO	NEW HAMPSHIRE	NH-02	MERRIMACK	PEMBROKE		SUNCOOK RIVER	HYDROELECTRIC	GRAVITY	1917	18	255	250	11010	PEMBROKE HYDRO CORPORATIO
3185.0201	3185	NH00377	NH	PEMBROKE	LOW	NO	NEW HAMPSHIRE	NH-02	MERRIMACK			SUNCOOK RIVER	HYDROELECTRIC	GRAVITY	1891	26	34	108	1848	PEMBROKE HYDRO CORPORATIO
3240.0201	3240	NH00348	NH	YORK	LOW	NO	NEW HAMPSHIRE	NH-02	MERRIMACK	CONCORD		CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1967	10	500	300	14150	NH DEPT. OF ENVIR. SERV. - WAT
3240.0101	3240	NH00614	NH	BRIAR PIPE	LOW	NO	NEW HAMPSHIRE	NH-02	MERRIMACK			CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1936	17	50	130	2100	BRIAR HYDRO ASSOCIATES
3265.0101	3265	NH00037	NH	STEELS POND	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	HILLSBORO		NORTH BRANCH CONTOO	HYDROELECTRIC	GRAVITY	1909	14	540	104	4300	NH DEPT. OF ENVIR. SERV. - WAT
3320.0101	3320	NH83003	NH	SUGAR RIVER I	SIGNIFICANT	YES	NEW HAMPSHIRE	NH-02	SULLIVAN	NEWPORT		SUGAR RIVER	HYDROELECTRIC	BUTTRESS	1928	18	70	175	2000	RUGER, WILLIAM B.
3342.0101	3342	NH83004	NH	ALLIED LEATHER FOREB	LOW	NO	NEW HAMPSHIRE	NH-02	MERRIMACK			CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1982	15	94	106		NEW HAMPSHIRE HYDRO ASSOC.
3342.0102	3342	NH83005	NH	PENACOOK LOWER FALL	LOW	NO	NEW HAMPSHIRE	NH-02	MERRIMACK			CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1982	15	94	134		NEW HAMPSHIRE HYDRO ASSOC.
3342.0103	3342	NH83006	NH	ALLIED LEATHER AUXILI	LOW	NO	NEW HAMPSHIRE	NH-02	MERRIMACK			CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1982	15	94	316	40000	NEW HAMPSHIRE HYDRO ASSOC.
3442.0101	3442	NH00116	NH	MINE FALLS	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	NASHUA	1	NASHUA RIVER	HYDROELECTRIC	GRAVITY	1889	20	2938	325	1700	NASHUA, CITY OF
3444.0101	3444	ME00391	ME	ROCKY GORGE UPPER	LOW	NO	MAINE	ME-01	YORK	SOUTH BERWICK	1	GREAT WORKS RIVER	HYDROELECTRIC	GRAVITY	1900	10	350	140	5600	ROCKY GORGE CORP.
3464.0101	3464	NH00144	NH	LOWER LISBON	LOW	NO	NEW HAMPSHIRE	NH-02	GRAFTON	BATH	1	AMMONOOSUC RIVER	HYDROELECTRIC	GRAVITY	1986	24	224	197	1200	WHITE MOUNTAIN HYDROELECTR
3472.0101	3472	CT83006	CT	WYRE - WYND	LOW	NO	CONNECTICUT		NEW LONDON	JEWETT CITY		QUINEBAUG RIVER	HYDROELECTRIC	GRAVITY	1913	14	3480	483	46000	SOUTHWIRE COMPANY
3562.0101	3562	ME83013	ME	BARKER MILL UPPER	LOW	NO	MAINE	ME-02	ANDROSCOGGIN	AUBURN	1	LITTLE ANDROSCOGGIN F	HYDROELECTRIC	GRAVITY	1987	24	665	230	19900	CONSOLIDATED HYDRO MAINE, I
3777.0101	3777	NH00396	NH	ROLLINSFORD	LOW	NO	NEW HAMPSHIRE		STRAFFORD	ROLLINSFORD		SALMON FALLS RIVER	HYDROELECTRIC	GRAVITY	1910	20	527	385	7000	ROLLINSFORD, TOWN OF
3820.0101	3820	NH00127	NH	SOMERSWORTH	LOW	NO	NEW HAMPSHIRE	NH-01	STRAFFORD	SOMERSWORTH		SALMON FALLS RIVER	HYDROELECTRIC	GRAVITY	1929	12	633	300	8000	GENERAL ELECTRIC COMPANY
3984.0101	3984	NH83049	NH	SOUTH MILTON	LOW	NO	NEW HAMPSHIRE		STRAFFORD	SOMMERSWORTH	10	SALMON FALLS RIVER	HYDROELECTRIC	GRAVITY	1893	15	62	160	10280	SALMON FALLS RIVER HYDRO CO
3985.0101	3985	NH00390	NH	NORTH ROCHESTER	SIGNIFICANT	YES	NEW HAMPSHIRE		STRAFFORD	ROCHESTER		SALMON FALLS RIVER	HYDROELECTRIC	GRAVITY	1903	27	700	1865	8100	TILLOTSON HEALTHCARE CORP.
4202.0101	4202	ME83014	ME	LOWELL TANNERY	LOW	NO	MAINE	ME-02	PENOBSCOT	EAST LOWELL		PASSADUMKEAG RIVER	HYDROELECTRIC	GRAVITY	1987	27	820	230	9623	CONSOLIDATED HYDRO MAINE, I
4254.0101	4254	NH00304	NH	EXETER RIVER	LOW	NO	NEW HAMPSHIRE	NH-01	ROCKINGHAM	EXETER		EXETER RIVER	HYDROELECTRIC	GRAVITY	1927	15	236	110	1125	PHILLIPS, PAUL T. II
4293.0101	4293	ME00111	ME	WAVERLY AVENUE	HIGH	YES	MAINE	ME-02	SOMERSET	PITTSFIELD	1	SEBASTICOOK RIVER	HYDROELECTRIC	GRAVITY	1893	11	7300	272	400	PITTSFIELD, TOWN OF
4318.0101	4318	NH00427	NH	NOONE MILLS	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	PETERBOROUGH	1	CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1938	14	315	200	6700	RIVER STREET ASSOCIATES
4320.0101	4320	MA00091	MA	SOUTH BARRE MILL PON	LOW	NO	MASSACHUSETTS	MA-01	WORCESTER	SOUTH BARRE		WARE RIVER	HYDROELECTRIC	GRAVITY	1981	20	260	315	17230	SOUTH BARRE HYDRO ELECTRIC
4413.0101	4413	ME00028	ME	MAHANEY	LOW	NO	MAINE	ME-02	FRANKLIN	RANGELEY	6	KENNEBAGO RIVER	HYDROELECTRIC	GRAVITY	1932	15	13600	232	6687	KENNEBAGO HYDRO CORP., INC.
4413.0201	4413	ME00317	ME	KENNEBAGO FALLS	LOW	NO	MAINE	ME-02	FRANKLIN	RANGELEY	6	KENNEBAGO RIVER	HYDROELECTRIC	GRAVITY	1915	15	315	160	1364	KENNEBAGO HYDRO CORP., INC.
4451.0101	4451	NH00126	NH	LOWER GREAT FALLS	SIGNIFICANT	YES	NEW HAMPSHIRE		STRAFFORD	ROLLINSFORD	1	SALMON FALLS RIVER	HYDROELECTRIC	GRAVITY	1984	36	464	270	7850	SOMERSWORTH, CITY OF
4542.0101	4542	NH83015	NH	BOSTON FELT	LOW	NO	NEW HAMPSHIRE		STRAFFORD	EAST ROCHESTER		SALMON FALLS RIVER	HYDROELECTRIC	GRAVITY	1983	12	406	150	100	BOSTON FELT COMPANY

APPENDIX C National Inventory of Dams Database 4 of 10

FERC#	FERC#	NID #	STATE	DAM_NAME	HAZARD	EAP	STATE_NAME	CONG_DIST	COUNTY	NEAR_CITY	DIST_CIT	RIVER	PRM_PURPOSE	NID_DAMTYP	YEAR_	NID_HEIGHT	NID_STOR	DAM_LENGTH	MAX_DISCH	OWNER
4609.0101	4609	NH00061	NH	AMMONOOSUC RIVER	LOW	NO	NEW HAMPSHIRE	NH-02	GRAFTON	BATH		AMMONOOSUC RIVER	HYDROELECTRIC	GRAVITY	1900	17	352	365	40000	NEW HAMPSHIRE WOOD PRODUC
4718.0101	4718	NH00547	NH	COCHECO FALLS	LOW	NO	NEW HAMPSHIRE	NH-01	STRAFFORD	DOVER		COCHECO RIVER	HYDROELECTRIC	GRAVITY	1930	9	330	150	2900	DOVER, CITY OF
5018.0101	5018	MA00752	MA	BEN SMITH	LOW	NO	MASSACHUSETTS	MA-05	MIDDLESEX	MAYNARD		ASSABET RIVER	HYDROELECTRIC	GRAVITY	1907	10	130	168	3054	DIGITAL EQUIPMENT CORP.
5062.0101	5062	CT00513	CT	QUINEBAUG	LOW	NO	CONNECTICUT	CT-02	WINDHAM	BROOKLYN		QUINEBAUG RIVER	HYDROELECTRIC	GRAVITY	1865	14	340	250	3640	QUINEBAUG PARTNERSHIP
5062.0201	5062	CT00550	CT	FIVE MILE POND	SIGNIFICANT	YES	CONNECTICUT	CT-02	WINDHAM	KILLINGLY		FIVE MILE RIVER	HYDROELECTRIC	GRAVITY	1855	17	312	145	5283	QUINEBAUG PARTNERSHIP
5073.0101	5073	ME83016	ME	BENTON FALLS	LOW	NO	MAINE	ME-01	KENNEBEC	BENTON FALLS	1	SEBASTICOOK RIVER	HYDROELECTRIC	GRAVITY	1987	27	1536	500	23000	WHITMAN, E. & BENTON FALLS A
5274.0101	5274	NH00059	NH	SQUAM LAKE	SIGNIFICANT	YES	NEW HAMPSHIRE	NH-02	GRAFTON	ASHLAND	1	SQUAM RIVER	HYDROELECTRIC	GRAVITY	1856	16	53000	100	1470	NH DEPT. OF ENVIR. SERV. - WAT
5307.0101	5307	NH00069	NH	WOODSVILLE	LOW	NO	NEW HAMPSHIRE	NH-02	GRAFTON	HAVERHILL		AMMONOOSUC RIVER	HYDROELECTRIC	GRAVITY	1827	23	280	450	18500	WOODSVILLE, TOWN OF
5362.0201	5362	ME83017	ME	KESSLEN	LOW	NO	MAINE	ME-01	YORK	KENNEBUNK		MOUSAM RIVER	HYDROELECTRIC	GRAVITY	1954	18	351	140	6200	KENNEBUNK LIGHT & POWER DIS
5362.0301	5362	ME83018	ME	TWINE MILL	LOW	NO	MAINE	ME-01	YORK	KENNEBUNK	3	MOUSAM RIVER	HYDROELECTRIC	GRAVITY	1980	18	146	180	2400	KENNEBUNK LIGHT & POWER DIS
5362.0401	5362	ME83019	ME	DANE PERKINS	LOW	NO	MAINE	ME-01	YORK	KENNEBUNK		MOUSAM RIVER	HYDROELECTRIC	GRAVITY	1979	12	240	65	1150	KENNEBUNK LIGHT & POWER DIS
5379.0101	5379	NH00020	NH	HADLEY FALLS	LOW	NO	NEW HAMPSHIRE	NH-01	HILLSBOROUGH	GOFFSTOWN		PISCATAQUOG RIVER	HYDROELECTRIC	GRAVITY	1922	20	270	230	6620	NH DEPT. OF ENVIR. SERV. - WAT
5399.0101	5399	ME00095	ME	NEW MILLS	HIGH	YES	MAINE	ME-01	KENNEBEC	GARDINER	1	COBBOSSEECONTEE STR	HYDROELECTRIC	GRAVITY	1885	21	20360	167	106	GARDINER WATER DISTRICT
5613.0101	5613	ME00156	ME	BROWNS MILL	LOW	NO	MAINE	ME-02	PISCATAQUIS	DOVER - FOXCROFT		PISCATAQUIS RIVER	HYDROELECTRIC	BUTTRESS	1856	22	78	265	7600	DOVER - FOXCROFT, TOWN OF
5735.0101	5735	NH00204	NH	HOPKINTON	LOW	NO	NEW HAMPSHIRE	NH-02	MERRIMACK	HOPKINTON		CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1890	10	820	325	7000	HOPKINTON, TOWN OF
5824.0101	5824	MA00109	MA	NORTH VILLAGE POND	LOW	NO	MASSACHUSETTS	MA-02	WORCESTER	WEBSTER		FRENCH RIVER	HYDROELECTRIC	GRAVITY	1914	13	324	168	3237	WEBSTER HYDRO ELECTRIC CO.,
5912.0101	5912	ME00157	ME	UPPER DAM	LOW	NO	MAINE	ME-02	PISCATAQUIS	DOVER - FOXCROFT		PISCATAQUIS RIVER	HYDROELECTRIC	GRAVITY	1908	12	300	182	22000	DOVER - FOXCROFT, TOWN OF
6066.0103	6066	CT83010	CT	DERBY CANAL WEIR	LOW	YES	CONNECTICUT	CT-05	NEW HAVEN			HOUSATONIC RIVER	HYDROELECTRIC	GRAVITY	1870	10	4400	60	500	MCCALLUM ENTERPRISES I, LTD.
6066.0101	6066	CT00026	CT	LAKE HOUSATONIC	HIGH	YES	CONNECTICUT	CT-05	FAIRFIELD	DERBY		HOUSATONIC RIVER	HYDROELECTRIC	GRAVITY	1870	25	4400	850	160000	MCCALLUM ENTERPRISES I, LTD.
6132.0101	6132	ME00580	ME	WEST WINTERPORT	LOW	NO	MAINE	ME-02	WALDO	FRANKFORT	7	MARSH STREAM	HYDROELECTRIC	GRAVITY	1948	12	125	105	1800	JONES, JOHN C.
6240.0101	6240	NH00549	NH	WATSON	LOW	NO	NEW HAMPSHIRE	NH-01	STRAFFORD	DOVER		COCHECO RIVER	HYDROELECTRIC	GRAVITY	1900	12	560	290	9170	WATSON ASSOCIATES
6338.0101	6338	NH00120	NH	PITTSFIELD MILL	HIGH	YES	NEW HAMPSHIRE	NH-01	MERRIMACK	PITTSFIELD		SUNCOOK RIVER	HYDROELECTRIC	GRAVITY	1921	22	572	422	4700	NH DEPT. OF ENVIR. SERV. - WAT
6440.0101	6440	NH00216	NH	LAKEPORT	LOW	NO	NEW HAMPSHIRE	NH-01	BELKNAP	LACONIA		WINNIPESAUKEE RIVER	HYDROELECTRIC	GRAVITY	1958	10	208000	225	4080	NH DEPT. OF ENVIR. SERV. - WAT
6522.0101	6522	MA00715	MA	CHICOPEE	LOW	NO	MASSACHUSETTS	MA-02	HAMPDEN	CHICOPEE		CHICOPEE RIVER	HYDROELECTRIC	GRAVITY	1898	10	450	314	24800	CHICOPEE, CITY OF
6597.0301	6597	NH00250	NH	PIERCE	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	BENNINGTON		CONTOOCOOK RIVER	HYDROELECTRIC	BUTTRESS	1921	12	51	420	13400	MONADNOCK PAPER MILLS, INC.
6597.0401	6597	NH00251	NH	PAPER MILL	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	BENNINGTON		CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1922	9	50	280	13400	MONADNOCK PAPER MILLS, INC.
6597.0101	6597	NH00248	NH	POWDER MILL	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	BENNINGTON	1	CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1924	21	8600	366	18200	MONADNOCK PAPER MILLS, INC.
6597.0201	6597	NH00249	NH	MONADNOCK	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	BENNINGTON		CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1923	22	240	500	13400	MONADNOCK PAPER MILLS, INC.
6618.0101	6618	ME00149	ME	FRANKFORT	LOW	NO	MAINE	ME-02	WALDO	FRANKFORT	1	MARSH STREAM	HYDROELECTRIC	GRAVITY	1840	14	240	250	2200	FRANKFORT, TOWN OF
6689.0101	6689	NH83023	NH	PENACOOK UPPER FALL	LOW	NO	NEW HAMPSHIRE	NH-02	MERRIMACK	BOSCAWEN		CONTOOCOOK RIVER	HYDROELECTRIC	GRAVITY	1987	16	114	267	35000	BRIAR HYDRO ASSOCIATES
6752.0101	6752	NH00465	NH	AVERY	LOW	NO	NEW HAMPSHIRE	NH-01	BELKNAP	LACONIA		WINNIPESAUKEE RIVER	HYDROELECTRIC	GRAVITY	1947	13	5500	114	5960	NH DEPT. OF ENVIR. SERV. - WAT
6756.0101	6756	NH00139	NH	CPM	SIGNIFICANT	YES	NEW HAMPSHIRE	NH-02	SULLIVAN	CLAREMONT	2	SUGAR RIVER	HYDROELECTRIC	GRAVITY	1921	29	36	145	7245	SWEETWATER HYDROELECTRIC,
7148.0101	7148	MA00126	MA	ASSABET	HIGH	YES	MASSACHUSETTS	MA-05	MIDDLESEX	ACTON		ASSABET RIVER	HYDROELECTRIC	GRAVITY	1921	13	122	478	8695	A & D HYDRO, INC.
7189.0101	7189	ME00266	ME	GREEN LAKE	LOW	YES	MAINE	ME-02	HANCOCK	ELLSWORTH	6	REEDS BROOK	HYDROELECTRIC	GRAVITY	1911	8	113000	273	2500	GREEN LAKE WATER POWER CO.
7254.0101	7254	MA00114	MA	QUINEBAUG RIVER POND	LOW	NO	MASSACHUSETTS	MA-02	WORCESTER	THOMPSON, CT.	2	QUINEBAUG RIVER	HYDROELECTRIC	GRAVITY	1919	17	240	259	1970	A & D HYDRO, INC.
7473.0101	7473	ME00320	ME	GILMAN STREAM	LOW	NO	MAINE	ME-02	SOMERSET	NEW PORTLAND		GILMAN STREAM	HYDROELECTRIC	GRAVITY	1911	8	2785	228	835	GILMAN STREAM HYDRO
7528.0101	7528	NH00129	NH	CANAAN	LOW	NO	NEW HAMPSHIRE	NH-02	COOS	STEWARTSTOWN		CONNECTICUT RIVER	HYDROELECTRIC	GRAVITY	1943	18	400	275	37000	PUBLIC SERVICE COMPANY OF NE
7590.0101	7590	NH00121	NH	JACKSON MILLS	SIGNIFICANT	YES	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	NASHUA		NASHUA RIVER	HYDROELECTRIC	GRAVITY	1920	32	470	330	12000	NASHUA HYDRO ASSOC.
7887.0101	7887	NH00104	NH	MINNEWAWA	HIGH	YES	NEW HAMPSHIRE	NH-02	CHESHIRE	MARLBOROUGH	2	MINNEWAWA BROOK	HYDROELECTRIC	ARCH	1932	63	160	265	1700	MARLBOROUGH HYDRO ASSOCIA
7890.0101	7890	NH00603	NH	WENDELL	LOW	NO	NEW HAMPSHIRE	NH-02	SULLIVAN	NEWPORT	3	SUGAR RIVER	HYDROELECTRIC	GRAVITY	1924	9	57	56	1310	NEW HAMPSHIRE FISH & GAME D
7920.0101	7920	NH00355	NH	WATERLOOM FALLS	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	GREENVILLE	3	SOUHEGAN RIVER	HYDROELECTRIC	GRAVITY	1980	18	925	205	1270	GREENWOOD, ALDEN T.
7921.0101	7921	NH00041	NH	OTIS FALLS	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	GREENVILLE		SOUHEGAN RIVER	HYDROELECTRIC	GRAVITY	1982	27	97	150	2450	GREENWOOD, ALDEN T.
8012.0101	8012	MA00634	MA	HUNTS POND	LOW	NO	MASSACHUSETTS	MA-01	WORCESTER	WINCHENDON		MILLERS RIVER	HYDROELECTRIC	GRAVITY	1936	15	133	184	4900	BEHRENS ENERGY SYSTEMS, INC
8093.0101	8093	MA00178	MA	METHUEN FALLS	HIGH	YES	MASSACHUSETTS	MA-05	ESSEX	METHUEN		SPICKETT RIVER	HYDROELECTRIC	GRAVITY	1895	23	210	188	1800	METHUEN FALLS HYDRO ELECTR
8277.0101	8277	ME00009	ME	OTIS	LOW	NO	MAINE	ME-02	FRANKLIN	LIVERMORE FALLS		ANDROSCOGGIN RIVER	HYDROELECTRIC	GRAVITY	1898	17	2620	840	68000	OTIS HYDROELECTRIC CO.
8405.0101	8405	NH00159	NH	GLEN ROAD	SIGNIFICANT	YES	NEW HAMPSHIRE	NH-02	GRAFTON	LEBANON		MASCOMA RIVER	HYDROELECTRIC	GRAVITY	1988	16	28	175	8600	MASCOMA HYDRO CORP.
8417.0101	8417	ME00187	ME	BRIDGE STREET	LOW	NO	MAINE	ME-01	CUMBERLAND	YARMOUTH		ROYAL RIVER	HYDROELECTRIC	GRAVITY	1873	8	106	224	4000	YARMOUTH, TOWN OF
8450.0101	8450	ME83024	ME	STONY BROOK	LOW	NO	MAINE	ME-02	OXFORD			STONY BROOK	HYDROELECTRIC	GRAVITY	1976	12	108	100	500	SMALL HYDRO EAST
8640.0101	8640	ME00277	ME	SEABRIGHT	HIGH	YES	MAINE	ME-01	KNOX	CAMDEN	1	MEGUNTICOOK RIVER	HYDROELECTRIC	GRAVITY	1900	22	1290	372	1400	SEABRIGHT HYDRO, INC.
8736.0101	8736	ME00110	ME	PIONEER	LOW	NO	MAINE	ME-02	SOMERSET	PITTSFIELD		WEST BRANCH SEBASTIC	HYDROELECTRIC	GRAVITY	1890	12	388	170	15000	PITTSFIELD, TOWN OF
8794.0101	8794	CT00399	CT	RIMMON POND	LOW	NO	CONNECTICUT	CT-05	NEW HAVEN	SEYMOUR		NAUGATUCK RIVER	HYDROELECTRIC	GRAVITY	1850	17	118	280	5092	SOUTHERN NEW HAMPSHIRE HYD
8895.0101	8895	MA00854	MA	TANNERY POND	LOW	NO	MASSACHUSETTS	MA-01	WORCESTER	WINCHENDON		MILLERS RIVER	HYDROELECTRIC	GRAVITY	1936	10	81	248	2904	BEHRENS ENERGY SYSTEMS, INC
8924.0101	8924	NH00312	NH	MCLANE	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	MILFORD		SOUHEGAN RIVER	HYDROELECTRIC	GRAVITY	1929	18	83	230	9400	MILFORD, TOWN OF
9100.0101	9100	MA00942	MA	RIVERDALE MILLS	LOW	NO	MASSACHUSETTS	MA-03	WORCESTER	NORTHBRIDGE		BLACKSTONE RIVER	HYDROELECTRIC	GRAVITY	1957	10	173	152	5400	KNOTT, JAMES M.
9282.0101	9282	NH00258	NH	HILLSBOROUGH MILL	LOW	NO	NEW HAMPSHIRE	NH-02	HILLSBOROUGH	WILTON		SOUHEGAN RIVER	HYDROELECTRIC	GRAVITY	1925	27	98	200	3300	MACDONALD, WINSLOW H.
9340.0201	9340	ME00045	ME	UPPER KEZAR FALLS #1	LOW	NO	MAINE		YORK	KEZAR FALLS		OSSIPEE RIVER	HYDROELECTRIC	GRAVITY	1910	11	145	196	3360	CENTRAL MAINE POWER CO.
9411.0101	9411	ME00295	ME	BISCOE FALLS	LOW	NO	MAINE	ME-02	OXFORD	SOUTH PARIS		LITTLE ANDROSCOGGIN F	HYDROELECTRIC	GRAVITY	1986	15	210	115	530	JOHN CROUCH JR. & SONS
10163.0101	10163	MA00932	MA	CRESTICON UPPER	LOW	NO	MASSACHUSETTS	MA-01	WORCESTER	ATHOL		MILLERS RIVER	HYDROELECTRIC	GRAVITY	1931	12	457	280	2300	L. P. ATHOL CORP.
10675.0101	10675	MA00721	MA	DWIGHT	LOW	YES	MASSACHUSETTS	MA-02	HAMPDEN	CHICOPEE	1	CHICOPEE RIVER	HYDROELECTRIC	GRAVITY	1860	24	423	327	21000	WESTERN MASSACHUSETTS ELE
10677.0101	10677	MA00724	MA	PUTTS BRIDGE	LOW	YES	MASSACHUSETTS	MA-02	HAMPDEN	LUDLOW	1	CHICOPEE RIVER	HYDROELECTRIC	GRAVITY	1918	22	1090	223	21000	WESTERN MASSACHUSETTS ELE
10678.0101	10678	MA00722	MA	INDIAN ORCHARD	HIGH	YES	MASSACHUSETTS	MA-02	HAMPDEN	SPRINGFIELD	1	CHICOPEE RIVER	HYDROELECTRIC	GRAVITY	1846	28	1800	401	71000	WESTERN MASSACHUSETTS ELE
10898.0101	10898	NH00140	NH	COY PAPER MILL	SIGNIFICANT	YES	NEW HAMPSHIRE	NH-02	SULLIVAN	CLAREMONT		SUGAR RIVER	HYDROELECTRIC	GRAVITY	1922	33	300	314	14000	SWEETWATER HYDROELECTRIC,
10981.0101	10981	ME83029	ME	BASIN MILLS	LOW	NO	MAINE	ME-02	PENOBSCOT	ORONO		PENOBSCOT RIVER	HYDROELECTRIC	GRAVITY		18	6600	1650	265000	BANGOR HYDRO-ELECTRIC CO.
11058.0101	11058	MA83026	MA	FITCHBURG PAPER MILL	SIGNIFICANT	NO	MASSACHUSETTS	MA-01	WORCESTER	FITCHBURG		NORTH NASHUA RIVER	HYDROELECTRIC	GRAVITY	1907	10	3	200	3160	PWA ROLAND DECOR, INC.
11132.0101	11132	ME00129	ME	EUSTIS	LOW	NO	MAINE	ME-02	FRANKLIN	EUSTIS		NORTH BRANCH DEAD RI	HYDROELECTRIC	GRAVITY	1952	17	720	240	11345	CONSOLIDATED HYDRO MAINE, I
11142.0101	11142	ME00183	ME	ESTES LAKE	HIGH	YES	MAINE	ME-01	YORK	KENNEBUNK	8	MOUSAM RIVER	HYDROELECTRIC	GRAVITY	1906	40	5550	726	9500	CONSOLIDATED HYDRO MAINE, I

APPENDIX C National Inventory of Dams Database 5 of 10

FERC#	FERC#	NID #	STATE	DAM_NAME	HAZARD	EAP	STATE_NAME	CONG_DIST	COUNTY	NEAR_CITY	DIST_CIT	RIVER	PRM_PURPOSE	NID_DAMTYP	YEAR_	NID_HEIGHT	NID_STOR	DAM_LENGTH	MAX_DISCH	OWNER
11143.0101	11143	CT00579	CT	BRUNSWICK	LOW	NO	CONNECTICUT	CT-02	WINDHAM	MOOSUP	1	MOOSUP RIVER	HYDROELECTRIC	GRAVITY	1891	19	258	160	3960	GLEN FALLS REALTY PARTNERSH
11163.0101	11163	NH00395	NH	SOUTH BERWICK	LOW	NO	NEW HAMPSHIRE		STRAFFORD	DOVER		SALMON FALLS RIVER	HYDROELECTRIC	GRAVITY	1916	18	641	290	14747	CONSOLIDATED HYDRO MAINE,
11168.0103	11168	CT83024	CT	DAYVILLE EMERGENCY	LOW	NO	CONNECTICUT	CT-02	WINDHAM	DAYVILLE		FIVE MILE RIVER	HYDROELECTRIC	GRAVITY	1925	8	110	37		WILLIAM PRYM, INC.
11313.0101	11313	NH00611	NH	APTHORP	SIGNIFICANT	YES	NEW HAMPSHIRE	NH-02	GRAFTON	LITTLETON		AMMONOOSUC RIVER	HYDROELECTRIC	GRAVITY	1936	24	280	235	14800	WHITE MOUNTAIN HYDROELECTR
11365.0101	11365	ME00038	ME	SWANS FALLS	LOW	NO	MAINE	ME-02	OXFORD	FRYEBURG	2	SACO RIVER	HYDROELECTRIC	GRAVITY	1923	10	535	630	50800	SWANS FALLS CORP.
11433.0101	11433	ME00119	ME	SANDY RIVER	LOW	NO	MAINE	ME-02	SOMERSET	NORRIDGEWOCK, STARKS		SANDY RIVER	HYDROELECTRIC	GRAVITY	1902	18	1400	400	12000	MADISON, TOWN OF, DEPT. OF E
11472.0101	11472	ME00109	ME	BURNHAM	SIGNIFICANT	YES	MAINE		WALDO	BURNHAM	2	SEBASTICOOK RIVER	HYDROELECTRIC	BUTTRESS	1929	32	1904	615	12200	CONSOLIDATED HYDRO MAINE,
11475.0101	11475	VT00224	VT	CARVER FALLS	LOW	NO	VERMONT		RUTLAND	WHITEHALL, NY		POULTNEY RIVER	HYDROELECTRIC	GRAVITY	1894	34	105	455	6900	CENTRAL VERMONT PUBLIC SERV
11478.0201	11478	VT00212	VT	SUCKER BROOK DIVERS	SIGNIFICANT	YES	VERMONT	VT-01	ADDISON	LAKE DUNMORE	3	SUCKER BROOK	HYDROELECTRIC	GRAVITY	1917	36	20	725	4180	CENTRAL VERMONT PUBLIC SERV
11478.0301	11478	VT00176	VT	SUGAR HILL	HIGH	YES	VERMONT	VT-01	ADDISON	LAKE DUNMORE	5	SUCKER BROOK	HYDROELECTRIC	GRAVITY	1931	61	1861	855	3032	CENTRAL VERMONT PUBLIC SERV
11478.0101	11478	VT00196	VT	SILVER LAKE	HIGH	YES	VERMONT	VT-01	ADDISON	LAKE DUNMORE	3	SUCKER BROOK	HYDROELECTRIC	BUTTRESS	1917	30	4445	284	550	CENTRAL VERMONT PUBLIC SERV
11482.0101	11482	ME00379	ME	MECHANIC FALLS	LOW	NO	MAINE	ME-02	ANDROSCOGGIN	MECHANIC FALLS		LITTLE ANDROSCOGGIN	HYDROELECTRIC	GRAVITY	1866	15	240	172	1000	CONSOLIDATED HYDRO MAINE,
11547.0101	11547	CT01677	CT	HALE	LOW	NO	CONNECTICUT	CT-02	WINDHAM	PUTNAM		QUINEBAUG RIVER	HYDROELECTRIC	GRAVITY	1965	23	65	100		SUMMIT HYDROPOWER

APPENDIX C National Inventory of Dams Database 6 of 10

OWN_TYPE	STATE_AGCY	FED_AGCY	NONFED	PURPOSE	DAM_TYPE	DAM_HEIGHT	NORM_STOF	MAX_STOF	SURF_ARE/	DRAIN_AREA	SPILL_TYPE	SPILL_WDTH	INSP_DATE	PHASEI_INS	FD_INSPECT	FD_REGULA	SUPP_FED	SUPP_DATE	SOURC_AGCY	SOURC_DATE	LONGITUD_X	LATITUDE_Y	FIPS_STATE	FIPS_CNTY
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	HR	CNPG	37	1300	2000	134	429	C	228	34828	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.12333	41.66333	9	9015
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	CNPG	12	33	51	7	191	U	290	34844	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.925	43.00333	33	33011
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	CNPG	14	30	490	13	307	U	174	34842	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.01333	43.60333	50	50021
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	CNPG	34	250	2122	23	749	U	170	34842	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.19667	44.07	50	50001
PUBLIC UTILITY		DOE FERC	NO	HR	PGMS	23	4500	4500	664				34926		DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004			25	
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	HR	CNPGRE	20	4500	4500	664				34926	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.32778	42.64861	25	25017
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	15	4500	4500	664				34926	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.32778	42.64861	25	25017
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	H	MSCNPG	80	10000	16000	600	746	U	267	34843	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.71833	43.59833	33	33009
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	H	MSPG	62	2500	3040	125	613	U	275	34844	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.43	44.545	23	23009
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	HR	CNPG	18	65	70	7	74	U	93	34878	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.15833	43.36667	33	33019
PUBLIC UTILITY		DOE FERC	NO	HR	MS	29	5000	5500	417	946	U	352	34626	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.63	44.53833	23	23011
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	MSPG	30	150	210	12	353	C	125	34807	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.23333	44.08667	23	23001
PUBLIC UTILITY		DOE FERC	NO	HR	MSPG	35	64000	89215	5043	69	C	24	34891	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.325	46.55667	23	23003
PUBLIC UTILITY		DOE FERC	NO	HR	MSPG	50	207000	275000	9700	722	U	284	34627	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.81333	45.66	23	23025
PUBLIC UTILITY		DOE FERC	NO	HR	MSPG	32	1904	1904	304	570	C	208	34857	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.415	44.72167	23	
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	10	7500	11270	1510	10	C	11	34423	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.99667	44.52167	23	23027
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	HR	CNPGRE	20	456	527	57	230	U	255	34288	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.81833	43.23833	33	
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	HR	CNPGRE	27	390	700	65	118	C	157	34934	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.98333	43.38	33	
PUBLIC UTILITY		DOE FERC	NO	H	CNPGRE	14	135	315	19	68	U	140	34458	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.96167	42.86	33	33011
PUBLIC UTILITY		DOE FERC	NO	HRC	CNPG	16	21000	53000	7173	57	U	22	34843	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.63	43.705	33	33009
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	10	380	820	110	437	U	270	34570	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.71667	43.22167	33	33013
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	22	500	572	20	131	U	181	34814	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.33	43.30667	33	33013
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	13	3700	5500	455	374	C	90	34816	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.46833	43.52833	33	33001
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPGRE	32	150	470	40	414	U	180	34900	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.465	42.76333	33	33011
PUBLIC UTILITY		DOE FERC	NO	H	CNPG	27	64	97	7	30	U	94	34926	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.81167	42.76667	33	33011
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGRE	18	47	83	6	138	U	188	34486	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.64667	42.83667	33	33011
PUBLIC UTILITY		DOE FERC	NO	H	CNPG	27	70	98	7	97	U	128	34927	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.72833	42.83833	33	33011
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	12	420	457	9	201	U	79	34604	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.21833	42.59167	25	25027
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNTC	40	4339	5550	474	99	U	586	34653	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.665	43.42333	23	23031
PUBLIC UTILITY		DOE FERC	NO	HS	MSCNPG	18	1050	1400	150	578	U	331	34809	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.9	44.73	23	23025
PUBLIC UTILITY		DOE FERC	NO	HS	MSCNPG	50	54	551	9	150	C	116	34668	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.12833	43.99167	50	50017
PUBLIC UTILITY		DOE FERC	NO	HS	MSCNPG	15	54	94	8	766	C	80	34899	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.63333	43.26667	33	33013
PUBLIC UTILITY		DOE FERC	NO	HS	MSPG	15	54	94	8	766	C	104	34899	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.63333	43.26667	33	33013
PUBLIC UTILITY		DOE FERC	NO	HS	MSPG	10	165800	208000	46720	363	U	72	34816	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.46583	43.54833	33	33001
PUBLIC UTILITY		DOE FERC	NO	HS	MSPG	16	70	114	11	766	C	235	34487	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.63333	43.3	33	33013
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	46	30000	55560	2804	5414	C	572	34667	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.44667	43.13833	33	33005
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	CNPG	70	16600	28000	2000	7163	C	120	34935	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.55167	42.61	25	25011
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	CNPG	62	16600	28000	2000	7163	C	480	34935	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.55333	42.61	25	25011
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	CNPG	35	16600	28000	2000	7163	C	120	34935	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.57833	42.58833	25	25011
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	CNPG	29	4320	8100	478	2854	U	710	34456	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.47	43.00333	33	33011
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	CNPGRE	58	18300	54000	2550	6266	C	600	34667	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.51333	42.77167	33	33005
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	RECNPG	25	9800	14100	543	2200	C	520	34968	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.06	44.32833	33	
PUBLIC UTILITY	PSB	DOE FERC	NO	H	RECNPG	25	600	2000	263	1595	U	260	34562	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.55	43.61333	23	23031
PUBLIC UTILITY	PSB	DOE FERC	NO	HR	RECNPG	75	2840	6340	136	700	C	51	34772	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.18333	44.63833	50	50007
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGCB	25	93	2025	11	690	C	126	34772	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.11833	44.63667	50	50007
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGCB	45	1080	3725	152	529	C	280	34772	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.99	44.65167	50	50011
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	54	1200	2280	130	2865	U	738	34968	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.20167	44.135	23	23001
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	42	251	2000	300	3430	U	270	34968	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.96861	43.91944	23	23005
PUBLIC UTILITY		DOE FERC	NO	H	RECNPG	31	60	94	8	1372	C	476	34863	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.175	44.46833	33	33007
PRIVATE		DOE FERC	NO	H	CNPG	40	5000	5100	1310	4200	U	1135	34514	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.58333	44.63167	23	23011
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	CNPG	43	248	818	38	237	C	111	34836	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.93833	42.72167	25	25011
PUBLIC UTILITY		DOE FERC	NO	HR	RECNPG	29	248	818	38	11	C	160	34836	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.95333	42.705	25	
PRIVATE		DOE FERC	NO	HP	CNPG	76	350	589	63	508	U	277	34837	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.70667	42.57333	25	25011
PRIVATE		DOE FERC	NO	HRP	CNPG	21	221	551	42	500	C	451	34837	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.73833	42.60167	25	25011
PUBLIC UTILITY		DOE FERC	NO	HRC	CNCBRE	30	120	195	22	1350	C	296	34920	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.16667	44.48667	33	33007
PRIVATE		DOE FERC	NO	H	CNPG	58	200	400	28	1361	C	315	34920	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.18833	44.44833	33	33007
PRIVATE		DOE FERC	NO	H	CNPG	40	2900	3110	419	2069	U	464	34802	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.545	44.535	23	23017
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	37	50	510	21	501	U	335	34933	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.73	42.59167	25	25011
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	25	350	425	24	3148	U	774	34513	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.88833	44.79167	23	23025
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	38	6000	14500	650	3148	U	630	34513	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.88833	44.79833	23	23025
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGCB	12	300	782	46	2490	U	599	34801	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.19167	44.47	23	23001
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	17	1800	2331	206	2475	U	703	34801	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.22333	44.50167	23	23007
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CN	18	50	524	25	237	C	93	34667	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.00833	44.48667	50	50005
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNCB	18	70	2548	15	413	C	255	34667	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.02167	44.39833	50	50005
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	11	70	494	18	424	C	248	34667	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.02667	44.375	50	50005
PRIVATE		DOE FERC	NO	HC	CNPGRE	20	620	830	73	1338	C	657	34919	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.16667	44.48667	33	33007

APPENDIX C National Inventory of Dams Database 7 of 10

OWN_TYPE	STATE_AGCY	FED_AGCY	NONFED	PURPOSE	DAM_TYPE	DAM_HEIGHT	NORM_STOF	MAX_STOF	SURF_AREA	DRAIN_AREA	SPILL_TYPE	SPILL_WDTH	INSP_DATE	PHASEI_INS	FD_INSPECT	FD_REGULAT	SUPP_FED	SUPP_DATE	SOURC_AGCY	SOURC_DATE	LONGITUD_X	LATITUDE_Y	FIPS_STATE	FIPS_CNTY
PRIVATE		DOE FERC	NO	HC	CNPGRE	37	4570	9340	530	1003	U	301	34643	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.65833	43.44833	33	33013
PRIVATE		DOE FERC	NO	HC	CNPGRE	20	17240	21500	278	1	N		34934	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.55	42.61667	25	25011
PRIVATE		DOE FERC	NO	HC	CNPGRE	9	17240	21500	278	1	U	538	34934	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.55	42.61667	25	25011
PRIVATE		DOE FERC	NO	HC	RECNPG	39	100	592	10	82	C	104	34668	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.59833	43.38167	50	50027
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	18	100	385	21	190	C	194	34668	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.46833	43.63167	50	50027
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	49	28	266	14	1703	U	90	34562	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.44667	43.49667	23	23031
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNMSVA	12	711	2500	359	1703	U	177	34562	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.45167	43.49833	23	23031
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	12	711	2500	359	1703	U	197	34562	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.45167	43.49833	23	23031
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	30	1000	2530	255	832	C	314	34563	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.79583	43.8525	23	
PRIVATE		DOE FERC	NO	H	CNPGRE	34	9175	13300	918	5300	U	945	34843	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.64639	44.94056	23	23019
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGMS	8	9175	13300	918	5300	U	286	34843	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.64639	44.94056	23	23019
PRIVATE		DOE FERC	NO	HC	CNPGRE	33	900	1440	68	205	C	30	34626	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.64333	44.54667	23	23011
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGRE	14	50	110	10	178	C	63	34808	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.71333	44.54667	23	23011
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	13	110000	118300	3600	177	C	104	34808	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.725	44.54	23	23011
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	20	600	1830	82	4228	U	710	34808	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.62667	44.54833	23	23011
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	140	74000	86100	1870	1391	C	293	34954	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.29667	41.44833	9	9009
PUBLIC UTILITY		DOE FERC	NO	HR	MSPG	22	1800	3120	120	784	U	195	34955	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.51167	41.67667	9	9005
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGOT	7	172000	218650	5600	40	N		34954	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.43833	41.56333	9	9005
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGRE	17	172000	218650	5600	40	N		34954	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.43833	41.50833	9	9005
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	83	26900	37200	1063	1542	C	735	34954	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.17167	41.38333	9	
PUBLIC UTILITY		DOE FERC	NO	H	CNPGRE	16	1135	3100	100	634	U	300	34955	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.37333	41.96333	9	9005
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	45	11250	17900	1125	5100	U	360	34486	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.65	45.25	23	23019
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	40	3900	6150	250	4270	C	755	34514	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.62167	44.56333	23	23011
PUBLIC UTILITY		DOE FERC	NO	HR	CNCBPG	50	21700	26740	2521	164	C	155	34549	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70	45.87333	23	23025
LOCAL GOVT		DOE FERC	NO	HR	CNPG	35	1500	1980	120	2120	U	343	34529	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.54667	45.60667	23	23019
PUBLIC UTILITY		DOE FERC	NO	HR	MSPG	25	3040	3830	300	7602	U	908	34843	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.68333	44.91	23	23019
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CN	17	3400	4370	270	1500	U	570	34486	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.65833	45.24	23	23019
PUBLIC UTILITY		DOE FERC	NO	H	CNPG	30	600	5100	59	750	C	20	34436	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.21667	44.06667	50	50001
PUBLIC UTILITY		DOE FERC	NO	H	CNPG	15	45	677	16	632	U	270	34926	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.17833	44.025	50	50001
PRIVATE		DOE FERC	NO	HC	CNPGRE	15	4500	4500	664		C	60	34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.315	42.64333	25	25017
PRIVATE		DOE FERC	NO	H	CNPG	12	11	100	10	569	U	102	34571	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.37	43.68	23	23005
PUBLIC UTILITY	DEP	DOE FERC	NO	HR	CNPG	9	11	100	10	569	U	220	34571	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.37	43.68	23	23005
PUBLIC UTILITY	DEP	DOE FERC	NO	HR	CNPG	24	1000	1261	71	497	U	250	34863	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.43833	43.74833	23	23005
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	24	20	60	5	482	C	78	34570	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.51667	43.5	33	33001
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	23	300	360	32	369	C	128	34596	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.51833	42	44	44007
PUBLIC UTILITY	DEP	DOE FERC	NO	HR	CNPG	24	1350	2290	129	214	U	192	34842	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.49667	42.99333	33	33011
PUBLIC UTILITY	DEP	DOE FERC	NO	HR	ERCN	12	136	400	25	500	C	176	34667	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.05	44.33333	50	50005
PUBLIC UTILITY		DOE FERC	NO	HR	PGMS	18	147	255	15	259	U	154	34487	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.45167	43.12833	33	33013
PUBLIC UTILITY	DEP	DOE FERC	NO	HR	CNPG	10	150	500	50	760	U	235	34899	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.61333	43.27	33	33013
PUBLIC UTILITY		DOE FERC	NO	H	CNPG	14	190	540	38	60	U	75	34900	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.96833	43.08	33	33011
PRIVATE		DOE FERC	NO	HRP	CNPG	15	54	94	8	766	U	310	34899	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.63333	43.26667	33	33013
PUBLIC UTILITY		DOE FERC	NO	HSR	RECNPG	10	141	350	43	85	C	103	34654	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.79667	43.22	23	23031
PUBLIC UTILITY		DOE FERC	NO	HSR	CNPGRE	24	96	224	64	280	C	16	34514	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.91333	44.215	33	33009
PUBLIC UTILITY		DOE FERC	NO	HRSC	CNCBRE	27	680	820	69	301	C	116	34892	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.46667	45.2	23	23019
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HS	CNPGRE	15	200	236	24	65	U	84	34652	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.94833	42.98167	33	33015
PRIVATE		DOE FERC	NO	HC	CNPG	15	8500	13600	1700	112	U	130	34556	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.76	45.10667	23	23007
PRIVATE		DOE FERC	NO	HC	CNPGRE	15	15	315	2	146	U	75	34556	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.77833	45.10333	23	23007
PRIVATE		DOE FERC	NO	HC	RECNPG	17	280	352	24	395	U	273	34969	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.97667	44.16667	33	33009
PRIVATE		DOE FERC	NO	HC	RECNPG	9	110	330	55	187	U	140	34933	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.875	43.19667	33	33017
PUBLIC UTILITY	DEP	DOE FERC	NO	HR	CBCNPG	23	226	280	18	420	U	300	34514	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.03333	44.15	33	33009
PUBLIC UTILITY		DOE FERC	NO	H	CNPG	18	224	351	20	125	C	132	34289	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.58333	43.41667	23	23031
PUBLIC UTILITY		DOE FERC	NO	HRSC	CNPGRE	18	104	146	12	125	C	172	34289	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.6	43.43333	23	23031
PUBLIC UTILITY		DOE FERC	NO	HRSC	CNPGRE	12	150	240	25	125	C	57	34289	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.61667	43.45	23	23031
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGCB	20	150	270	24	197	U	176	34568	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.59833	43.01833	33	33011
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	12	200	300	30	295	U	122	34528	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.23	45.18333	23	23021
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	10	4020	4400	320	1574	C	27	34857	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.1	41.33333	9	9009
PUBLIC UTILITY		DOE FERC	NO	HR	CNCB	12	100	125	50	134	U	90	34842	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.97167	44.61833	23	23027
PUBLIC UTILITY		DOE FERC	NO	HR	CNPGRE	12	236	560	54	500	U	240	34933	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.92167	43.21333	33	33017
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	9	25	50	5	191	U	142	34844	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.92667	43.00667	33	33011
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	29	24	36	2	252	U	91	34877	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.34667	43.37333	33	33019
		DOE FERC	NO	HRNPC	CN	17	201	240	31	268	U	199	34667	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.98167	42.05	25	25027
		DOE FERC	NO	HRNPC	CN	18	200	400	20	381	U	140	34921	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.53167	44.99833	33	33007
		DOE FERC	YES	HRNPC	CN	9	35	57	11	50	U	30	34878	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.10667	43.37833	33	33019
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HRNPC	CNPG	18	663	925	75	23	U	75	34926	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.83667	42.75	33	33011
		DOE FERC	YES	HRNPC	MS	15	120	133	13	54	U	97	34872	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.04833	42.67833	25	25027
PRIVATE		DOE FERC	NO	HRNPC	MSCN	17	1700	2620	115	2490	U	593	34801	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.20167	44.47833	23	23007

APPENDIX C National Inventory of Dams Database 8 of 10

OWN_TYPE	STATE_AGCY	FED_AGCY	NONFED	PURPOSE	DAM_TYPE	DAM_HEIGHT	NORM_STOF	MAX_STOF	SURF_ARE	DRAIN_AREA	SPILL_TYPE	SPILL_WDTH	INSP_DATE	PHASEI_INS	FD_INSPECT	FD_REGULA	SUPP_FED	SUPP_DATE	SOURC_AGC	SOURC_DATE	LONGITUD_X	LATITUDE_Y	FIPS_STATE	FIPS_CNTY
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HRNPC	MSCNOT	16	10	28	2	194	U	123	34877	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.305	43.635	33	33009
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HRNPC	MSPG	12	60	108	12	2	C	22	34471	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.76667	44.51667	23	23017
		DOE FERC	YES	HRNPC	MSPG	12	250	388	30	320	U	160	34512	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.38167	44.78667	23	23025
PRIVATE		DOE FERC	NO	HRNPC	MSPG	10	89	173	12	142	C	142	34666	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.64	42.13833	25	25027
PRIVATE		DOE FERC	NO	HRNPC	MSPG	11	130	145	10	416	U	176	34564	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.89167	43.80667	23	
PRIVATE		DOE FERC	NO	HRNPC	MSPG	22	715	1090	65	686	U	200	34969	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.48333	42.15667	25	25013
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HRNPC	MSPGOT	33	150	300	30	270	U	143	34877	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.37667	43.39	33	33019
PRIVATE		DOE FERC	NO	HRNPC	MSPGOT	18	5000	6600	325	7800	U	1640	34087	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.7	44.83333	23	23019
		DOE FERC	NO	HRNPC	MSREST	18	525	641	58	235	U	220	34288	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.81167	43.22667	33	
		DOE FERC	NO	HRNPC	MSST	24	210	280	20	205	U	180	34514	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.74667	44.30833	33	33009
		DOE FERC	NO	HRNPC	MSST	34	75	105	10	164	C	455	34493	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.30667	43.62667	50	
		DOE FERC	YES	HRNPC	MSST	8	142590		4625	57	C	55	34421	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.52833	44.06167	23	23015
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	MSPG	38	18600	22300	930	3894	C	507	34514	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.72167	44.765	23	23025
PRIVATE		DOE FERC	NO	H	CNMSPG	51	18600	22300	930	3894	C	245	34514	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.72167	44.765	23	23025
PRIVATE		DOE FERC	NO	H	CNPGCB	30	3500	4800	390	7800	U	760	34487	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.70167	44.83167	23	23019
PRIVATE		DOE FERC	NO	H	MSPG	15	812	1300	140	2300	U	617	34843	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.665	44.88333	23	23019
PRIVATE		DOE FERC	NO	H	MSPG	21	72	82	5	19	N		34423	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.99667	44.41667	23	
PRIVATE		DOE FERC	NO	H	CNCBPG	23	1300	1663	98	444	U	272	34862	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.45	43.80167	23	23005
PRIVATE		DOE FERC	NO	H	MSCNPG	13	2320	5440	347	1563	U	339	34856	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.61167	43.68667	23	23031
PRIVATE		DOE FERC	NO	H	CNPG	25	25		3	53	U	150	34862	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.185	44.12833	33	33003
PRIVATE		DOE FERC	NO	H	CNPG	59	55000	79800	3100	3375	C	521	34968	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.30333	43.66667	33	33009
PRIVATE		DOE FERC	NO	H	CNPG	170	46800	57700	1093	1635	U	801	34968	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.00167	44.325	33	33009
PRIVATE		DOE FERC	NO	H	MSCNPG	144	200000	223722	3490	1600	C	373	34968	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.88167	44.33667	33	33009
PRIVATE		DOE FERC	NO	HR	CNPGRE	165	72250	108000	3666	1355	C	272	34858	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.86667	45.46167	23	23025
PRIVATE		DOE FERC	NO	H	CNPG	40	6000	11520	740	690	C	387	34772	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.11333	44.64167	50	50007
LOCAL GOVT	RHODE ISLAND DEM	DOE FERC	NO	HSC	CNPG	99	55100	56100	2862	2863	C	370	34968	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.21	44.15333	23	23001
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	MSPG	48	467	1067	75	404	U	241	34837	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.745	42.62	25	25011
PRIVATE		DOE FERC	NO	HDO	MSOT	24	1950	2970	128	2111	C	366	34963	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.57667	45.60667	23	23019
PRIVATE	RHODE ISLAND DEM	DOE FERC	NO	H	MSPG	56	41956	56290	2048	2108	C	521	34963	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.60667	45.63333	23	23019
PRIVATE		DOE FERC	NO	H	MSPG	27	8100	14520	1344	1890	C	1086	34963	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.73	45.63833	23	23019
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HP	CNPG	20	45370	87670	8640	122	C	115	34961	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.73333	45.74167	23	23019
PRIVATE		DOE FERC	NO	H	MSPG	16	187100	214470	18250	417	C	45	34933	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-67.42833	45.56833	23	23029
PUBLIC UTILITY		DOE FERC	NO	H	CNPG	45	55785	69100	1664	3308	C	657	34960	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.41	45.57	23	23019
PRIVATE	RHODE ISLAND DEM	DOE FERC	NO	H	MSPG	75	25250	33500	488	1622	C	495	34856	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.56	43.575	23	23031
PRIVATE		DOE FERC	NO	H	MSPG	67	2320	5440	347	1563	N	164	34856	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.61167	43.68667	23	23031
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	MSPG	30	12300	13200	131	1572	U	334	34563	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.60333	43.65667	23	23031
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HRP	MSCNOT	73	710000	977000	29270	1422	C	480	34961	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.17667	45.88333	23	23021
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	OTERCN	17	35000	39400	2231	89	U	452	34445	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.87333	45.35	23	23025
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HRP	CNPGRE	53	1830	2565	46	346	U	652	34752	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.82667	42.16667	25	25013
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HR	CNPG	60	117800	159000	6838	526	C	429	34549	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.73333	45.91167	23	23025
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	MSPG	20	1080000	1400000	74200	1268	C	484	34627	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.715	45.58667	23	
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	18	1080000	1400000	74200	1268	C	50	34627	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.745	45.65167	23	23025
PRIVATE		DOE FERC	NO	H	MSPG	43	144670	145000	12200	452	C	70	34844	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.44167	44.59167	23	23009
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HR	CNPG	44	2900	3337	190	443	U	150	34864	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.45333	43.78	23	23005
PRIVATE		DOE FERC	NO	H	CNCB	60	3600	4695	138	200	U	472	34925	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.56833	43.01833	33	33011
PRIVATE		DOE FERC	NO	H	CNOT	20	115	260	23	104	U	310	34871	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.095	42.38667	25	25027
PRIVATE		DOE FERC	NO	H	CNOT	27	855	1536	83	860	C	50	34625	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.6	44.56667	23	23011
PRIVATE		DOE FERC	NO	H	CNPG	21	2400	8600	435	184	U	228	34844	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.925	42.99333	33	33011
LOCAL GOVT	NEW HAMPSHIRE WRD	DOE FERC	NO	HRS	MSCNPG	22	217	240	4	190	U	165	34844	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.92667	43	33	33011
PRIVATE		DOE FERC	NO	H	CNPG	22	970	1290	97	33	U	54	34842	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.08333	44.21667	23	23013
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	17	570	720	74	236	C	178	34809	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.47667	45.21833	23	23007
PRIVATE		DOE FERC	NO	HR	MSCNPG	10	450	535	150	446	U	455	34564	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.98333	44.03667	23	23017
PRIVATE		DOE FERC	NO	H	MSPG	16	960	2000	210	1494	C	205	34920	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.115	44.405	33	33007
LOCAL GOVT	NEW HAMPSHIRE WRD	DOE FERC	NO	HFRP	CNMSPG	11	2550	7300	850	313	U	183	34947	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.38667	44.795	23	23025
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HSP	MSPG	63	120	160	10	23	U	45	34948	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.18	42.91667	33	33005
PRIVATE		DOE FERC	NO	H	MSCNOT	20	1800	3120	120	784	U	131	34955	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.51167	41.675	9	9005
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNMSPG	36	26000	68900	2550				34968	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.60167	42.21333	25	
PRIVATE		DOE FERC	NO	HP	CNPG	19	4500	4500	664		U	15	34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.32556	42.64694	25	25017
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	12	4500	4500	664		C	65	34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.31389	42.65139	25	25017
LOCAL GOVT		DOE FERC	NO	H	CNTC	8	93	110	31		U		34283		DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.89167	41.85	9	9015
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNMSPG	22	10	78	4	352	U	160	34893	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.23	45.18	23	23021
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	CNPGRE	20	4500	4500	664		C	78	34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.30833	42.84333	25	25017
PRIVATE		DOE FERC	NO	H	CNPG	11	20800	33280	4264	428	C	160	34816	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.535	43.47333	33	33001
PRIVATE		DOE FERC	NO	H	CNPG	15	53	62	3	250	C	140	34570	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004			33	
LOCAL GOVT	NEW HAMPSHIRE WRD	DOE FERC	NO	H	MSCNPG	18	2700	5700	250	2427	U	550	34457	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.5	43.16667	33	33013
PRIVATE		DOE FERC	NO	H	MSOT	27	1600	2800	200	2901	U	814	34969	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.22167	44.10167	23	23001

APPENDIX C National Inventory of Dams Database 9 of 10

OWN_TYPE	STATE_AGCY	FED_AGCY	NONFED	PURPOSE	DAM_TYPE	DAM_HEIGHT	NORM_STOF	MAX_STOF	SURF_ARE/	DRAIN_AREA	SPILL_TYPE	SPILL_WDTH	INSP_DATE	PHASEI_INS	FD_INSPECT	FD_REGULA	SUPP_FED	SUPP_DATE	SOURC_AGCY	SOURC_DATE	LONGITUD_X	LATITUDE_Y	FIPS_STATE	FIPS_CNTY
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	9	1600	2800	200	2901	U	15	34969	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.16667	44.16667	23	23001
LOCAL GOV'T	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	9	1600	2800	200	2901	C	28	34969	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.16667	44.16667	23	23001
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	MSPG	24	108	120	3	220	U	100	34857	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.78333	44.23333	23	23011
PRIVATE	DEP	DOE FERC	NO	H	MSPG	14	31	56	7	503	U	263	34863	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.42	43.72833	23	23005
PRIVATE	DEP	DOE FERC	NO	H	MSPG	20	1970	2938	242	405	U	145	34900	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.50667	42.74833	33	33011
PRIVATE		DOE FERC	NO	H	CNPGRE	14	2900	3480	246	650	C	473	34458	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.08333	41.96667	9	
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HPP	CNMSPG	36	272	464	32	220	C	178	34935	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.86	43.26	33	
LOCAL GOV'T	NEW HAMPSHIRE WRD	DOE FERC	NO	HS	CNPG	13	183	324	47	84	U	178	34871	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.88167	42.06333	25	25027
LOCAL GOV'T		DOE FERC	NO	HR	CNPG	25	4020	4400	320	1574	U	675	34857	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.10333	41.325	9	9001
LOCAL GOV'T		DOE FERC	NO	HR	CNPG	14	200	240	20	166	U	200	34422	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.87333	44.61	23	23027
LOCAL GOV'T		DOE FERC	NO	HR	CNPG	10	51	81	9	54	U	138	34872	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.05333	42.68	25	25027
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HPP	CNPG	15	126	210	21	76	U	65	34808	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.51	44.22333	23	23017
LOCAL GOV'T		DOE FERC	NO	HS	MSPG	10	3	3	1	58	U	160	34688	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.85	42.56667	25	25027
LOCAL GOV'T		DOE FERC	NO	HP	MSCNCB	15	103	240	27	250	U	126	34598	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.39167	44.11167	23	23001
LOCAL GOV'T	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNMSPG	14	500		65	1250	C	350	34457	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.05	41.59667	9	9011
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	MSCNPG	15	15	75	20	284	N	310	34969	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.4	42.5	25	25017
LOCAL GOV'T		DOE FERC	NO	HC	CNPG	12	232	406	58	140	U	103	34654	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.93333	43.35	33	
PRIVATE		DOE FERC	NO	HC	CNPG	8	107000	113000	2989	58	U	80	34422	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-68.44333	44.62667	23	23009
PRIVATE	DEP	DOE FERC	NO	HC	MSCNPG	11	1650	4160	405	2805	U	590	34457	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.46667	43.10167	33	33013
PRIVATE		DOE FERC	NO	H	CNPG	30	26000	68900	2550	8309	U	1010	34968	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.60167	42.21333	25	
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	20	26000	68900	2550	8309	C	98	34968	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.6	42.2	25	25013
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HRS	CNMSPG	18	26000	68900	2550	8309	C	100	34968	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.6	42.2	25	25013
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HRC	CNOT	26	26000	68900	2550	8309	C	147	34968	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.6	42.2	25	25013
LOCAL GOV'T	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HCPR	MSPG	14	1600	2800	200	2901	C	57	34969	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.5	44.1	23	
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HS	CBCNPG	18	1600	2800	200	2901	C	40	34969	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.5	44.1	23	
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HS	CNPG	14	1600	2800	200	2901	C	15	34969	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.16667	44.18333	23	23001
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HS	CNPGRE	16	28	266	14	1703	U	275	34562	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.45167	43.49833	23	23031
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HS	CNPGRE	36	600	750	25	207	U	32	34626	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.65333	44.53333	23	23011
LOCAL GOV'T		DOE FERC	NO	H	MSCNPG	16	4500	4500	664	3979	U	1083	34926	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.33333	42.64833	25	25017
PRIVATE		DOE FERC	NO	H	CNOT	16	4500	4500	664				34926	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.33194	42.64917	25	25017
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HPP	CNMSPG	8	4500	4500	664		C	16	34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.31	42.65556	25	25017
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HS	CNPG	15	4500	4500	664		U	78	34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.31389	42.65139	25	25017
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	MSREOT	7	4500	4500	664		C	17	34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.31	42.65556	25	25017
PRIVATE		DOE FERC	NO	HPSRF	MSOT	39	18000	19900	655	4460	U	920	34793	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.16667	42.7	25	25009
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	CNPG	15	1620	1800	70	19	N		34423	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.00667	44.45667	23	23027
PRIVATE		DOE FERC	NO	H	OTCN	15	200	270	16	18	N		34423	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.00333	44.44	23	23027
PUBLIC UTILITY	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	12	50	50	13	244	U	102	34956	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.285	42.275	25	25003
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNMSPG	30	442	530	45	73	U	110	34282	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.52167	41.70667	44	44003
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNVA	13	305	366	40	261	U	200	34969	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004			44	
STATE	NEW HAMPSHIRE WRD	DOE FERC	NO	HRF	CNPG	11	150	180	26	473	C	140	34596	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.4	41.86667	44	44007
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	10	80	96	15	446	U	165	34596	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.39	41.89833	44	44007
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNMSPG	18	90	145	10	167	U	115	34753	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.23333	42.26667	25	25015
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	CNPG	34	746	985	40	167	U	115	34753	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.235	42.26167	25	25015
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	MSPG	26	30	34	1	259	U	77	34487	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.45333	43.13	33	33013
PRIVATE		DOE FERC	NO	H	CNPG	17	37	50	3	760	U	80	34899	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.60333	43.27333	33	33013
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	24	255	665	41	350	C	86	34807	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.23333	44.07917	23	23001
LOCAL GOV'T		DOE FERC	NO	HCFPR	MSPG	12	377	633	55	218	U	287	34570	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.86333	43.26333	33	33017
PRIVATE		DOE FERC	NO	HP	CNPG	10	63	130	19	105	U	166	34794	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.47	42.42667	25	25017
PRIVATE		DOE FERC	NO	HPR	CNPGRE	14	283	340	85	384	U	130	34751	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.885	41.80167	9	9015
LOCAL GOV'T		DOE FERC	NO	H	CNPG	17	260	312	65	77	U	135	34751	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.88667	41.80333	9	9015
PRIVATE	DEP	DOE FERC	NO	H	MSPG	21	14100	20360	1456	217	C	55	34856	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.79	44.22	23	23011
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	MSCNPG	10	310	450	120	714	C	256	34751	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.58167	42.16	25	25013
LOCAL GOV'T	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNMSPG	23	210	210	30	74	C	100	34794	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.19	42.72667	25	25009
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HSC	CNPG	8	70	106	9	140	C	140	34572	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.18333	43.80167	23	23005
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNMSPG	17	118	118	5	297	U	278	34928	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.07833	41.39333	9	9009
PRIVATE		DOE FERC	NO	H	CNPG	24	200	423	32	718	U	306	34970	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.6	42.15	25	25013
PRIVATE		DOE FERC	NO	H	MSCNPG	28	1050	1800	74	687	U	400	34970	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.50333	42.165	25	25013
PRIVATE	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	H	CNMSPG	19	215	258	43	77	U	150	34667	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.86	41.71667	9	9015
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	MSPG	24	590		40		U	325	34289	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.63667	43.41667	23	23031
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	CNPG	13	4500	4500	664	3979	C	158	34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.33	42.64333	25	25017
PUBLIC UTILITY	MA DEPT OF ENVIRONMENTAL	DOE FERC	NO	HR	MSPG	19	4500	4500	664		U	16	34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.31	42.65556	25	25017
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	13	122	122	30	123	U	476	34794	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.43167	42.44	25	25017
PUBLIC UTILITY		DOE FERC	NO	HR	CNPG	31	4500	4500	664		N		34926	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.33194	42.64833	25	25017
PRIVATE		DOE FERC	NO	H	MSCNPG	28	4500	4500	664				34926	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.1625	42.64944	25	
PRIVATE		DOE FERC	NO	H	CNPGRE	32	4500	4500	664		C	60	34926	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.32889	42.64861	25	25017
PRIVATE		DOE FERC	NO	H	CNMSPG	120	4500	4500	664				34927	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.32583	42.64333	25	25017

APPENDIX C National Inventory of Dams Database 10 of 10

OWN_TYPE	STATE_AGCY	FED_AGCY	NONFED	PURPOSE	DAM_TYPE	DAM_HEIGHT	NORM_STOF	MAX_STOF	SURF_AREA	DRAIN_AREA	SPILL_TYPE	SPILL_WDTH	INSP_DATE	PHASEI_INS	FD_INSPECT	FD_REGULA	SUPP_FED	SUPP_DATE	SOURC_AGCY	SOURC_DATE	LONGITUD_X	LATITUDE_Y	FIPS_STATE	FIPS_CNTY
PRIVATE	DEP	DOE FERC	NO	H	MSPG	8	1600	2785	790	100	C	72	34513	NO	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-70.025	44.92333	23	23025
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	23	65		13	289	C		34906		DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.91167	41.92667	9	9015
PRIVATE		DOE FERC		H	MSCN	25	80000	119250	7850	1045	C	72	34556	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-71.125	44.78833	33	33007
PRIVATE	NEW HAMPSHIRE WRD	DOE FERC	NO	H	CNPG	35	16600	28000	2000		N		34935		DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.57833	42.58833	25	25011
PRIVATE		DOE FERC	NO	HR	CNPGTC	22	1800	3120	120		C	9	34955		DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.51167	41.67667	9	9005
LOCAL GOV'T		DOE FERC	NO	H	CNMSPG	36	1	20	1	10	U	60	34927	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.04167	43.90167	50	50001
PRIVATE		DOE FERC	NO	H	CNCBRE	61	1240	1861	67	3	U	150	34927	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.005	43.915	50	50001
PUBLIC UTILITY	PSB	DOE FERC	NO	H	CNPG	30	3120	4445	110	1	U	8	34927	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-73.05333	43.89833	50	50001
PUBLIC UTILITY	PSB	DOE FERC,	NO	H	RECN	110	3593	5480	218	236	U	179	34836	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.93	42.73	25	25011
PUBLIC UTILITY	DEC	DOE FERC	NO	H	RECN	50	412	600	30	90	U	137	34835	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.93333	42.86667	50	50003
PUBLIC UTILITY	PSB	DOE FERC,	NO	H	RECNCB	110	57345	190000	1514	30	U	192	34835	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-72.95	42.96667	50	50025
PRIVATE		DOE FERC	NO	H	MSCNPG	155	208910	255000	3240	2619	C	430	34948	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.90667	45.07	23	23025
PRIVATE		DOE FERC	NO	HC	OTCNPG	45	4575	6700	446	2720	C	508	34858	YES	DOE FERC	DOE FERC	DOE FERC	35004	DOE FERC	35004	-69.87	44.96	23	23025

APPENDIX D Characteristics of NE and HQ Dams Used in this Study 1 of6

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
2441	453	CT	GREENVILLE	LOW	SHETUCKET RI	1888	15	453	65,630	410	15	10.671625	66935	TC	373	80	1264
2576	3120	CT	BULLS BRIDGE	SIGNIFICANT	HOUSATONIC R	1902	22	3120	49,059	203	22	10.98505	45000	CNPG	1800	120	784
2576	3120	CT	SPOONER	SIGNIFICANT	HOUSATONIC R	1902	20	3120	33,994	156	20	10.8955	45000	ERCN	1800	120	784
2576	3120	CT	BULLS BRIDGE CANAL SPILL	SIGNIFICANT	HOUSATONIC R	1902	22	3120	49,059	203	22	10.98505	2000	PG	1800	120	
2576	3120	CT	BULLS BRIDGE MOUNTAINSI	SIGNIFICANT	HOUSATONIC R	1902	22	3120	49,059	203	22	10.98505	150	PGMS	1800	120	
2576	218650	CT	ROCKY RIVER CANAL DIKE	HIGH	ROCKY RIVER	1902	20	218650	10,896	50	20	10.8955		RE	172000	5600	
2576	3120	CT	BULLS BRIDGE FOREBAY DIK	SIGNIFICANT	HOUSATONIC R	1903	39	3120	121,397	265	39	11.746225	1250	RE	1800	120	784
2576	37200	CT	STEVENSON	HIGH	HOUSATONIC R	1919	83	37200	1,423,069	1250	83	13.716325	70000	CNPG	26900	1063	1542
2576	218650	CT	ROCKY RIVER MAIN DAM	HIGH	ROCKY RIVER	1929	100	218650	1,378,258	952	100	14.4775		RE	172000	5600	40
2576	218650	CT	NORTH LANESVILLE DIKE	HIGH	ROCKY RIVER	1929	7	218650	13,067	181	7	10.313425		CNPG	172000	5600	40
2576	218650	CT	MIDDLE LANESVILLE DIKE	HIGH	ROCKY RIVER	1929	45	218650	90,292	167	45	12.014875		RE	172000	5600	40
2576	218650	CT	SOUTH LANESVILLE DIKE	HIGH	ROCKY RIVER	1929	17	218650	71,530	391	17	10.761175		CNPG	172000	5600	40
2576	218650	CT	DANBURY DIKE NO. 1	HIGH	ROCKY RIVER	1929	42	218650	435,612	873	42	11.88055		RE	172000	5600	40
2576	86100	CT	SHEPAUG	HIGH	HOUSATONIC R	1955	140	86100	3,215,957	1412	140	16.2685	180000	CNPG	74000	1870	1391
2576	218650	CT	DANBURY DIKE NO. 2	HIGH	HOUSATONIC R	1989	7	218650	9,385	130	7	10.313425		RE	172000	5600	
2597	3100	CT	FALLS VILLAGE	SIGNIFICANT	HOUSATONIC R	1913	16	3100	54,868	320	16	10.7164	38000	CNPG	1135	100	634
2662	2000	CT	SCOTLAND	HIGH	SHETUCKET RI	1909	37	2000	207,454	481	37	11.656675	60000	CBCNPG	1300	134	429
3472	3480	CT	WYRE - WYND	LOW	QUINEBAUG RI	1913	14	3480	71,859	483	14	10.62685	46000	MSCNPG	2900	246	650
5062	340	CT	QUINEBAUG	LOW	QUINEBAUG RI	1855	14	340	37,194	250	14	10.62685	3640	MSPG	283	85	384
5062	312	CT	FIVE MILE POND	SIGNIFICANT	FIVE MILE RIVE	1855	17	312	26,526	145	17	10.761175	5283	MSPG	260	65	77
6066	4400	CT	LAKE HOUSATONIC	HIGH	HOUSATONIC R	1870	25	4400	236,287	850	25	11.119375	160000	MSCNPG	4020	320	1574
6066	4400	CT	DERBY DIKE	LOW	HOUSATONIC R	1870	10	4400	41,791	400	10	10.44775		RE	4020	320	1574
6066	4400	CT	DERBY CANAL WEIR	LOW	HOUSATONIC R	1870	10	4400	6,269	60	10	10.44775	500	CNPG	4020	320	1574
6066	4400	CT	SHELTON CANAL DIKE	LOW	HOUSATONIC R	1870	25	4400	489,253	1760	25	11.119375	448	RE	4020	320	25
11143	258	CT	BRUNSWICK	LOW	MOOSUP RIVER	1891	19	258	32,986	160	19	10.850725	3960	MSPG	215	43	77
11168	110	CT	DAYVILLE DIKE	LOW	FIVE MILE RIVE	1925	14	110	297,552	2000	14	10.62685		RE	93	31	
11168	110	CT	DAYVILLE EMERGENCY SPILL	LOW	FIVE MILE RIVE	1925	8	110	3,066	37	8	10.3582		MSCN	93	31	
11168	110	CT	DAYVILLE WASTEWAY	LOW	FIVE MILE RIVE	1925	14	110	3,868	26	14	10.62685		STMS	93	31	
11547		CT	HALE	LOW	QUINEBAUG RI	1965	23	65	25,369	100	23	11.029825		OTCNPG	65	13	289
1889	28000	MA	TURNERS FALLS DIKE	LOW	CONNECTICUT	1905	10	28000	52,239	500	10	10.44775	15000	RE	16600	2000	7163
1889	28000	MA	MONTAGUE	SIGNIFICANT	CONNECTICUT	1915	62	28000	499,033	630	62	12.77605	280000	CNPG	16600	2000	7163
1889	28000	MA	CABOT SPILLWAY	LOW	CONNECTICUT	1915	35	28000	68,015	168	35	11.567125	15000	CNPG	16600	2000	7163
1889	28000	MA	CABOT STATION	LOW	CONNECTICUT	1916	35	28000	95,140	235	35	11.567125		PGMS	16600	2000	
1889	28000	MA	GILL	SIGNIFICANT	CONNECTICUT	1970	70	28000	453,263	493	70	13.13425	280000	CNPG	16600	2000	7163
2004	68900	MA	OVERFLOW NO. 1	LOW	CONNECTICUT	1850	30	68900	283,808	834	30	11.34325	3364	MSPGRE	26000	2550	
2004	68900	MA	OVERFLOW NO. 2	LOW	HOLYOKE CAN	1860	20	68900	21,791	100	20	10.8955	2615	MSPG	26000	2550	8309
2004	68900	MA	OVERFLOW NO. 3	LOW	HOLYOKE CAN	1860	18	68900	20,812	107	18	10.80595	1935	MSPG	26000	2550	8309
2004	68900	MA	OVERFLOW NO. 4	LOW	HOLYOKE CAN	1891	26	68900	43,540	150	26	11.16415	950	MSPG	26000	2550	8309
2004	68900	MA	HOLYOKE DAM	HIGH	CONNECTICUT	1900	30	68900	347,103	1020	30	11.34325	300000	MSPG	26000	2550	8309
2004	68900	MA	CANAL GATE HOUSE	SIGNIFICANT	CONNECTICUT	1900	36	68900	75,245	180	36	11.6119		MS	26000	2550	
2323	818	MA	DEERFIELD NO. 5 - CANAL	LOW	DEERFIELD RIV	1910	39	818	3,060,585	6681	39	11.746225		RE	248	38	237
2323	818	MA	DEERFIELD NO. 5 - CANAL	LOW	DEERFIELD RIV	1910	33	818	541,627	1430	33	11.477575		RE	248	38	237
2323	818	MA	DEERFIELD NO. 5 - CANAL	LOW	DEERFIELD RIV	1910	16	818	332,466	1939	16	10.7164		RE	248	38	237
2323	551	MA	DEERFIELD NO. 3	LOW	DEERFIELD RIV	1912	21	551	109,129	475	21	10.940275	23300	CNPG	221	42	500
2323	551	MA	DEERFIELD NO. 3 - FOREBAY	LOW	DEERFIELD RIV	1912	23	551	253,686	1000	23	11.029825		RE	221	42	500
2323	1067	MA	DEERFIELD NO. 4	LOW	DEERFIELD RIV	1912	48	1067	297,412	510	48	12.1492	19100	CNPGRE	467	75	404
2323	1067	MA	DEERFIELD NO. 4 - FOREBAY	LOW	DEERFIELD RIV	1912	20	1067	137,283	630	20	10.8955		RE	467	75	404
2323	589	MA	DEERFIELD NO. 2	SIGNIFICANT	DEERFIELD RIV	1913	76	589	455,323	447	76	13.4029	31200	CNPG	350	63	508
2323	5480	MA	SHERMAN	HIGH	DEERFIELD RIV	1927	110	5480	1,669,688	1017	110	14.92525	87000	RECNPG	3593	218	236
2323	818	MA	DEERFIELD NO. 5	LOW	DEERFIELD RIV	1992	43	818	77,431	151	43	11.925325	35800	CNPG	248	38	237

APPENDIX D Characteristics of NE and HQ Dams Used in this Study 2 of6

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
2323	818	MA	DEERFIELD NO. 5 - DUNBAR	LOW	DUNBAR BROO	1993	29	818	52,425	160	29	11.298475	6800	CNPG	248	38	11
2334	510	MA	GARDNERS FALLS	LOW	DEERFIELD RIVE	1904	37	510	145,347	337	37	11.656675	65250	CNPG	50	21	501
2485	21500	MA	NORTHFIELD MOUNTAIN	HIGH	CONNECTICUT	1972	144	21500	26,526,689	11200	144	16.4476		ERRE	17240	278	1
2485	21500	MA	NORTHFIELD MT. - UPPER R	LOW	CONNECTICUT	1972	9	21500	51,588	551	9	10.402975	11400	CNPG	17240	278	1
2485	21500	MA	NORTHFIELD MT. - UPPER R	HIGH	CONNECTICUT	1973	20	21500	107,430	493	20	10.8955		CNPG	17240	278	1
2608	200	MA	WEST SPRINGFIELD	LOW	WESTFIELD RIV	1840	18	200	106,979	550	18	10.80595	4800	TCCN	200	20	512
2631	2565	MA	WORONOCO	LOW	WESTFIELD RIV	1938	53	2565	967,265	1475	53	12.373075	210000	CNPGRE	1830	46	346
2669	*6800*	MA	*BEAR SWAMP - NORTH DIKE*	LOW	*DEERFIELD RIVE*	*1974*	*155*	*6800*	*3,602,487*	*1372*	*155*	*16.940125*	*9900*	ERRE	*5100*	*118*	1
2669	6800	MA	BEAR SWAMP - DIKE 'A'	LOW	DEERFIELD RIVE	1974	23	6800	89,297	352	23	11.029825		ERRE	5100	118	1
2669	6800	MA	BEAR SWAMP - EAST DIKE	HIGH	DEERFIELD RIVE	1974	50	6800	482,819	789	50	12.23875		ERRE	5100	118	1
2669	6800	MA	BEAR SWAMP - SOUTH DIKE	HIGH	DEERFIELD RIVE	1974	140	6800	6,292,981	2763	140	16.2685		ERRE	5100	118	1
2669	7580	MA	FIFE BROOK	HIGH	DEERFIELD RIVE	1974	130	7580	1,851,028	900	130	15.82075	84200	ERREPG	5300	152	250
2800	19900	MA	GREAT STONE	LOW	MERRIMACK RI	1848	39	19900	431,991	943	39	11.746225	124600	MSPG	18000	655	4460
2801	570	MA	GLENDALE	LOW	HOUSATONIC R	1906	26	570	52,248	180	26	11.16415	9000	PG	87	40	272
2985	50	MA	WILLOW MILL	SIGNIFICANT	HOUSATONIC R	1872	12	50	22,761	180	12	10.5373	10000	MSPG	50	13	244
3127	145	MA	WARE LOWER	LOW	WARE RIVER	1890	18	145	22,563	116	18	10.80595	5770	MSPG	90	10	167
8093	210	MA	METHUEN FALLS	HIGH	SPICKETT RIVE	1895	23	210	47,693	188	23	11.029825	1800	MSPG	210	30	74
9100	173	MA	RIVERDALE MILLS	LOW	BLACKSTONE F	1957	10	173	15,881	152	10	10.44775	5400	CNPG	89	12	142
2142	108000	ME	HARRIS	HIGH	KENNEBEC RIVE	1955	165	108000	5,781,034	2015	165	17.387875	22000	CNPGRE	72250	3666	1355
2194	2000	ME	BAR MILLS	LOW	SACO RIVER	1956	25	2000	111,194	400	25	11.119375	16320	CNPG	600	263	1595
2283	2280	ME	DEER RIPS	LOW	ANDROSCOGGI	1903	54	2280	629,660	939	54	12.41785	2000	CNPG	1200	130	2865
2283	56100	ME	GULF ISLAND	HIGH	ANDROSCOGGI	1926	99	56100	3,554,953	2488	99	14.432725	50000	CNPGRE	55100	2862	2863
2284	2000	ME	BRUNSWICK	LOW	ANDROSCOGGI	1982	42	2000	301,885	605	42	11.88055	20000	CNPG	251	300	3430
2302	2800	ME	BATES WEIR	LOW	LEWISTON CR	1859	14	2800	10,563	71	14	10.62685	1054	MSPG	1600	200	2901
2302	2800	ME	RED SHOP WEIR	LOW	LEWISTON CR	1859	18	2800	11,670	60	18	10.80595	1573	MSPG	1600	200	2901
2302	2800	ME	GULLY BROOK LOWER	LOW	LEWISTON CAN	1859	9	2800	8,426	90	9	10.402975	1200	MSCNPG	1600	200	2901
2302	2800	ME	ANDROSCOGGIN WEIR	LOW	LEWISTON CAN	1859	9	2800	2,996	32	9	10.402975	480	MSCNPG	1600	200	2901
2302	2800	ME	GREAT STONE	HIGH	ANDROSCOGGI	1865	27	2800	289,022	955	27	11.208925	8050	MSCNPG	1600	200	2901
2302	2800	ME	CONTINENTAL WEIR	LOW	LEWISTON CR	1920	14	2800	4,463	30	14	10.62685	1030	MSPG	1600	200	2901
2312	2244	ME	GREAT WORKS	LOW	PENOBSCOT RI	1914	20	2244	236,650	1086	20	10.8955	62200	TCERPG	1600	160	6670
2322	5100	ME	SHAWMUT	LOW	KENNEBEC RIVE	1912	40	5100	698,027	1480	40	11.791	12540	CNPG	5000	1310	4200
2325	22300	ME	WESTON NORTH CHANNEL	LOW	KENNEBEC RIVE	1921	38	22300	235,223	529	38	11.70145	143000	CNPGCB	18600	930	3894
2325	22300	ME	WESTON SOUTH CHANNEL	LOW	KENNEBEC RIVE	1921	51	22300	245,572	392	51	12.283525	51500	CNPGCB	18600	930	3894
2329	255000	ME	WYMAN	HIGH	KENNEBEC RIVE	1930	155	255000	8,018,947	3054	155	16.940125	59630	RECNPG	208910	3240	2619
2333	183	ME	RUMFORD FALLS MIDDLE DA	LOW	ANDROSCOGGI	1892	20	183	93,265	428	20	10.8955	132500	TCER	141	21	2080
2333	3110	ME	RUMFORD FALLS UPPER DA	SIGNIFICANT	ANDROSCOGGI	1918	40	3110	247,139	524	40	11.791	121900	CNPG	2900	419	2069
2335	6700	ME	WILLIAMS	LOW	KENNEBEC RIVE	1939	45	6700	367,655	680	45	12.014875	48790	RECNPG	4575	446	2720
2364	425	ME	ABENAKI	LOW	KENNEBEC RIVE	1922	25	425	277,984	1000	25	11.119375	126000	CNPG	350	24	3148
2365	14500	ME	ANSON	LOW	KENNEBEC RIVE	1923	38	14500	380,180	855	38	11.70145	90000	CNPG	6000	650	3148
2367	2025	ME	CARIBOU	LOW	AROOSTOOK R	1889	24	2025	133,427	502	24	11.0746	63000	TCERCN	1821	162	1943
2367	29033	ME	MILLINOCKET LAKE	LOW	MILLINOCKET S	1943	11	29033	26,315	228	11	10.492525	2735	TCER	22900	2788	70
2368	89215	ME	SQUA PAN	HIGH	SQUA PAN STR	1928	35	89215	236,837	585	35	11.567125	5300	CNCBRE	64000	5043	69
2375	11560	ME	RILEY	LOW	ANDROSCOGGI	1897	23	11560	202,949	800	23	11.029825	66000	TCER	3600	578	2440
2375	782	ME	LIVERMORE FALLS	LOW	ANDROSCOGGI	1908	12	782	106,595	843	12	10.5373	65000	CNPG	300	46	2490
2375	2331	ME	JAY	LOW	ANDROSCOGGI	1912	17	2331	145,803	797	17	10.761175	55000	CNPG	1800	206	2475
2389	25000	ME	EDWARDS	HIGH	KENNEBEC RIVE	1870	42	25000	520,938	1044	42	11.88055	87000	TCER	16985	1143	5550
2403	4800	ME	VEAZIE	LOW	PENOBSCOT RI	1913	30	4800	286,530	842	30	11.34325	100500	CNPGCB	3500	390	7800
2458	14520	ME	STONE DAM	HIGH	WEST BRANCH	1900	27	14520	381,933	1262	27	11.208925	109000	CNPGRE	8100	1344	1890
2458	56290	ME	DOLBY	HIGH	WEST BRANCH	1906	56	56290	977,078	1395	56	12.5074	75000	CNPGRE	41956	2048	2108
2458	2970	ME	EAST MILLINOCKET	LOW	WEST BRANCH	1907	24	2970	192,166	723	24	11.0746	75500	CNPGRE	1950	128	2111

APPENDIX D Characteristics of NE and HQ Dams Used in this Study 3 of6

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
2458	87670	ME	MILLINOCKET LAKE	HIGH	MILLINOCKET S	1910	20	87670	138,373	635	20	10.8955	7000	CNPGRE	45370	8640	122
2458	392680	ME	NORTH TWIN	HIGH	WEST BRANCH	1934	35	392680	425,497	1051	35	11.567125	72000	RECNPG	346000	17790	1877
2519	1663	ME	NORTH GORHAM	HIGH	PRESUMPSCOT	1901	23	1663	229,078	903	23	11.029825	1320	CNPGMS	1300	98	444
2520	69100	ME	MATTACEUNK	HIGH	PENOBSCOT RI	1939	45	69100	632,583	1170	45	12.014875	125000	CNPGRE	55785	1664	3308
2527	33500	ME	SKELTON	HIGH	SACO RIVER	1948	75	33500	1,698,152	1695	75	13.358125	69600	CNPGRE	25250	488	1622
2528	266	ME	WEST CHANNEL DAM	LOW	SACO RIVER	1895	16	266	56,583	330	16	10.7164	2250	MSPG	28	14	1703
2528	2500	ME	SPRINGS	LOW	SACO RIVER	1925	12	2500	34,014	269	12	10.5373	3405	CNPG	711	359	1703
2528	2500	ME	BRADBURY	LOW	SACO RIVER	1929	12	2500	25,922	205	12	10.5373	2060	CNPG	711	359	1703
2528	266	ME	CATARACT	LOW	SACO RIVER	1938	49	266	98,588	165	49	12.193975	5625	CNPG	28	14	1703
2529	5440	ME	BONNY EAGLE	SIGNIFICANT	SACO RIVER	1911	67	5440	682,860	784	67	12.999925		CNPGRE	2320	347	1563
2529	5440	ME	NEW RIVER CHANNEL DAM	SIGNIFICANT	SACO RIVER	1911	13	5440	48,148	350	13	10.582075	17000	CNPGOT	2320	347	1563
2530	2530	ME	HIRAM	LOW	SACO RIVER	1917	30	2530	147,009	432	30	11.34325	16475	CNPG	1000	255	832
2531	13200	ME	WEST BUXTON	LOW	SACO RIVER	1907	30	13200	218,811	643	30	11.34325	4930	CNPGRE	12300	131	1572
2534	13300	ME	MILFORD	LOW	PENOBSCOT RI	1906	34	13300	548,464	1400	34	11.52235	70265	CNPG	9175	918	5300
2534	13300	ME	GILMAN FALLS	LOW	STILLWATER RI	1906	8	13300	39,361	475	8	10.3582	35132	CNPG	9175	918	5300
2552	5500	ME	FORT HALIFAX	LOW	SEBASTICOOK I	1908	29	5500	154,981	473	29	11.298475	46500	CNCBPG	5000	417	946
2555	1440	ME	AUTOMATIC	LOW	MESSALONSKE	1924	33	1440	30,680	81	33	11.477575	1910	CNPG	900	68	205
2556	750	ME	UNION GAS	LOW	MESSALONSKE	1924	36	750	143,384	343	36	11.6119	2460	MSPG	600	25	207
2557	1500	ME	RICE RIPS	SIGNIFICANT	MESSALONSKE	1908	23	1500	55,811	220	23	11.029825	4945	CBPGRE	1000	87	185
2559	110	ME	OAKLAND	LOW	MESSALONSKE	1901	14	110	17,109	115	14	10.62685	200	CNPG	50	10	178
2559	118300	ME	MESSALONSKEE LAKE	HIGH	MESSALONSKE	1992	13	118300	22,836	166	13	10.582075	2400	CNPG	110000	3600	177
2572	977000	ME	RIPOGENUS	HIGH	WEST BRANCH	1916	73	977000	770,042	795	73	13.268575	92800	CNPGRE	710000	29270	1422
2574	1830	ME	LOCKWOOD	LOW	KENNEBEC RIVE	1919	20	1830	196,991	904	20	10.8955	123000	CNPG	600	82	4228
2600	17900	ME	RUN AROUND	LOW	MERRILL BROOI	1894	15	17900	32,015	200	15	10.671625	2000	RE	11250	1125	5100
2600	17900	ME	WEST ENFIELD	LOW	PENOBSCOT RI	1988	45	17900	359,004	664	45	12.014875	96000	CNPG	11250	1125	5100
2611	6150	ME	HYDRO - KENNEBEC	LOW	KENNEBEC RIVE	1989	40	6150	400,894	850	40	11.791	667000	CNPG	3900	250	4270
2615	275000	ME	BRASSUA	HIGH	MOOSE RIVER	1927	50	275000	1,094,756	1789	50	12.23875	27000	CNCBRE	207000	9700	722
2618	639580	ME	WEST GRAND LAKE	SIGNIFICANT	WEST BRANCH	1836	13	639580	66,720	485	13	10.582075	5450	TCRE	556190	23825	224
2634	26740	ME	CANADA FALLS	LOW	WEST BRANCH	1921	50	26740	467,520	764	50	12.23875	10060	CNPG	21700	2521	164
2634	159000	ME	SEBOOMOOK	LOW	WEST BRANCH	1936	60	159000	472,699	621	60	12.6865	45000	CNPGRE	117800	6838	526
2634	40170	ME	RAGGED LAKE	LOW	RAGGED STREA	1937	30	40170	409,718	1204	30	11.34325	6680	RECNPG	30490	2786	40
2634	103800	ME	CAUCOMGOMOC	LOW	CAUCOMGOMC	1981	12	103800	339,006	2681	12	10.5373	14750	RECNPG	42516	5728	178
2660	113330	ME	FOREST CITY	LOW	EAST BRANCH	1949	16	113330	85,731	500	16	10.7164		TCRE	105300	16070	138
2666	1980	ME	MEDWAY	LOW	WEST BRANCH	1922	35	1980	207,688	513	35	11.567125	18700	CNPG	1500	120	2120
2671	1400000	ME	MOOSEHEAD - EAST OUTLE	SIGNIFICANT	KENNEBEC RIVE	1835	20	1400000	218,782	1004	20	10.8955	25100	CNPGRE	1080000	74200	1268
2671	1400000	ME	MOOSEHEAD - WEST OUTLE	SIGNIFICANT	KENNEBEC RIVE	1835	18	1400000	161,441	830	18	10.80595	3900	CNPGRE	1080000	74200	1268
2710	1300	ME	ORONO	LOW	STILLWATER RI	1917	15	1300	188,888	1180	15	10.671625	43500	CNPGCB	812	140	2300
2712	3830	ME	STILLWATER	LOW	STILLWATER RI	1902	25	3830	475,909	1712	25	11.119375	25000	CNPG	3040	300	7602
2721	4370	ME	HOWLAND	LOW	PISCATAQUIS R	1916	17	4370	120,740	660	17	10.761175	42525	CNPG	3400	270	1500
2727	3040	ME	ELLSWORTH	HIGH	UNION RIVER	1907	62	3040	298,627	377	62	12.77605	17000	CNCB	2500	125	613
2727	145000	ME	GRAHAM	HIGH	UNION RIVER	1924	43	145000	384,592	750	43	11.925325	19000	CNPGRE	144670	12200	452
2804	1800	ME	MASONS	LOW	GOOSE RIVER	1835	15	1800	13,766	86	15	10.671625		MSPG	1620	70	19
2804	270	ME	KELLY	LOW	GOOSE RIVER	1835	15	270	21,610	135	15	10.671625		MSPG	200	16	18
2804	11270	ME	SWAN LAKE	LOW	GOOSE RIVER	1900	10	11270	26,119	250	10	10.44775	90	CNMSPG	7500	1510	10
2804	82	ME	CMP	LOW	GOOSE RIVER	1908	21	82	53,071	231	21	10.940275		CNPGCB	72	5	19
2808	210	ME	BARKER'S MILL	LOW	LITTLE ANDROS	1874	30	210	78,268	230	30	11.34325	9400	CNCBPG	150	12	353
2809	120	ME	AMERICAN TISSUE	HIGH	COBBOSSEECC	1900	24	120	60,334	227	24	11.0746	5392	MSCNPG	108	3	220
2897	100	ME	SACCARAPPA WEST	LOW	PRESUMPSCOT	1911	12	100	12,898	102	12	10.5373	10000	CNPG	11	10	569
2897	100	ME	SACCARAPPA EAST	LOW	PRESUMPSCOT	1911	9	100	20,598	220	9	10.402975	14000	CNPG	11	10	569
2931	1261	ME	GAMBO	LOW	PRESUMPSCOT	1911	24	1261	93,027	350	24	11.0746	14600	CNPG	1000	71	497

APPENDIX D Characteristics of NE and HQ Dams Used in this Study 4 of6

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
2932	56	ME	MALLISON FALLS	LOW	PRESUMPSCOT	1900	14	56	42,847	288	14	10.62685	5682	MSCNPG	31	7	503
2942	3337	ME	DUNDEE	HIGH	PRESUMPSCOT	1913	44	3337	724,191	1375	44	11.9701	22800	CNPGRE	2900	190	443
2984	383990	ME	EEL WEIR	HIGH	PRESUMPSCOT	1879	23	383990	111,622	440	23	11.029825	29800	MSPGRE	330000	29184	436
3428	2960	ME	WORUMBO	LOW	ANDROSCOGGI	1988	17	2960	159,158	870	17	10.761175	136735	TCERPG	1700	180	3370
3562	665	ME	BARKER MILL UPPER	LOW	LITTLE ANDROS	1987	24	665	61,132	230	24	11.0746	19900	MSPG	255	41	350
4026	321195	ME	AZISCOHOS	HIGH	MAGALLOWAY	1911	74	321195	867,951	881	74	13.31335	7746	CBPGRE	221355	8320	214
4026	321195	ME	ABBOTT BROOK DIKE	HIGH	ABBOTT BROOI	1911	27	321195	272,377	900	27	11.208925		RE	221355	8320	214
4202	820	ME	LOWELL TANNERY	LOW	PASSADUMKEA	1987	27	820	69,607	230	27	11.208925	9623	CNPG	680	69	301
4784	5191	ME	PEJEPSCOT	LOW	ANDROSCOGGI	1896	48	5191	326,570	560	48	12.1492	95000	TCERCN	3278	225	3420
5073	1536	ME	BENTON FALLS	LOW	SEBASTICOOK I	1987	27	1536	151,320	500	27	11.208925	23000	CNPGRE	955	83	860
5362	351	ME	KESSLEN	LOW	MOUSAM RIVEF	1954	18	351	27,231	140	18	10.80595	6200	CNPG	224	20	125
5362	240	ME	DANE PERKINS	LOW	MOUSAM RIVEF	1979	12	240	8,219	65	12	10.5373	1150	CNPG	150	25	125
5362	146	ME	TWINE MILL	LOW	MOUSAM RIVEF	1980	18	146	35,011	180	18	10.80595	2400	CNPG	104	12	125
6398	774	ME	HACKETT MILLS	LOW	LITTLE ANDROS	1986	8	774	18,230	220	8	10.3582	474	TCERCN	480	60	313
7189	113000	ME	GREEN LAKE	LOW	REEDS BROOK	1911	8	113000	22,622	273	8	10.3582	2500	MSOT	107000	2989	58
8277	2620	ME	OTIS	LOW	ANDROSCOGGI	1898	17	2620	153,670	840	17	10.761175	68000	CNPG	1700	115	2490
9340	145	ME	UPPER KEZAR FALLS #2	LOW	OSSIPEE RIVER	1860	8	145	22,374	270	8	10.3582	16600	TCER	130	10	416
9340	175	ME	LOWER KEZAR FALLS	LOW	OSSIPEE RIVER	1910	9	175	41,196	440	9	10.402975	17180	TCERCN	150	5	417
9340	145	ME	UPPER KEZAR FALLS #1	LOW	OSSIPEE RIVER	1910	11	145	22,622	196	11	10.492525	3360	CNPG	130	10	416
11132	720	ME	EUSTIS	LOW	NORTH BRANC	1952	17	720	43,906	240	17	10.761175	11345	CNPGRE	570	74	236
11433	1400	ME	SANDY RIVER	LOW	SANDY RIVER	1902	18	1400	77,803	400	18	10.80595	12000	CNMSPG	1050	150	578
11482	240	ME	MECHANIC FALLS	LOW	LITTLE ANDROS	1866	15	240	27,533	172	15	10.671625	1000	MSCNPG	103	27	250
1855	55560	NH	BELLOWS FALLS	LOW	CONNECTICUT	1907	48	55560	374,973	643	48	12.1492	157600	CNPG	30000	2804	5414
1892	79800	NH	WILDER	HIGH	CONNECTICUT	1950	59	79800	2,162,999	2900	59	12.641725	213300	CNPGRE	55000	3100	3375
1893	5700	NH	GARVINS FALLS	LOW	MERRIMACK RI\	1901	18	5700	125,457	645	18	10.80595	113000	MSCNPG	2700	250	2427
1893	8100	NH	AMOSKEAG	LOW	MERRIMACK RI\	1921	29	8100	352,230	1075	29	11.298475	87000	CNPG	4320	478	2854
1893	4180	NH	HOOKSETT	LOW	MERRIMACK RI\	1927	11	4180	76,984	667	11	10.492525	78500	MSPG	1650	405	2805
1904	54000	NH	VERNON	LOW	CONNECTICUT	1909	58	54000	698,476	956	58	12.59695	224700	CNPG	18300	2550	6266
2077	57700	NH	COMERFORD	HIGH	CONNECTICUT	1930	170	57700	6,745,476	2253	170	17.61175	288200	CNPGRE	46800	1093	1635
2077	14100	NH	MCINDOES	SIGNIFICANT	CONNECTICUT	1931	25	14100	202,929	730	25	11.119375	138500	CNPG	9800	543	2200
2077	223722	NH	MOORE	HIGH	CONNECTICUT	1957	144	223722	6,915,887	2920	144	16.4476	211300	CNPGRE	200000	3490	1600
2287	94	NH	J. BRODIE SMITH	HIGH	ANDROSCOGGI	1948	31	94	194,166	550	31	11.388025	56000	CNPG	60	8	1372
2288		NH	GORHAM	LOW	ANDROSCOGGI	1958	20	258	93,701	430	20	10.8955	43000	TCERPG	258	32	1431
2300	2000	NH	SHELBURNE	LOW	ANDROSCOGGI	1906	16	2000	120,195	701	16	10.7164	23000	CNTC	960	210	1494
2311	685	NH	GORHAM	LOW	ANDROSCOGGI	1904	24	685	205,988	775	24	11.0746	47500	TCERRE	370	45	1384
2326	195	NH	CROSS	HIGH	ANDROSCOGGI	1903	30	195	201,796	593	30	11.34325	21000	CNPG	120	22	1350
2327	400	NH	CASCADE	HIGH	ANDROSCOGGI	1903	58	400	425,953	583	58	12.59695	40000	CNPG	200	28	1361
2392	1030	NH	GILMAN	LOW	CONNECTICUT	1920	30	1030	94,603	278	30	11.34325	3538	PGTCER	705	130	1514
2422	830	NH	SAWMILL	LOW	ANDROSCOGGI	1965	20	830	181,955	835	20	10.8955	33000	CNPG	620	73	1338
2423	95	NH	RIVERSIDE	LOW	ANDROSCOGGI	1970	23	95	209,291	825	23	11.029825	37800	PGTCER	60	7	1338
2456	16000	NH	AYERS ISLAND	SIGNIFICANT	PEMIGEWASSE	1924	80	16000	759,505	699	80	13.582	72000	CNCB	10000	600	746
2457	9340	NH	EASTMAN FALLS	SIGNIFICANT	PEMIGEWASSE	1937	37	9340	178,557	414	37	11.656675	75000	CNPG	4570	530	1003
2861	2283	NH	PONTOOK	LOW	ANDROSCOGGI	1909	15	2283	63,870	399	15	10.671625	20500	TCER	883	280	1214
2966	60	NH	CLEMENT	LOW	WINNIPESAUKE	1984	24	60	31,895	120	24	11.0746	7750	CNPG	20	5	482
3025	2290	NH	KELLEY'S FALLS	HIGH	PISCATAQUOG	1916	24	2290	58,474	220	24	11.0746	21300	CNPG	1350	129	214
3133	119250	NH	ERROL	LOW	ANDROSCOGGI	1887	25	119250	56,987	205	25	11.119375	19700	OTERCN	80000	7850	1045
3342	94	NH	ALLIED LEATHER FOREBAY	LOW	CONTOOCOOK	1982	15	94	16,968	106	15	10.671625		CNOT	54	8	766
3342	94	NH	PENACOOK LOWER FALLS D	LOW	CONTOOCOOK	1982	15	94	21,450	134	15	10.671625		CNOT	54	8	766
3342	94	NH	ALLIED LEATHER AUXILIARY	LOW	CONTOOCOOK	1982	15	94	50,584	316	15	10.671625	40000	CNPG	54	8	766
3442	2938	NH	MINE FALLS	LOW	NASHUA RIVER	1889	20	2938	70,821	325	20	10.8955	1700	MSCNPG	1970	242	405

APPENDIX D Characteristics of NE and HQ Dams Used in this Study 5 of6

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
3777	527	NH	ROLLINSFORD	LOW	SALMON FALLS	1910	20	527	83,895	385	20	10.8955	7000	CNMSPG	456	57	230
3820	633	NH	SOMERSWORTH	LOW	SALMON FALLS	1929	12	633	37,934	300	12	10.5373	8000	MSPG	377	55	218
4451	464	NH	LOWER GREAT FALLS	SIGNIFICANT	SALMON FALLS	1984	36	464	112,868	270	36	11.6119	7850	MSCNPG	272	32	220
4718	330	NH	COCHECO FALLS	LOW	COCHECO RIVE	1930	9	330	14,044	150	9	10.402975	2900	CNPG	110	55	187
6440	208000	NH	LAKEPORT	LOW	WINNIPESAUKE	1958	10	208000	23,507	225	10	10.44775	4080	CNOT	165800	46720	363
6597	51	NH	PIERCE	LOW	CONTOOCOOK	1921	12	51	53,108	420	12	10.5373	13400	CBCNPG	33	7	191
6597	50	NH	PAPER MILL	LOW	CONTOOCOOK	1922	9	50	26,215	280	9	10.402975	13400	CNPG	25	5	191
6597	240	NH	MONADNOCK	LOW	CONTOOCOOK	1923	22	240	120,836	500	22	10.98505	13400	CNPGRE	217	4	190
6597	8600	NH	POWDER MILL	LOW	CONTOOCOOK	1924	21	8600	84,087	366	21	10.940275	18200	CNPGRE	2400	435	184
6689	114	NH	PENACOOK UPPER FALLS	LOW	CONTOOCOOK	1987	16	114	45,780	267	16	10.7164	35000	CNOT	70	11	766
7528	400	NH	CANAAN	LOW	CONNECTICUT	1943	18	400	53,489	275	18	10.80595	37000	CNPG	200	20	381
7883	320	NH	WESTON	LOW	UPPER AMMON	1987	20	320	45,761	210	20	10.8955	14250	TCER	275	30	263
7887	160	NH	MINNEWAWA	HIGH	MINNEWAWA B	1932	63	160	214,044	265	63	12.820825	1700	CNVA	120	10	23
8405	28	NH	GLEN ROAD	SIGNIFICANT	MASCOMA RIVE	1988	16	28	30,006	175	16	10.7164	8600	CNPG	10	2	194
8924	83	NH	MCLANE	LOW	SOUHEGAN RIV	1929	18	83	44,737	230	18	10.80595	9400	CNMSPG	47	6	138
9282	98	NH	HILLSBOROUGH MILL	LOW	SOUHEGAN RIV	1925	27	98	60,528	200	27	11.208925	3300	CNMSPG	70	7	97
10898	300	NH	COY PAPER MILL	SIGNIFICANT	SUGAR RIVER	1922	33	300	118,931	314	33	11.477575	14000	CNPG	150	30	270
11128	725	NH	RED	LOW	UPPER AMMON	1900	10	725	28,731	275	10	10.44775	12500	TCER	200	75	247
11128	240	NH	BROOKLYN	LOW	UPPER AMMON	1910	19	240	56,695	275	19	10.850725	12500	TCER	50	26	254
11163	641	NH	SOUTH BERWICK	LOW	SALMON FALLS	1916	18	641	56,407	290	18	10.80595	14747	CNPG	525	58	235
11313	280	NH	APTHORP	SIGNIFICANT	AMMONOOSUC	1936	24	280	62,461	235	24	11.0746	14800	CNPG	210	20	205
2972	360	RI	WOONSOCKET FALLS	LOW	BLACKSTONE R	1960	23	360	67,988	268	23	11.029825	33000	CNPG	300	32	369
3011	530	RI	ARCTIC	LOW	SOUTH BRANC	1885	30	530	40,836	120	30	11.34325	4000	MSPG	442	45	73
3023	366	RI	TUPPERWARE	LOW	BLACKSTONE R	1904	13	366	28,889	210	13	10.582075	12750	MSPG	305	40	261
3037	180	RI	ELIZABETH WEBBING MILLS	LOW	BLACKSTONE R	1891	11	180	18,005	156	11	10.492525	8900	MSPG	150	26	473
3063	96	RI	VALLEY FALLS	LOW	BLACKSTONE R	1859	10	96	20,896	200	10	10.44775	19310	MSPG	80	15	446
2205	3725	VT	FAIRFAX FALLS	LOW	LAMOILLE RIVE	1919	45	3725	185,990	344	45	12.014875	66900	CNPG	1080	152	529
2205	2025	VT	MILTON	LOW	LAMOILLE RIVE	1929	25	2025	40,030	144	25	11.119375	83000	CNPG	93	11	690
2205	11520	VT	CLARK FALLS	HIGH	LAMOILLE RIVE	1937	40	11520	400,894	850	40	11.791	85000	CNPGRE	6000	740	690
2205	6340	VT	PETERSON	HIGH	LAMOILLE RIVE	1949	75	6340	347,645	347	75	13.358125	93000	CNPG	2840	136	700
2306	6060	VT	ECHO	LOW	CLYDE RIVER	1922	16	6060	20,575	120	16	10.7164	693	FG	5000	530	24
2306	420	VT	WEST CHARLESTON	LOW	CLYDE RIVER	1928	30	420	66,698	196	30	11.34325	1049	OT	220	100	107
2306	3400	VT	NEWPORT NO. 1	HIGH	CLYDE RIVER	1936	23	3400	92,595	365	23	11.029825	3209	FG	3000	200	142
2323	190000	VT	SOMERSET	HIGH	EAST BRANCH	1913	110	190000	3,449,375	2101	110	14.92525	27000	RECNPG	57345	1514	30
2323	600	VT	SEARSBURG	LOW	DEERFIELD RIVE	1922	50	600	374,506	612	50	12.23875	12200	RECNPG	412	30	90
2323	318000	VT	HARRIMAN	HIGH	DEERFIELD RIVE	1924	216	318000	5,311,278	1250	216	19.6714	35200	FE	117300	2039	184
2396	524	VT	PIERCE MILLS	LOW	PASSUMPSIC RI	1928	18	524	27,231	140	18	10.80595	6430	CNPG	50	25	237
2397	2548	VT	GAGE	LOW	PASSUMPSIC RI	1928	18	2548	62,437	321	18	10.80595	27700	CNPG	70	15	413
2399	427	VT	ARNOLD FALLS	LOW	PASSUMPSIC RI	1928	20	427	91,522	420	20	10.8955	10300	TCER	46	7	254
2400	494	VT	PASSUMPSIC	LOW	PASSUMPSIC RI	1929	11	494	29,778	258	11	10.492525	21400	CNPG	70	18	424
2445	490	VT	CENTER RUTLAND	LOW	OTTER CREEK	1898	14	490	25,887	174	14	10.62685	1120	CN	30	13	307
2489	592	VT	CAVENDISH	LOW	BLACK RIVER	1907	39	592	59,553	130	39	11.746225	18400	CNPG	100	10	82
2490	385	VT	TAFTSVILLE	LOW	OTTAUQUECHE	1910	18	385	42,792	220	18	10.80595	15300	CNPG	100	21	190
2513	6085	VT	ESSEX NO. 19	SIGNIFICANT	WINOOSKI RIVE	1917	53	6085	252,473	385	53	12.373075	150000	FG	1950	352	1043
2547	24278	VT	HIGHGATE FALLS	SIGNIFICANT	MISSISQUOI RIV	1918	46	24278	133,139	240	46	12.05965	8200	FG	7000	65	815
2558	2122	VT	HUNTINGTON FALLS	LOW	OTTER CREEK	1910	34	2122	73,259	187	34	11.52235	2587	CN	250	23	749
2558	3369	VT	PROCTOR	LOW	OTTER CREEK	1910	16	3369	21,947	128	16	10.7164	2328	ST	460	92	347
2558	1730	VT	BELDENS EAST	LOW	OTTER CREEK	1913	27	1730	16,948	56	27	11.208925	775	FG	150	22	632
2558	1730	VT	BELDENS WEST	LOW	OTTER CREEK	1913	15	1730	9,124	57	15	10.671625	788	FG	150	22	632
2629	1000	VT	CADYS FALLS	LOW	LAMOILLE RIVE	1894	29	1000	121,560	371	29	11.298475	140000	FG	1000	150	250

APPENDIX D Characteristics of NE and HQ Dams Used in this Study 6 of6

FERC#	MAX_STOR	STATE	DAM_NAME	HAZARD	RIVER	YEAR_COMP	NID_HEIGHT	NID_STOR	est. volume	DAM_LENGTH	DAM_HEIGHT	estimated width	MAX_DISCH	DAM_TYPE	NORM_STOR	SURF_AREA	DRAIN_AREA
2629	1038	VT	MORRISVILLE DAM	LOW	LAMOILLE RIVE	1924	37	1038	107,824	250	37	11.656675	140000	FG	150	15	222
2629	1038	VT	MORRISVILLE BACK SPILLW/	LOW	LAMOILLE RIVE	1924	8	1038	12,430	150	8	10.3582	35000	FG	150	15	
2629	17000	VT	GREEN RIVER DAM	HIGH	GREEN RIVER	1947	110	17000	525,369	320	110	14.92525	2535	VA	16900	625	14
2629	17000	VT	GREEN RIVER DIKE	SIGNIFICANT	GREEN RIVER	1947	22	17000	60,418	250	22	10.98505		FE	16900	625	
2674	1649	VT	VERGENNES NO. 9	LOW	OTTER CREEK	1912	12	1649	68,029	538	12	10.5373	3459	FG	350	70	866
2731	5100	VT	WEYBRIDGE WEST	LOW	OTTER CREEK	1944	30	5100	51,045	150	30	11.34325	46000	CNPG	600	59	750
2731	5100	VT	WEYBRIDGE EAST	LOW	OTTER CREEK	1951	30	5100	37,433	110	30	11.34325	46000	FG	600	59	750
2737	677	VT	MIDDLEBURY LOWER EAST	LOW	OTTER CREEK	1917	15	677	49,623	310	15	10.671625	13700	CNPG	45	16	632
2737	677	VT	MIDDLEBURY LOWER WEST	LOW	OTTER CREEK	1917	15	677	12,806	80	15	10.671625	1275	FG	45	16	632
2756	400	VT	CHACE MILL	LOW	WINOOSKI RIVE	1876	29	400	78,637	240	29	11.298475	30000	FG	34	50	1060
2839	160	VT	GREAT FALLS	HIGH	PASSUMPSIC RI	1915	34	160	62,682	160	34	11.52235	1550	FG	135	12	220
2879	18558	VT	BOLTON FALLS	LOW	WINOOSKI RIVE	1898	75	18558	190,353	190	75	13.358125	68000	TCER	355	70	835
2905	7471	VT	ENOSBERG FALLS	LOW	MISSISQUOI RIV	1928	21	7471	44,800	195	21	10.940275	26443	FG	750	120	587
5261	14	VT	NEWBURY	SIGNIFICANT	WELLS RIVER	1912	20	14	19,612	90	20	10.8955	3200	FG	12	12	90
5944	209	VT	MORETOWN NO. 8	SIGNIFICANT	MAD RIVER	1910	31	209	117,559	333	31	11.388025	122000	FG	209	36	143
6470	69	VT	WINOOSKI NO. 8	LOW	WINOOSKI RIVE	1985	29	69	74,378	227	29	11.298475	14500	FG	34	7	199
7186	2250	VT	SHELDON SPRINGS	LOW	MISSISQUOI RIV	1920	38	2250	125,837	283	38	11.70145	3822	CB	750	175	794
7725	793	VT	BARTON VILLAGE	LOW	CLYDE RIVER	1949	9	793	7,209	77	9	10.402975	762	OT	560	187	108
9648	90	VT	FELLOWS	LOW	BLACK RIVER	1990	10	90	20,896	200	10	10.44775	1780	FG	60	21	190

APPENDIX E Summary of Emissions for Dam Assessed in this Study 1 of4

Dam #	VOCs to air (S	NOx to air (ST	CO to air (ST)	SO2 to air (ST	PM10 to air (S	Fossil CO2 (m	TRI Rel Air (lbs	TRI Rel Water	TRI Rel UnGnd	TRI Rel Land (	TRI Tf POTW (	TRI Tf OffSite	Cost D&T ($I
7591.0101	5.5596E-06	1.8382E-05	2.9694E-05	3.6225E-05	5.319E-06	0.00573654	0.00372311	0.00038292	0.00146089	0.00200248	0.00083912	0.01587577	1.2085E-05
4253.0101	4.6285E-05	0.00015303	0.0002472	0.00030158	4.4281E-05	0.04775743	0.0309954	0.00318784	0.01216206	0.01667086	0.00698578	0.13216781	0.00010061
7961.0101	2.0645E-05	6.8259E-05	0.00011027	0.00013452	1.9752E-05	0.02130231	0.01382557	0.00142194	0.00542491	0.00743608	0.00311602	0.05895376	4.4878E-05
11168.0101	3.4538E-05	0.00011419	0.00018446	0.00022504	3.3043E-05	0.03563704	0.02312906	0.0023788	0.00907544	0.01243995	0.00521285	0.09862486	7.5077E-05
7888.0101	5.1306E-06	1.6963E-05	2.7402E-05	3.3429E-05	4.9085E-06	0.00529381	0.00343578	0.00035337	0.00134814	0.00184793	0.00077436	0.01465053	1.1153E-05
7464.0101	0.00147729	0.00488429	0.00789008	0.00962555	0.00141336	1.52429843	0.98929612	0.10174789	0.3881827	0.53209254	0.22296869	4.21846821	0.00321126
10163.0201	1.3637E-05	4.5086E-05	7.2832E-05	8.8851E-05	1.3046E-05	0.01407045	0.00913196	0.00093921	0.00358322	0.00491162	0.00205817	0.03893971	2.9642E-05
5362.0401	2.7961E-05	9.2445E-05	0.00014934	0.00018218	2.6751E-05	0.02885038	0.0187244	0.00192578	0.00734713	0.01007091	0.00422013	0.07984291	6.078E-05
8791.0101	0.00022908	0.00075738	0.00122347	0.00149258	0.00021916	0.23636458	0.15340471	0.01577749	0.06019336	0.08250866	0.03457453	0.65413468	0.00049795
10934.0101	3.9568E-05	0.00013082	0.00021133	0.00025781	3.7855E-05	0.0408267	0.02649724	0.00272521	0.01039706	0.01425153	0.00597198	0.11298715	8.601E-05
6474.0101	*5.2946E-05*	*0.00017505*	*0.00028278*	*0.00034498*	*5.0654E-05*	*0.05463046*	*0.03545612*	*0.00364662*	*0.01391237*	*0.01907006*	*0.00799114*	*0.15118882*	*0.00011509*
8450.0101	0.00011229	0.00037126	0.00059974	0.00073166	0.00010743	0.11586499	0.07519839	0.00773406	0.02950655	0.04044542	0.0169483	0.32065425	0.00024409
2897.0101	2.946E-06	9.7402E-06	1.5734E-05	1.9195E-05	2.8185E-06	0.00303973	0.00197284	0.0002029	0.00077411	0.00106109	0.00044464	0.00841241	6.4038E-06
6132.0101	2.9727E-05	9.8285E-05	0.00015877	0.00019369	2.8441E-05	0.03067303	0.01990733	0.00204744	0.00781129	0.01070715	0.00448674	0.08488707	6.4619E-05
4718.0101	8.8036E-06	2.9107E-05	4.7019E-05	5.7362E-05	8.4226E-06	0.00908375	0.00589551	0.00060635	0.0023133	0.0031709	0.00132874	0.02513912	1.9137E-05
3265.0101	9.4221E-06	3.1152E-05	5.0323E-05	6.1391E-05	9.0143E-06	0.00972189	0.00630968	0.00064894	0.00247581	0.00339366	0.00142208	0.02690516	2.0481E-05
9100.0101	3.679E-05	0.00012164	0.00019649	0.00023971	3.5198E-05	0.03796046	0.02463699	0.00253388	0.00966713	0.013251	0.00555271	0.10505487	7.9972E-05
6752.0101	2.8533E-05	9.4337E-05	0.00015239	0.00018591	2.7298E-05	0.02944082	0.0191076	0.00196519	0.00749749	0.01027702	0.00430649	0.08147693	6.2023E-05
7410.0201	2.7567E-05	9.1142E-05	0.00014723	0.00017961	2.6373E-05	0.0284437	0.01846045	0.00189863	0.00724356	0.00992895	0.00416064	0.07871742	5.9923E-05
3342.0101	2.3483E-06	7.7641E-06	1.2542E-05	1.5301E-05	2.2467E-06	0.00242304	0.00157259	0.00016174	0.00061706	0.00084582	0.00035443	0.00670571	5.1046E-06
2556.0301	3.8793E-06	1.2826E-05	2.0719E-05	2.5276E-05	3.7114E-06	0.00400272	0.00259784	0.00026718	0.00101935	0.00139725	0.0005855	0.01107746	8.4326E-06
5274.0101	0.00011943	0.00039485	0.00063784	0.00077814	0.00011426	0.12322543	0.07997544	0.00822538	0.03138098	0.04301476	0.01802496	0.34102414	0.0002596
4254.0101	0.00013403	0.00044314	0.00071585	0.0008733	0.00012823	0.13829591	0.08975645	0.00923134	0.03521888	0.04827547	0.02022941	0.38273143	0.00029135
8486.0101	0.00016123	0.00053306	0.0008611	0.00105051	0.00015425	0.16635826	0.1079694	0.01110452	0.04236532	0.0580713	0.02433427	0.46039346	0.00035047
8242.0101	9.7932E-05	0.00032379	0.00052305	0.0006381	9.3694E-05	0.10104862	0.06558231	0.00674506	0.02573336	0.03527342	0.01478102	0.27965023	0.00021288
9411.0101	0.00017915	0.00059233	0.00095684	0.0011673	0.0001714	0.18485382	0.11997333	0.01233911	0.04707546	0.06452761	0.02703973	0.51157958	0.00038943
7473.0101	0.00010067	0.00033284	0.00053767	0.00065593	9.6313E-05	0.10387284	0.06741528	0.00693358	0.02645259	0.03625928	0.01519413	0.2874662	0.00021883
8736.0101	4.165E-05	0.00013771	0.00022245	0.00027138	3.9848E-05	0.04297538	0.02789177	0.00286863	0.01094425	0.01500158	0.00628628	0.11893358	9.0537E-05
7410.9999	2.6797E-05	8.8596E-05	0.00014312	0.0001746	2.5637E-05	0.02764921	0.01794482	0.0018456	0.00704124	0.00965161	0.00404442	0.07651869	5.8249E-05
9340.0201	2.1916E-05	7.2459E-05	0.00011705	0.0001428	2.0967E-05	0.02261304	0.01467626	0.00150943	0.00575871	0.00789362	0.00330775	0.06258118	4.7639E-05
5563.0201	0.00019692	0.00065107	0.00105174	0.00128307	0.0001884	0.20318699	0.13187188	0.01356286	0.05174425	0.07092724	0.02972144	0.5623163	0.00042806
3309.0101	5.8456E-05	0.00019327	0.00031221	0.00038088	5.5926E-05	0.06031612	0.0391462	0.00402614	0.01536029	0.02105477	0.00882282	0.16692375	0.00012707
5912.0101	5.39E-05	0.00017821	0.00028788	0.0003512	5.1567E-05	0.0556152	0.03609523	0.00371235	0.01416314	0.0194138	0.00813518	0.15391404	0.00011717
4318.0101	4.5452E-05	0.00015028	0.00024276	0.00029615	4.3485E-05	0.04689863	0.03043802	0.00313051	0.01194335	0.01637108	0.00686016	0.12979109	9.8802E-05
3128.0101	1.1195E-05	3.7014E-05	5.9792E-05	7.2944E-05	1.0711E-05	0.01155139	0.00749705	0.00077106	0.00294171	0.00403229	0.00168969	0.03196827	2.4335E-05
5824.0101	6.8051E-05	0.00022499	0.00036346	0.0004434	6.5106E-05	0.07021662	0.0455718	0.004687	0.01788159	0.02451078	0.01027102	0.19432321	0.00014793
2445.0101	5.5395E-05	0.00018315	0.00029586	0.00036094	5.2998E-05	0.05715778	0.03709639	0.00381532	0.01455598	0.01995228	0.00836083	0.15818313	0.00012042
6597.0401	2.5135E-05	8.3103E-05	0.00013424	0.00016377	2.4047E-05	0.02593486	0.01683218	0.00173117	0.00660466	0.00905318	0.00379366	0.07177427	5.4637E-05
2396.0101	3.6048E-05	0.00011919	0.00019253	0.00023488	3.4488E-05	0.03719551	0.02414053	0.00248282	0.00947233	0.01298397	0.00544082	0.10293789	7.836E-05
5362.0201	7.2547E-05	0.00023986	0.00038747	0.0004727	6.9408E-05	0.07485596	0.04858282	0.00499668	0.01906306	0.02613025	0.01094965	0.20716251	0.0001577
11482.0101	1.341E-05	4.4338E-05	7.1624E-05	8.7378E-05	1.283E-05	0.0138372	0.00898059	0.00092364	0.00352383	0.0048302	0.00202405	0.03829421	2.9151E-05
8012.0101	7.3853E-05	0.00024418	0.00039444	0.0004812	7.0657E-05	0.07620327	0.04945724	0.00508662	0.01940617	0.02660056	0.01114673	0.21089116	0.00016054
8615.0101	1.8925E-05	6.2572E-05	0.00010108	0.00012331	1.8106E-05	0.01952768	0.0126738	0.00130348	0.00497298	0.0068166	0.00285644	0.05404249	4.1139E-05
2400.0101	1.6408E-05	5.4249E-05	8.7634E-05	0.00010691	1.5698E-05	0.01693007	0.01098791	0.00113009	0.00431147	0.00590984	0.00247647	0.04685367	3.5667E-05
8405.0101	1.0659E-05	3.524E-05	5.6927E-05	6.9449E-05	1.0197E-05	0.01099787	0.00713781	0.00073411	0.00280075	0.00383907	0.00160873	0.0304364	2.3169E-05

APPENDIX E Summary of Emissions for Dam Assessed in this Study 2 of4

Dam #	VOCs to air (S	NOx to air (ST	CO to air (ST)	SO2 to air (ST	PM10 to air (S	Fossil CO2 (m	TRI Rel Air (lbs	TRI Rel Water	TRI Rel UnGn	TRI Rel Land (	TRI Tf POTW (	TRI Tf OffSite	Cost D&T ($
2555.0101	2.1498E-05	7.1078E-05	0.00011482	0.00014008	2.0568E-05	0.02218228	0.01439668	0.00148068	0.00564901	0.00774325	0.00324474	0.06138905	4.6732E-05
4293.0101	2.6764E-05	8.8488E-05	0.00014294	0.00017439	2.5606E-05	0.0276156	0.017923	0.00184336	0.00703268	0.00963988	0.00403951	0.07642567	5.8178E-05
2966.0101	6.7978E-06	2.2475E-05	3.6307E-05	4.4292E-05	6.5036E-06	0.00701412	0.00455229	0.0004682	0.00178624	0.00244845	0.001026	0.01941146	1.4777E-05
5638.0101	0.00010831	0.00035809	0.00057846	0.0007057	0.00010362	0.11175427	0.07253046	0.00745967	0.0284597	0.03901048	0.016347	0.30927792	0.00023543
5735.0101	5.5669E-05	0.00018405	0.00029732	0.00036272	5.3259E-05	0.05744016	0.03727966	0.00383417	0.01462789	0.02005085	0.00840213	0.15896461	0.00012101
3320.0101	0.00011161	0.00036902	0.00059611	0.00072722	0.00010678	0.11516302	0.07474279	0.0076872	0.02932778	0.04020038	0.01684562	0.31871155	0.00024262
11547.0101	3.1165E-05	0.00010304	0.00016645	0.00020306	2.9816E-05	0.03215672	0.02087027	0.00214648	0.00818913	0.01122507	0.00470377	0.08899315	6.7745E-05
10163.0101	7.546E-05	0.00024949	0.00040303	0.00049167	7.2194E-05	0.07786127	0.05053332	0.00519729	0.0198284	0.02717932	0.01138926	0.21547966	0.00016403
3051.0101	1.0561E-05	3.4919E-05	5.6408E-05	6.8815E-05	1.0104E-05	0.01089757	0.00707271	0.00072742	0.00277521	0.00380406	0.00159406	0.03015883	2.2958E-05
6240.0101	9.7694E-05	0.000323	0.00052177	0.00063654	9.3466E-05	0.10080254	0.0654226	0.00672863	0.0256707	0.03518752	0.01474502	0.2789692	0.00021236
7920.0101	*0.0002623*	*0.00086722*	*0.0014009*	*0.00170904*	*0.00025095*	*0.27064324*	*0.17565216*	*0.01806561*	*0.06892287*	*0.09447445*	*0.03958868*	*0.74900026*	*0.00057017*
2490.0101	5.3934E-05	0.00017832	0.00028806	0.00035142	5.16E-05	0.05565029	0.036118	0.00371469	0.01417208	0.01942605	0.00814032	0.15401116	0.00011724
2932.0101	1.6514E-05	5.4599E-05	8.8199E-05	0.0001076	1.5799E-05	0.01703934	0.01105883	0.00113739	0.00433929	0.00594799	0.00249245	0.04715607	3.5897E-05
5362.0301	5.7779E-05	0.00019103	0.00030859	0.00037647	5.5278E-05	0.05961743	0.03869274	0.0039795	0.01518236	0.02081088	0.00872061	0.16499014	0.0001256
11566.0101	5.0758E-05	0.00016782	0.00027109	0.00033072	4.8561E-05	0.05237318	0.0339911	0.00349594	0.01333752	0.0182821	0.00766095	0.14494182	0.00011034
7921.0101	0.00026876	0.00088859	0.00143543	0.00175116	0.00025713	0.27731245	0.17998059	0.01851078	0.07062127	0.09680249	0.04056423	0.76745716	0.00058422
6689.0101	1.301E-05	4.3013E-05	6.9484E-05	8.4767E-05	1.2447E-05	0.01342369	0.0087122	0.00089604	0.00341852	0.00468586	0.00196357	0.03714981	2.828E-05
2941.0101	1.4456E-05	4.7794E-05	7.7206E-05	9.4188E-05	1.383E-05	0.01491551	0.00968043	0.00099562	0.00379843	0.00520661	0.00218179	0.04127842	3.1423E-05
7254.0101	9.1805E-05	0.00030353	0.00049032	0.00059817	8.7831E-05	0.09472586	0.06147873	0.00632301	0.02412319	0.03306631	0.01385615	0.26215211	0.00019956
6756.0101	3.6164E-05	0.00011957	0.00019315	0.00023563	3.4599E-05	0.03731476	0.02421793	0.00249078	0.0095027	0.0130256	0.00545826	0.10326793	7.8612E-05
3253.9999	6.8502E-05	0.00022648	0.00036586	0.00044634	6.5537E-05	0.07068161	0.04587359	0.00471804	0.018	0.02467309	0.01033904	0.19561006	0.00014891
5379.0101	9.7109E-05	0.00032107	0.00051865	0.00063273	9.2907E-05	0.10019942	0.06503116	0.00668838	0.0255171	0.03497698	0.0146568	0.27730006	0.00021109
2731.0101	7.7709E-06	2.5693E-05	4.1504E-05	5.0633E-05	7.4346E-06	0.00801816	0.00520393	0.00053522	0.00204193	0.00279893	0.00117287	0.02219012	1.6892E-05
7528.0101	1.5617E-05	5.1633E-05	8.3408E-05	0.00010175	1.4941E-05	0.01611381	0.01045814	0.00107561	0.00410359	0.00562491	0.00235707	0.04459467	3.3947E-05
10677.0101	7.4601E-06	2.4665E-05	3.9844E-05	4.8607E-05	7.1372E-06	0.00769744	0.00499577	0.00051381	0.00196025	0.00268697	0.00112595	0.02130253	1.6216E-05
6597.0301	4.8817E-05	*0.0001614*	0.00026073	*0.00031808*	4.6705E-05	0.05037087	0.03269157	0.00336229	0.01282761	0.01758315	0.00736806	0.13940048	0.00010612
2556.0201	2.2028E-05	7.283E-05	0.00011765	0.00014353	2.1075E-05	0.02272889	0.01475144	0.00151717	0.00578821	0.00793406	0.0033247	0.06290179	4.7883E-05
11163.0101	2.6716E-05	8.8329E-05	0.00014269	0.00017407	2.556E-05	0.027566	0.01789081	0.00184005	0.00702005	0.00962257	0.00403225	0.07628842	5.8074E-05
8505.0101	0.00069267	0.00229015	0.00369951	0.00451324	0.0006627	0.71471434	0.463862	0.04770764	0.18201143	0.249488	0.10454575	1.97795896	0.0015057
3133.0101	9.9555E-06	3.2915E-05	5.3171E-05	6.4867E-05	9.5246E-06	0.01027229	0.00666689	0.00068568	0.00261597	0.00358579	0.00150259	0.02842838	2.1641E-05
3025.0101	4.5526E-05	0.00015052	0.00024315	0.00029663	4.3555E-05	0.04697439	0.03048719	0.00313557	0.01196265	0.01639752	0.00687124	0.13000076	9.8962E-05
3464.0101	5.5895E-05	0.0001848	0.00029853	0.0003642	5.3476E-05	0.05767393	0.03743138	0.00384977	0.01468743	0.02013246	0.00843633	0.15961156	0.0001215
6116.0101	3.1392E-05	0.00010379	0.00016766	0.00020454	3.0033E-05	0.03239072	0.02102214	0.0021621	0.00824873	0.01130675	0.00473799	0.08964074	6.8238E-05
2489.0101	2.0777E-05	6.8694E-05	0.00011097	0.00013538	1.9878E-05	0.02143824	0.01391379	0.00143102	0.00545953	0.00748352	0.00313591	0.05932993	4.5164E-05
2809.0101	2.3813E-05	7.8733E-05	0.00012718	0.00015516	2.2783E-05	0.02457108	0.01594706	0.00164014	0.00625735	0.00857712	0.00359417	0.06800002	5.1764E-05
9282.0101	5.5967E-05	0.00018504	0.00029892	0.00036467	5.3545E-05	0.05774836	0.03747969	0.00385474	0.01470638	0.02015844	0.00844722	0.15981754	0.00012166
4320.0101	0.00029679	0.00098125	0.0015851	0.00193376	0.00028394	0.30622893	0.19874789	0.02044098	0.07798523	0.10689647	0.04479403	0.847483	0.00064514
2397.0101	4.811E-05	0.00015906	0.00025695	0.00031347	4.6028E-05	0.04964108	0.03221792	0.00331357	0.01264175	0.0173284	0.00726131	0.13738078	0.00010458
11313.0101	6.0511E-05	0.00020006	0.00032318	0.00039427	5.7892E-05	0.06243633	0.04052226	0.00416766	0.01590023	0.02179488	0.00913295	0.1727914	0.00013154
5613.0101	5.4495E-05	0.00018018	0.00029105	0.00035507	5.2137E-05	0.05622938	0.03649384	0.00375335	0.01431955	0.0196282	0.00822502	0.15561378	0.00011846
4609.0101	7.9494E-05	0.00026283	0.00042457	0.00051795	7.6053E-05	0.08202304	0.05323437	0.00547509	0.02088825	0.02863209	0.01199802	0.22699726	0.0001728
11365.0101	3.5071E-05	0.00011595	0.00018731	0.00022851	3.3553E-05	0.0361873	0.02348619	0.00241553	0.00921557	0.01263204	0.00529334	0.1001477	7.6236E-05
11574.0101	4.5985E-05	0.00015204	0.0002456	0.00029962	4.3994E-05	0.04744781	0.03079445	0.00316717	0.01208321	0.01656279	0.00694049	0.13131096	9.9959E-05
4202.0101	3.3219E-05	0.00010983	0.00017742	0.00021644	3.1781E-05	0.03427597	0.0222457	0.00228794	0.00872883	0.01196484	0.00501376	0.09485812	7.221E-05
3442.0101	1.4054E-05	4.6467E-05	7.5062E-05	9.1572E-05	1.3446E-05	0.01450137	0.00941164	0.00096798	0.00369297	0.00506205	0.00212121	0.04013229	3.055E-05

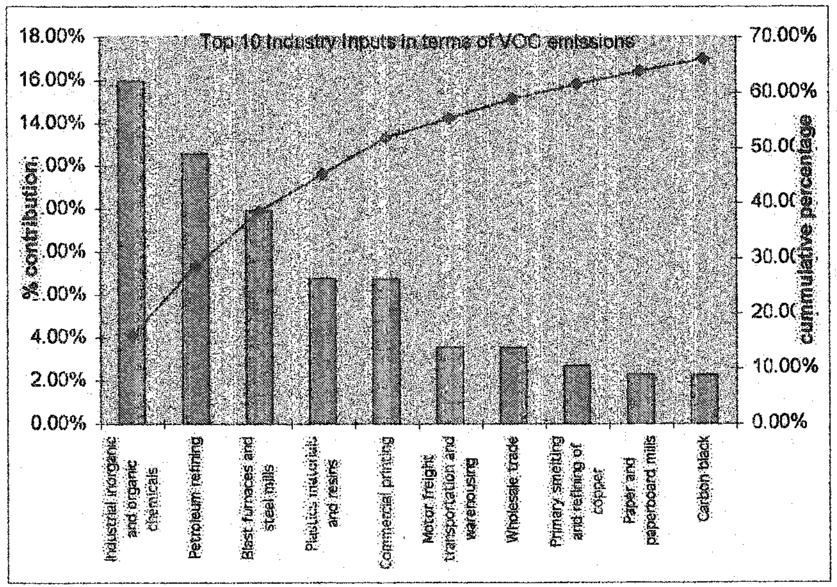
APPENDIX E Summary of Emissions for Dam Assessed in this Study 3 of4

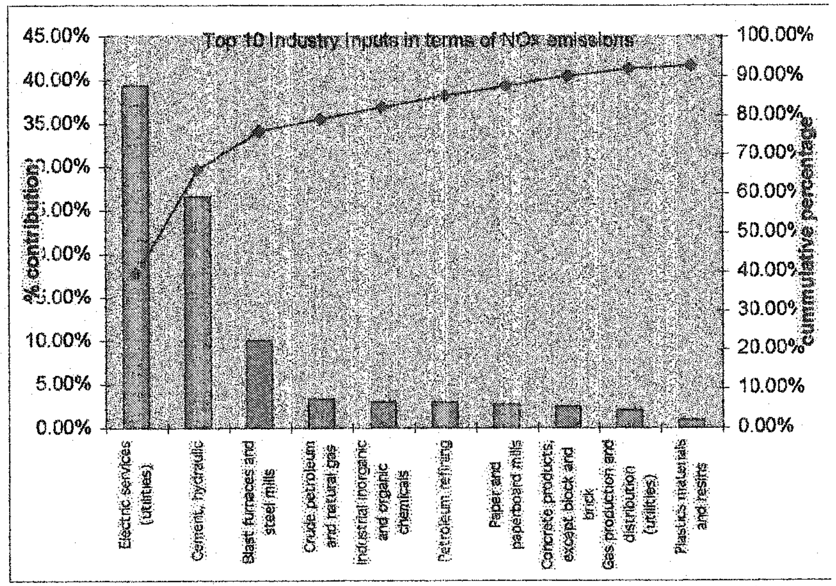
Dam #	VOCs to air (S	NOx to air (ST	CO to air (ST)	SO2 to air (ST	PM10 to air (S	Fossil CO2 (m	TRI Rel Air (lbs	TRI Rel Water	TRI Rel UnGnd	TRI Rel Land (	TRI Tf POTW (	TRI Tf OffSite	Cost D&T ($k
2558.0201	5.2117E-06	1.7231E-05	2.7835E-05	3.3958E-05	4.9862E-06	0.00537758	0.00349014	0.00035896	0.00136947	0.00187717	0.00078661	0.01488236	1.1329E-05
11433.0101	5.3628E-05	0.00017731	0.00028642	0.00034942	5.1307E-05	0.05533398	0.03591271	0.00369358	0.01409153	0.01931564	0.00809405	0.15313579	0.00011657
2323.0101	3.1021E-06	1.0256E-05	1.6568E-05	2.0212E-05	2.9678E-06	0.00320079	0.00207737	0.00021365	0.00081512	0.00111731	0.0004682	0.00885812	6.7431E-06
2808.0101	1.8956E-05	6.2674E-05	0.00010124	0.00012351	1.8136E-05	0.01955946	0.01269443	0.00130561	0.00498107	0.00682769	0.00286108	0.05413044	4.1206E-05
8640.0101	0.0005999	0.00198341	0.003204	0.00390873	0.00057393	0.61898552	0.40173234	0.04131768	0.15763283	0.21607158	0.09054289	1.71303119	0.00130403
3777.0101	2.7092E-05	8.9573E-05	0.0001447	0.00017652	2.592E-05	0.02795418	0.01814275	0.00186596	0.0071189	0.00975807	0.00408903	0.0773627	5.8891E-05
2931.0101	1.5299E-05	5.0581E-05	8.1708E-05	9.9681E-05	1.4636E-05	0.01578539	0.01024499	0.00105368	0.00401996	0.00551026	0.00230903	0.04368577	3.3255E-05
11478.0101	3.197E-05	0.0001057	0.00017075	0.0002083	3.0586E-05	0.03298693	0.02140909	0.0022019	0.00840056	0.01151487	0.0048252	0.09129072	6.9494E-05
2528.0101	4.5679E-06	1.5103E-05	2.4397E-05	2.9763E-05	4.3702E-06	0.00471325	0.00305898	0.00031461	0.00120029	0.00164527	0.00068944	0.01304383	9.9295E-06
11132.0101	0.00013208	0.00043669	0.00070543	0.00086059	0.00012636	0.13628272	0.08844985	0.00909696	0.03470619	0.04757272	0.01993493	0.37715996	0.00028711
6338.0101	0.00015526	0.00051333	0.00082923	0.00101162	0.00014854	0.16019982	0.10397246	0.01069344	0.040797	0.05592155	0.02343343	0.44335008	0.0003375
2608.0101	3.3729E-05	0.00011152	0.00018014	0.00021977	3.2269E-05	0.03480201	0.02258711	0.00232306	0.00886279	0.01214847	0.00509071	0.09631393	7.3318E-05
2375.0101	9.8909E-06	3.2702E-05	5.2826E-05	6.4446E-05	9.4628E-06	0.01020562	0.00662362	0.00068123	0.00259899	0.00356251	0.00149284	0.02824386	2.15E-05
2323.0301	7.8844E-06	2.6068E-05	4.211E-05	5.1372E-05	7.5432E-06	0.00813527	0.00527993	0.00054303	0.00207175	0.00283981	0.00119	0.02251421	1.7139E-05
2194.0101	1.1285E-05	3.7312E-05	6.0273E-05	7.3531E-05	1.0797E-05	0.01164432	0.00755736	0.00077727	0.00296538	0.00406472	0.00170329	0.03222543	2.4531E-05
4451.0101	*4.3149E-05*	*0.00014266*	*0.00023046*	*0.00028115*	*4.1282E-05*	0.0445223	0.02889574	0.00297189	0.01133819	0.01554156	0.00651256	0.12321465	9.3796E-05
2721.0101	3.2258E-05	0.00010665	0.00017229	0.00021018	3.0862E-05	0.0332846	0.02160229	0.00222177	0.00847636	0.01161878	0.00486875	0.09211454	7.0121E-05
7590.0101	6.4329E-05	0.00021269	0.00034357	0.00041915	6.1545E-05	0.06637575	0.04307901	0.00443062	0.01690346	0.02317003	0.0097092	0.18369367	0.00013983
6597.0201	0.00019811	0.00065499	0.00105807	0.0012908	0.00018953	0.20441099	0.13266628	0.01364456	0.05205595	0.07135451	0.02990048	0.56570371	0.00043064
1893.0301	5.008E-06	1.6558E-05	2.6748E-05	3.2631E-05	4.7913E-06	0.0051674	0.00335373	0.00034493	0.00131595	0.0018038	0.00075587	0.01430068	1.0886E-05
2300.0101	1.3647E-05	4.5119E-05	7.2885E-05	8.8917E-05	1.3056E-05	0.01408087	0.00913873	0.00093991	0.00358588	0.00491526	0.0020597	0.03896856	2.9664E-05
2326.0101	1.4428E-05	4.7703E-05	7.7059E-05	9.4008E-05	1.3804E-05	0.01488708	0.00966197	0.00099372	0.00379119	0.00519669	0.00217763	0.04119972	3.1363E-05
2334.0101	1.8662E-05	6.17E-05	9.967E-05	0.00012159	1.7854E-05	0.01925534	0.01249705	0.00128531	0.00490363	0.00672153	0.0028166	0.05328879	4.0565E-05
2530.0101	5.8163E-06	1.923E-05	3.1064E-05	3.7897E-05	5.5645E-06	0.00600134	0.00389498	0.00040059	0.00152832	0.00209491	0.00087785	0.01660861	1.2643E-05
5073.0101	2.5782E-05	8.5243E-05	0.0001377	0.00016799	2.4667E-05	0.02660284	0.01726571	0.00177576	0.00677476	0.00928635	0.00389136	0.07362288	5.6045E-05
2552.0101	4.2229E-05	0.00013962	0.00022554	0.00027515	4.0401E-05	0.04357266	0.02827941	0.0029085	0.01109635	0.01521007	0.00637365	0.12058653	9.1795E-05
2488.0101	5.7341E-05	0.00018958	0.00030626	0.00037362	5.486E-05	0.05916599	0.03839975	0.00394937	0.0150674	0.02065329	0.00865458	0.1637408	0.00012465
2375.0301	3.3053E-05	0.00010928	0.00017654	0.00021537	3.1623E-05	0.03410512	0.02213482	0.00227654	0.00868532	0.0119052	0.00498877	0.09438531	7.185E-05
2422.0101	2.1256E-05	7.0278E-05	0.00011353	0.0001385	2.0336E-05	0.02193259	0.01423463	0.00146401	0.00558542	0.00765609	0.00320822	0.06069804	4.6206E-05
11475.0101	5.2409E-05	0.00017328	0.00027991	0.00034148	5.014E-05	0.0540762	0.03509639	0.00360962	0.01377122	0.01887658	0.00791006	0.1496549	0.00011392
2666.0101	1.3891E-05	4.5926E-05	7.4189E-05	9.0507E-05	1.329E-05	0.01433272	0.00930219	0.00095672	0.00365002	0.00500318	0.00209654	0.03966555	3.0195E-05
2710.0101	2.7055E-05	8.9451E-05	0.0001445	0.00017628	2.5884E-05	0.02791604	0.01811799	0.00186341	0.00710919	0.00974476	0.00408345	0.07725713	5.8811E-05
2288.0101	2.9988E-05	9.9147E-05	0.00016016	0.00019539	2.869E-05	0.03094187	0.02008181	0.00206539	0.00787976	0.01080099	0.00452606	0.08563107	6.5186E-05
2574.0101	7.9217E-06	2.6191E-05	4.2309E-05	5.1615E-05	7.5789E-06	0.00817377	0.00530492	0.0005456	0.00208156	0.00285325	0.00119563	0.02262077	1.722E-05
2077.0101	8.9176E-06	2.9484E-05	4.7628E-05	5.8105E-05	8.5317E-06	0.00920141	0.00597187	0.0006142	0.00234326	0.00321197	0.00134595	0.02546474	1.9385E-05
2458.0101	1.2237E-05	4.0459E-05	6.5357E-05	7.9733E-05	1.1707E-05	0.01262649	0.00819481	0.00084283	0.0032155	0.00440758	0.00184696	0.03494358	2.66E-05
2457.0101	1.701E-05	5.624E-05	9.0849E-05	0.00011083	1.6274E-05	0.01755134	0.01139112	0.00117156	0.00446968	0.00612671	0.00256734	0.04857301	3.6976E-05
7887.0101	0.00013034	0.00043094	0.00069614	0.00084926	0.0001247	0.13448914	0.08728579	0.00897724	0.03424943	0.04694663	0.01967257	0.37219626	0.00028333
8277.0101	9.2684E-06	3.0644E-05	4.9502E-05	6.039E-05	8.8673E-06	0.00956336	0.00620679	0.00063836	0.00243544	0.00333832	0.00139889	0.02646643	2.0147E-05
2531.0101	1.4132E-05	4.6724E-05	7.5478E-05	9.208E-05	1.352E-05	0.01458172	0.00946379	0.00097334	0.00371343	0.00509009	0.00213296	0.04035464	3.072E-05
2368.0101	0.00049474	0.00163574	0.00264238	0.00322358	0.00047333	0.510485	0.33131362	0.0340752	0.13000174	0.1781969	0.07467184	1.41275797	0.00107545
2325.0102	6.3813E-06	2.1098E-05	3.4082E-05	4.1579E-05	6.1051E-06	0.00658437	0.00427337	0.00043951	0.0016768	0.00229843	0.00096314	0.01822211	1.3871E-05
2333.0201	3.0836E-06	1.0195E-05	1.6469E-05	2.0092E-05	2.9502E-06	0.00318173	0.002065	0.00021238	0.00081027	0.00111066	0.00046541	0.00880539	6.703E-06
2403.0101	1.0529E-05	3.4812E-05	5.6235E-05	6.8604E-05	1.0073E-05	0.01086415	0.00705102	0.00072519	0.0027667	0.00379239	0.00158917	0.03006634	2.2888E-05
2302.0101	5.1603E-06	1.7061E-05	2.7561E-05	3.3623E-05	4.937E-06	0.00532449	0.00345569	0.00035541	0.00135595	0.00185864	0.00077885	0.01473542	1.1217E-05

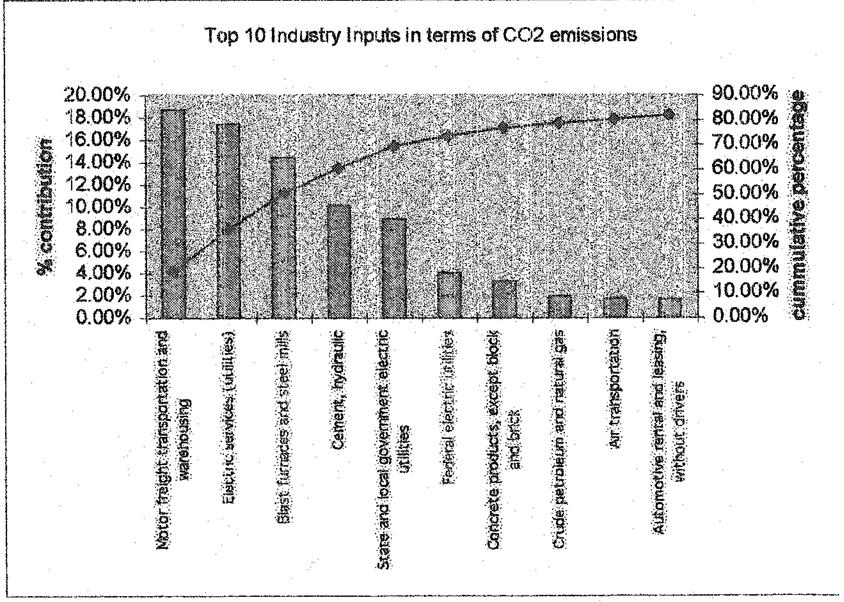
APPENDIX E Summary of Emissions for Dam Assessed in this Study 4 of4

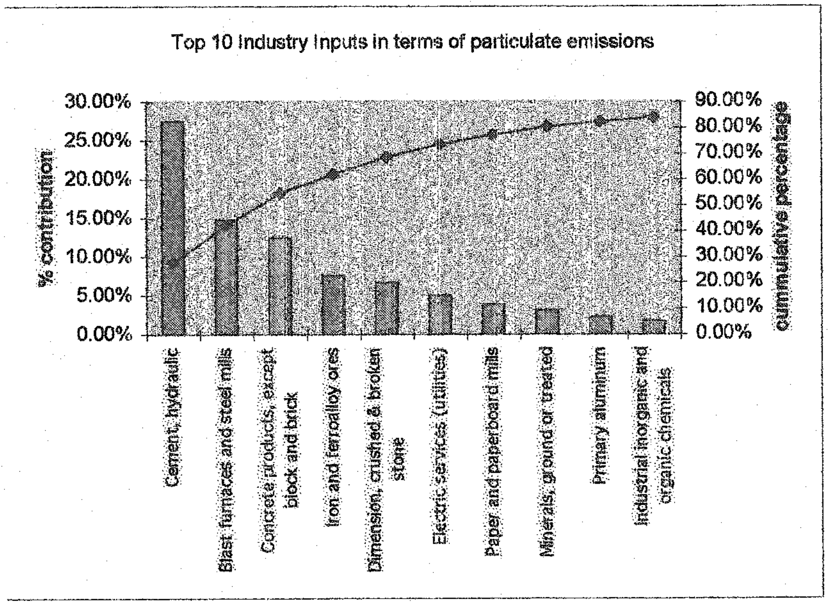
Dam #	VOCs to air (S	NOx to air (ST	CO to air (ST)	SO2 to air (ST	PM10 to air (S	Fossil CO2 (m	TRI Rel Air (lb	TRI Rel Water	TRI Rel UnGn	TRI Rel Land (	TRI Tf POTW (	TRI Tf OffSite	Cost D&T ($
2323.0401	2.383E-05	7.8788E-05	0.00012727	0.00015527	2.2799E-05	0.0245884	0.0159583	0.00164129	0.00626176	0.00858317	0.0035967	0.06804796	5.1801E-05
2727.0101	2.0616E-05	6.8161E-05	0.00011011	0.00013433	1.9724E-05	0.02127177	0.01380575	0.0014199	0.00541714	0.00742542	0.00311156	0.05886925	4.4814E-05
2287.0101	6.1712E-06	2.0403E-05	3.296E-05	4.0209E-05	5.9041E-06	0.00636755	0.00413265	0.00042504	0.00162158	0.00222274	0.00093142	0.01762207	1.3415E-05
2513.0101	1.8279E-05	6.0436E-05	9.7629E-05	0.0001191	1.7488E-05	0.01886106	0.01224116	0.00125899	0.00480322	0.0065839	0.00275893	0.05219764	3.9735E-05
2519.0101	6.0755E-05	0.00020087	0.00032449	0.00039586	5.8125E-05	0.06268811	0.04068567	0.00418447	0.01596435	0.02188277	0.00916978	0.17348821	0.00013207
1893.0101	8.6788E-06	2.8694E-05	4.6353E-05	5.6548E-05	8.3032E-06	0.00895495	0.00581192	0.00059775	0.0022805	0.00312594	0.0013099	0.02478266	1.8866E-05
2335.0101	8.3361E-06	2.7561E-05	4.4522E-05	5.4315E-05	7.9753E-06	0.00860133	0.00558241	0.00057414	0.00219044	0.0030025	0.00125817	0.02380403	1.8121E-05
2323.0701	3.2185E-05	0.00010641	0.0001719	0.00020971	3.0792E-05	0.0332093	0.02155341	0.00221674	0.00845719	0.01159249	0.00485773	0.09190613	6.9963E-05
1855.0101	3.6195E-06	1.1967E-05	1.9331E-05	2.3584E-05	3.4629E-06	0.00373468	0.00242387	0.00024929	0.00095109	0.00130368	0.0005463	0.01033567	7.8679E-06
2458.0301	4.004E-06	1.3238E-05	2.1385E-05	2.6089E-05	3.8308E-06	0.00413145	0.00268138	0.00027578	0.00105213	0.00144218	0.00060433	0.01143371	8.7038E-06
2365.0101	1.4819E-05	4.8994E-05	7.9145E-05	9.6553E-05	1.4177E-05	0.01529016	0.00992358	0.00102063	0.00389384	0.00533739	0.00223659	0.04231523	3.2212E-05
2611.0101	1.004E-05	3.3195E-05	5.3624E-05	6.5418E-05	9.6056E-06	0.01035962	0.00672357	0.00069151	0.00263821	0.00361627	0.00151537	0.02867005	2.1825E-05
2327.0101	1.7009E-05	5.6235E-05	9.0842E-05	0.00011082	1.6273E-05	0.01754987	0.01139017	0.00117146	0.0044693	0.0061262	0.00256713	0.04856893	3.6973E-05
2458.0401	1.9173E-05	6.339E-05	0.0001024	0.00012492	1.8343E-05	0.01978281	0.01283939	0.00132052	0.00503795	0.00690566	0.00289376	0.05474856	4.1677E-05
2323.0201	3.8206E-05	0.00012632	0.00020406	0.00024894	3.6553E-05	0.03942204	0.02558559	0.00263145	0.01003934	0.0137612	0.00576651	0.10909977	8.3051E-05
2712.0101	7.7311E-05	0.00025561	0.00041291	0.00050373	7.3965E-05	0.07977066	0.05177254	0.00532474	0.02031465	0.02784584	0.01166855	0.22076385	0.00016805
2600.0101	1.4001E-05	4.6291E-05	7.4778E-05	9.1226E-05	1.3395E-05	0.01444644	0.00937599	0.00096431	0.00367898	0.00504287	0.00211317	0.03998027	3.0435E-05
2534.0101	2.3612E-05	7.8068E-05	0.00012611	0.00015385	2.259E-05	0.02436365	0.01581243	0.00162629	0.00620452	0.00850471	0.00356382	0.06742595	5.1327E-05
2283.0301	1.0237E-05	3.3845E-05	5.4673E-05	6.6699E-05	9.7936E-06	0.0105624	0.00685518	0.00070505	0.00268985	0.00368706	0.00154503	0.02923125	2.2252E-05
2520.0101	1.2823E-05	4.2397E-05	6.8487E-05	8.3551E-05	1.2268E-05	0.01323117	0.00858726	0.00088319	0.00336949	0.00461866	0.00193541	0.03661704	2.7874E-05
2529.0101	3.1044E-05	0.00010264	0.00016581	0.00020228	2.9701E-05	0.03203227	0.0207895	0.00213817	0.00815744	0.01118162	0.00468556	0.08864873	6.7483E-05
2322.0101	2.4269E-05	8.0241E-05	0.00012962	0.00015813	2.3219E-05	0.02504175	0.01625253	0.00167155	0.00637721	0.00874142	0.00366301	0.0693026	5.2756E-05
1904.0101	8.2475E-06	2.7268E-05	4.4049E-05	5.3738E-05	7.8906E-06	0.00850995	0.0055231	0.00056804	0.00216717	0.0029706	0.0012448	0.02355113	1.7928E-05
2456.0101	3.6551E-05	0.00012085	0.00019521	0.00023815	3.4969E-05	0.03771357	0.02447676	0.00251741	0.00960426	0.01316482	0.0055166	0.10437163	7.9452E-05
2942.0101	9.7737E-05	0.00032314	0.00052201	0.00063682	9.3507E-05	0.10084732	0.06545166	0.00673162	0.0256821	0.03520315	0.01475157	0.27909313	0.00021246
4026.0101	7.1149E-05	0.00023524	0.00038	0.00046359	6.807E-05	0.07341326	0.04764648	0.00490038	0.01869565	0.02562664	0.01073862	0.20316986	0.00015466
2631.0101	0.00024232	0.00080118	0.00129422	0.00157889	0.00023183	0.25003277	0.1622756	0.01668985	0.06367414	0.08727987	0.03657386	0.69196115	0.00052675
2572.0101	8.459E-06	2.7967E-05	4.5179E-05	5.5116E-05	8.0929E-06	0.00872813	0.00566471	0.00058261	0.00222273	0.00304676	0.00127672	0.02415493	1.8388E-05
3180.0101	0.00025361	0.00083849	0.00135449	0.00165242	0.00024263	0.26167703	0.16983293	0.01746711	0.06663951	0.09134458	0.03827714	0.72418644	0.00055128
2615.0101	0.00013564	0.00044846	0.00072444	0.00088379	0.00012977	0.13995657	0.09083424	0.00934219	0.03564179	0.04885516	0.02047233	0.38732726	0.00029485
2458.0201	2.6541E-05	8.7752E-05	0.00014175	0.00017293	2.5393E-05	0.02738577	0.01777384	0.00182802	0.00697415	0.00955965	0.00400589	0.07578963	5.7694E-05
2323.0501	0.00012399	0.00040996	0.00066224	0.00080791	0.00011863	0.12793997	0.08303526	0.00854007	0.0325816	0.04466048	0.01871458	0.35407153	0.00026953
2527.0101	3.3699E-05	0.00011142	0.00017999	0.00021957	3.2241E-05	0.03477163	0.02256739	0.00232103	0.00885505	0.01213786	0.00508626	0.09622986	7.3254E-05
1892.0101	3.0971E-05	0.0001024	0.00016541	0.0002018	2.9631E-05	0.03195659	0.02074038	0.00213312	0.00813817	0.0111552	0.00467449	0.08843927	6.7323E-05
2284.0101	7.2022E-05	0.00023812	0.00038466	0.00046927	6.8905E-05	0.07431407	0.04823112	0.00496051	0.01892506	0.02594109	0.01087039	0.20566284	0.00015656
2077.0201	4.8009E-05	0.00015873	0.00025641	0.00031281	4.5931E-05	0.04953694	0.03215033	0.00330662	0.01261523	0.01729204	0.00724608	0.13709257	0.00010436
2077.0301	5.6955E-05	0.00018831	0.00030419	0.0003711	5.449E-05	0.0587674	0.03814106	0.00392276	0.01496589	0.02051416	0.00859628	0.16263771	0.00012381
2329.0101	4.8E-05	0.0001587	0.00025636	0.00031275	4.5922E-05	0.04952701	0.03214389	0.00330596	0.01261271	0.01728858	0.00724463	0.13706511	0.00010434

Appendix F Upstream Emissions by Industry 1 of 3


Top 10 Industry Inputs in terms of VOC emissions

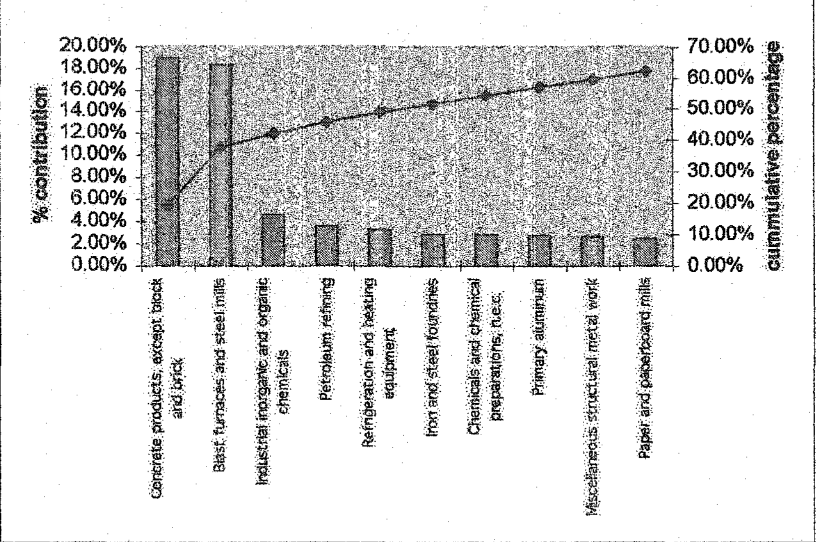

Top 10 Industry Inputs in terms of NOx emissions


Top 10 Industry Inputs in terms of CO2 emissions

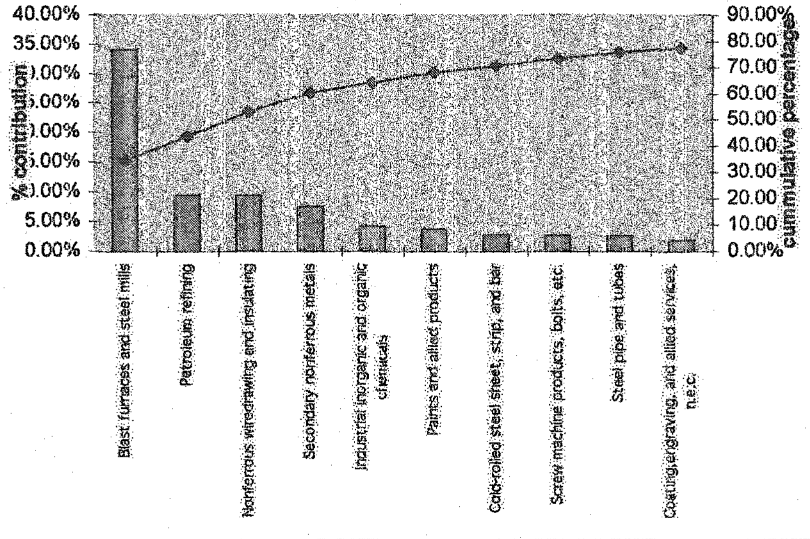

Top 10 Industry Inputs in terms of particulate emissions

Appendix F Upstream Emissions by Industry 2 of 3

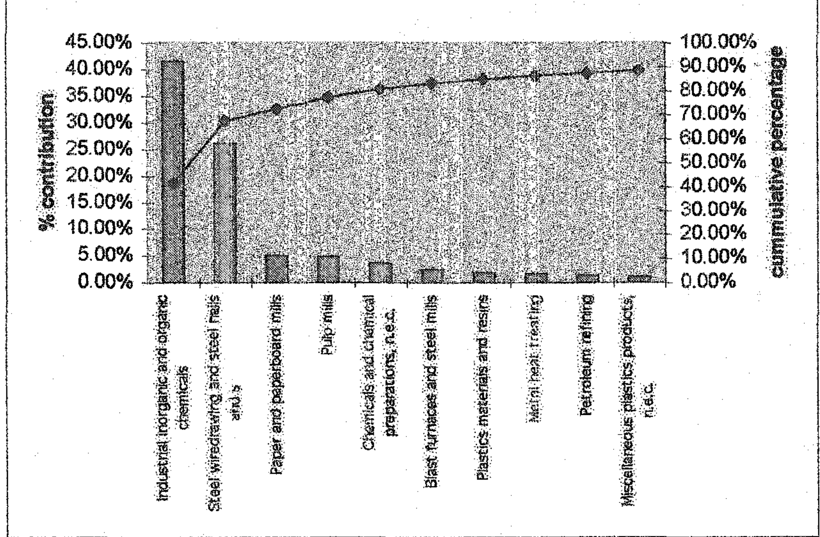
Top 10 Industry Inputs in terms of Cost D&T emissions



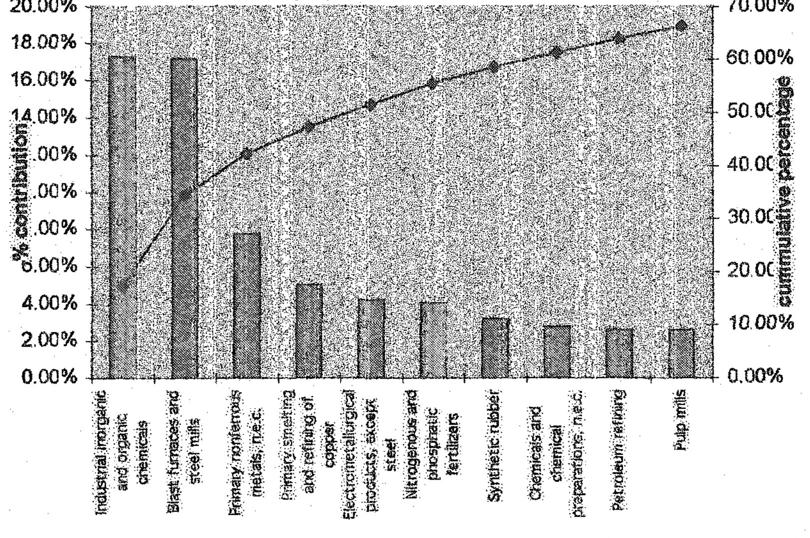
Top 10 Industry Inputs in terms of TRI Off Site emissions



Top 10 Industry Inputs in terms of TRI POTW emissions

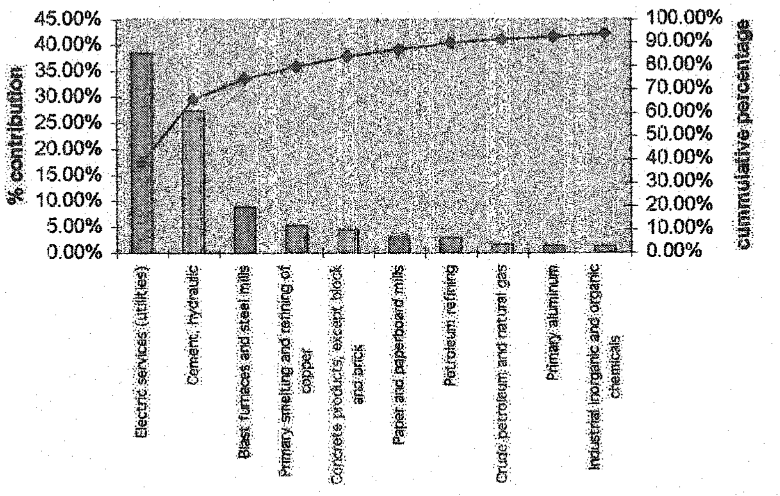


Top 10 Industry Inputs in terms of TRI Env. emissions

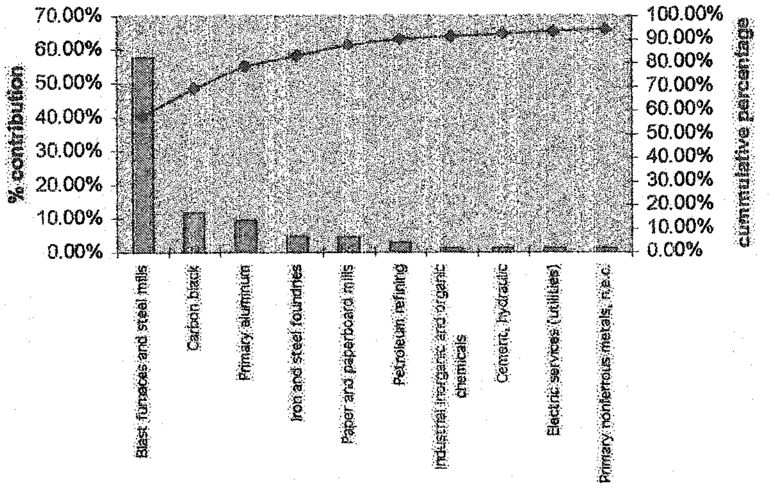


Appendix F Upstream Emissions by Industry 3 of 3

Top 10 Industry Inputs in terms of SO2 emissions



Top 10 Industry Inputs in terms of CO emissions



Appendix G - Assessment of Environmental Impacts Based on Literature Review. Page 1 of 2

Air Emissions					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
CO_2, SO_2, NO_x, CH_4, particulate	Released from production of construction materials	Human health, terrestrial ecosystems	Partially quantified	None	Recognized
CO_2, CH_4,	Released from biomass decomposition in impoundment	Global warming	Partially quantified	None	None

Hydrology					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
Flow Alteration	D tailrace velocity	Bio-diversity, aquatic	None	Assessed	Quantified
	dewatering construction	Bio-diversity, aquatic	None	Assessed	Quantified
	> in-stream flow	Bio-diversity, aquatic	None	Assessed	Quantified
	Entrainment	Bio-diversity, aquatic	None	Assessed	Quantified
	Dam as barrier to fish migration	Bio-diversity, aquatic	None	Assessed	Quantified
Flooding	Flooding from dam failure	Human injury & property damage	None	Assessed	Recognized
Fluctuation	Flow D inundates and dries habitat	Aquatic organisms, bio-diversity	None	Assessed	Recognized

Water Quality					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
Emissions from infrastructure construction	Direct and indirect releases from materials and processes	Eutrophication, biodiverstiy, aquatic	Recognized	None	Recognized
Dissolved Oxygen	Reduced aeration	Aquatic org.	None	Assessed	Assessed
D Temperature	Temp differential between impoundment and river	Aquatic Org.	None	Assessed	Assessed
Increased sedimentation	Erosion from construction, or dam failure	Aquatic Org., human health and property, recreation	None	Assessed	Quantified
Heavy metals	Contaminated sediments, or anoxic release	Aquatic orgs, human health	None	Assessed	Recognized
New impoundment	Stratified temp, nutrients, and oxygen	Aquatic ogr. and recreation.	None	Assessed	Recognized
salinization			None	None	None

Land Use					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
Solid Waste	Direct and indirect land fill from construction materials and processes		Partially Quantified	None	None
D in Land use	New transmission path, and roads	Bio-diversity	None	Assessed	Assessed
D in Land use	Increased/ decreased recreational usage	Bio-diversity, aquatic effects	None	Assessed	Assessed
Creation of impoundment	Decreased terrestrial habitat, increased aquatic habitat	D in bio-diversity	None	Assessed	Recognized

Socio-economic					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost

Land use change	New infrastructure	Aesthetics, culture, recreation	None	Assessed	Assessed
Jobs	New construction, operation & maintenance	Economic benefit	None	Assessed	Quantified
Decimation of fisheries,			None	None	Recognized
Flooded hunting territories,			None	None	Recognized

Other					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
seismic effects			None	None	None
D local climate	Weather changes from large impoundment		None	None	None
D speed of earth's rotation	Change in rotation of earth caused by large impoundment		None	None	None
D magnetic field	Change in magnetic flux lines caused by flooding magnetic fields and change in earth rotation.		None	None	None

(Tables adapted from DOE, 94)

Appendix H NID Classification Page 1of 2

1) The NID ID is the Corps Identification No assigned to each dam in the 1981 National Inventory of Dams update, under the National Dam Inspection Program (P.L. 92-367). For those dams that were not included in the 1981 update, an identification number was generated.

2) STATE (ALPHANUMERIC, 2) The two letter abbreviation for the state in which the dam is located. A calculated field based on field item #1 NID ID.

3) DAM_NAME (ALPHANUMERIC, 65) Official name of the dam. For dams that do not have an official name, the popular name is used.

4) OTHER_NAME (ALPHANUMERIC, 65) Reservoir name or names in common use other than the official name of the dam. Names are separated with semi-colons.

5) HAZARD (ALPHANUMERIC, 11) Term indicating the potential hazard to the downstream area resulting from failure or mis-operation of the dam or facilities. Terms used are as follows: Low, Significant, High.

6) EAP (ALPHANUMERIC, 3) Term indicating whether this dam has an Emergency Action Plan (EAP), which is defined as a plan of action to be taken to reduce the potential for property damage and loss of life in an area affected by a dam failure or large flood. Terms used are as follows: Yes; No; N/R. (N/R = Not required by submitting agency. For name of submitting agency, see field item #53 Source Agency)

7) STATE_NAME (ALPHANUMERIC, 20) The state name in which the dam is located. A calculated field based on the NID ID.

8) CONG_DIST (ALPHANUMERIC, 5) The 104th Congressional District in which the dam is located (example, KS-02). A calculated field based on items #56 LONGITUDE_X and #57 LATITUDE_Y, using as a source the MapInfo Corporation 104th Congressional District Boundaries dataset.

9) COUNTY (ALPHANUMERIC, 30) Name of county in which the dam is located.

10) NEAR_CITY (ALPHANUMERIC, 30) Name of the nearest downstream city, town, or village that is most likely to be affected by floods resulting from the failure of the dam.

11) DIST_CITY (NUMERIC) Distance from the dam to the nearest downstream affected City-Town-Village, to the nearest mile. (See field item #10 NEAR CITY)

12) RIVER (ALPHANUMERIC, 30) Official name of the river or stream on which the dam is built. If the stream is unnamed, it is identified as a tributary ("TR") to the named river. If the dam is located offstream, the name of the river or stream is entered plus "-OS" or "OFFSTREAM".

13) PRM_PURPOSE (ALPHANUMERIC,15) Term indicating the primary purpose for which the reservoir is used. A calculated field based on the leading code provided in field item #26 PURPOSE. Terms used are as follows: Irrigation; Hydroelectric; Flood Control; Navigation; Water Supply; Recreation; Fire/Farm Pond; Fish & Wildlife; Debris Control; Tailings; Other.

14) NID_DAMTYP (ALPHANUMERIC, 8) Term indicating dam type as one of the following: Arch, Buttress, Gravity. A calculated field, based on the codes provided in field item #27 DAM TYPE, using the following precedence: (VA or MV) = Arch; B = Buttress; not (VA, MV or B) = Gravity.

15) YEAR_COMPL (NUMERIC) Year when the original main dam structure was completed.

16) NID_HEIGHT (NUMERIC) A calculated field based on the maximum value of field items #28 DAM HEIGHT, #29 HYDRAULIC HEIGHT, and #30 STRUCTURAL HEIGHT, providing a single height value to facilitate database queries.

Appendix H NID Classification Page 1of 2

1) The NID ID is the Corps Identification No assigned to each dam in the 1981 National Inventory of Dams update, under the National Dam Inspection Program (P.L. 92-367). For those dams that were not included in the 1981 update, an identification number was generated.

2) STATE (ALPHANUMERIC, 2) The two letter abbreviation for the state in which the dam is located. A calculated field based on field item #1 NID ID.

3) DAM_NAME (ALPHANUMERIC, 65) Official name of the dam. For dams that do not have an official name, the popular name is used.

4) OTHER_NAME (ALPHANUMERIC, 65) Reservoir name or names in common use other than the official name of the dam. Names are separated with semi-colons.

5) HAZARD (ALPHANUMERIC, 11) Term indicating the potential hazard to the downstream area resulting from failure or mis-operation of the dam or facilities. Terms used are as follows: Low, Significant, High.

6) EAP (ALPHANUMERIC, 3) Term indicating whether this dam has an Emergency Action Plan (EAP), which is defined as a plan of action to be taken to reduce the potential for property damage and loss of life in an area affected by a dam failure or large flood. Terms used are as follows: Yes; No; N/R. (N/R = Not required by submitting agency. For name of submitting agency, see field item #53 Source Agency)

7) STATE_NAME (ALPHANUMERIC, 20) The state name in which the dam is located. A calculated field based on the NID ID.

8) CONG_DIST (ALPHANUMERIC, 5) The 104th Congressional District in which the dam is located (example, KS-02). A calculated field based on items #56 LONGITUDE_X and #57 LATITUDE_Y, using as a source the MapInfo Corporation 104th Congressional District Boundaries dataset.

9) COUNTY (ALPHANUMERIC, 30) Name of county in which the dam is located.

10) NEAR_CITY (ALPHANUMERIC, 30) Name of the nearest downstream city, town, or village that is most likely to be affected by floods resulting from the failure of the dam.

11) DIST_CITY (NUMERIC) Distance from the dam to the nearest downstream affected City-Town-Village, to the nearest mile. (See field item #10 NEAR CITY)

12) RIVER (ALPHANUMERIC, 30) Official name of the river or stream on which the dam is built. If the stream is unnamed, it is identified as a tributary ("TR") to the named river. If the dam is located offstream, the name of the river or stream is entered plus "-OS" or "OFFSTREAM".

13) PRM_PURPOSE (ALPHANUMERIC,15) Term indicating the primary purpose for which the reservoir is used. A calculated field based on the leading code provided in field item #26 PURPOSE. Terms used are as follows: Irrigation; Hydroelectric; Flood Control; Navigation; Water Supply; Recreation; Fire/Farm Pond; Fish & Wildlife; Debris Control; Tailings; Other.

14) NID_DAMTYP (ALPHANUMERIC, 8) Term indicating dam type as one of the following: Arch, Buttress, Gravity. A calculated field, based on the codes provided in field item #27 DAM TYPE, using the following precedence: (VA or MV) = Arch; B = Buttress; not (VA, MV or B) = Gravity.

15) YEAR_COMPL (NUMERIC) Year when the original main dam structure was completed.

16) NID_HEIGHT (NUMERIC) A calculated field based on the maximum value of field items #28 DAM HEIGHT, #29 HYDRAULIC HEIGHT, and #30 STRUCTURAL HEIGHT, providing a single height value to facilitate database queries.

17) NID_STOR (NUMERIC) A calculated field based on the maximum value of field items #31 NORMAL STORAGE, and #32 MAXIMUM STORAGE providing a single storage value to facilitate database queries.

18) DAM_LENGTH (NUMERIC) Dam length in feet. It is defined as the length along the top of the dam. Included in dam length are spillway, powerplant, navigation lock, fish pass, etc., if these form part of the length of the dam; if detached from the dam, these structures are not included.

19) MAX_DISCH (NUMERIC) Number of cubic feet per second (cu ft/sec) which the spillway is capable of discharging when the reservoir is at its maximum designed water surface elevation.

20) OWNER (ALPHANUMERIC, 50) Name of the owner of the dam.

21) OWN_TYPE (ALPHANUMERIC, 14) Term indicating owner type. Terms used are as follows: Federal, State, Local Gov't, Public Utility, Private.

~22) STATE_AGCY (ALPHANUMERIC, 30) Name of the primary state agency with regulatory or approval authority over the dam.

23) FED_AGCY (ALPHANUMERIC,20) Code identifying federal agency involvement in the dam. Codes are concatenated if several agencies were involved. See field items #43-50 and the related Federal Agency

Appendix G - Assessment of Environmental Impacts Based on Literature Review. Page 1 of 2

Air Emissions					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
CO_2, SO_2, NO_x, CH_4, particulate	Released from production of construction materials	Human health, terrestrial ecosystems	Partially quantified	None	Recognized
CO_2, CH_4,	Released from biomass decomposition in impoundment	Global warming	Partially quantified	None	None

Hydrology					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
Flow Alteration	Δ tailrace velocity	Bio-diversity, aquatic	None	Assessed	Quantified
	dewatering construction	Bio-diversity, aquatic	None	Assessed	Quantified
	> in-stream flow	Bio-diversity, aquatic	None	Assessed	Quantified
	Entrainment	Bio-diversity, aquatic	None	Assessed	Quantified
	Dam as barrier to fish migration	Bio-diversity, aquatic	None	Assessed	Quantified
Flooding	Flooding from dam failure	Human injury & property damage	None	Assessed	Recognized
Fluctuation	Flow Δ inundates and dries habitat	Aquatic organisms, bio-diversity	None	Assessed	Recognized

Water Quality					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
Emissions from infrastructure construction	Direct and indirect releases from materials and processes	Eutrophication, biodiverstiy, aquatic	Recognized	None	Recognized
Dissolved Oxygen	Reduced aeration	Aquatic org.	None	Assessed	Assessed
Δ Temperature	Temp differential between impoundment and river	Aquatic Org.	None	Assessed	Assessed
Increased sedimentation	Erosion from construction, or dam failure	Aquatic Org., human health and property, recreation	None	Assessed	Quantified
Heavy metals	Contaminated sediments, or anoxic release	Aquatic orgs, human health	None	Assessed	Recognized
New impoundment	Stratified temp, nutrients, and oxygen	Aquatic ogr. and recreation.	None	Assessed	Recognized
salinization			None	None	None

Land Use					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
Solid Waste	Direct and indirect land fill from construction materials and processes		Partially Quantified	None	None
Δ in Land use	New transmission path, and roads	Bio-diversity	None	Assessed	Assessed
Δ in Land use	Increased/ decreased recreational usage	Bio-diversity, aquatic effects	None	Assessed	Assessed
Creation of impoundment	Decreased terrestrial habitat, increased aquatic habitat	Δ in bio-diversity	None	Assessed	Recognized

Socio-economic					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost

Land use change	New infrastructure	Aesthetics, culture, recreation	None	Assessed	Assessed
Jobs	New construction, operation & maintenance	Economic benefit	None	Assessed	Quantified
Decimation of fisheries,			None	None	Recognized
Flooded hunting territories,			None	None	Recognized

Other					
Impact Area	Path	Affect	Hydro LCA	FERC	Externality Cost
seismic effects			None	None	None
Δ local climate	Weather changes from large impoundment		None	None	None
Δ speed of earth's rotation	Change in rotation of earth caused by large impoundment		None	None	None
Δ magnetic field	Change in magnetic flux lines caused by flooding magnetic fields and change in earth rotation.		None	None	None

(Tables adapted from DOE, 94)

APPENDIX I Per Unit Externality Values Used in This Study 1 of 2

	A	B	C	D	E	F	G
2	**Conventional Air Pollutants (1992 $ /metric ton)**					**Greenhouse Gas (1992 $ / metric ton)**	
3		Low	Midpoint	High		CO2	$24
4	VOC	$87	$1,485	$7,862		CH4	$128
5	PMK	$699	$2,970	$11,794		Nitrous Oxide (N	$3,371
6	NOx	$175	$2,009	$5,242			
7	SO2	$1,747	$5,067	$5,242			
8	CO	$0	$2	$3			
9	Lead	$174,720	$742,560	$1,397,760			
10							(USED MEDIUM ESTIMATES FOR NE & LOW ESTIMATES FOR HQ TO ACCOUNT FOR RURAL PROXIMITY)
11							$$/ mWh
12	**Conventional Water Pollutants (1992 $ /metric ton)**						
13	BOD	8,718					
14							
15							
16	**Disposal & Inceneration (1992 $/ metric ton)**						
17		*Landfill*					
18	Urban	Rural	Onsite				
19	4	4	3				
20		*Incinerator*					
21	Urban	Regional	Onsite-urban	Onsite-rural			
22	6	6	6	4			
23							
24	**Toxic Chemical Externality Estimates (1992 $/unit)**						

	A	B	E	F	I	J	M	N	Q	R
25	1992 $/lbs - fro	TextTable Value Tri_er_c2g	1992 $/lbs - fro	TextTable Value Tri_er_c2g	1992 $/lbs - f	TextTable Value Tri_er_c2g	1992 $/lbs - f	TextTable Value Tri_er_c2g	1992 $/lbs - f	TextTable Value Tri_er_c2g
26	10.58	ACETALDEHYDE		C.I. SOLVENT YELLOW 14	0.01	DIETHYL PHTHALATE	0.06	METHYL ISOBUTYL KETONE		QUINOLINE
27		ACETAMIDE		C.I.FOOD RED 15		DIETHYL SULFATE		METHYL ISOCYANATE		QUINONE
28	0.48	ACETONE	8,653.39	CADMIUM	0.01	DIMETHYL PHTHALATE	0.01	METHYL METHACRYLATE		QUINTOZENE
29	0.10	ACETONITRILE		CADMIUM COMPOUNDS		DIMETHYL SULFATE	0.00	METHYL TERT-BUTYL ETHER		SACCHARIN (MANUFACTURIN
30	240.37	ACROLEIN		CALCIUM CYANAMIDE	96.48	DINITROTOLUENE (MIXED ISOMERS)		METHYLENE BROMIDE		SEC-BUTYL ALCOHOL
31	6,249.67	ACRYLAMIDE		CAPTAN	5.77	EPICHLOROHYDRIN		METHYLENEBIS(PHENYLISOCYANATE)		SELENIUM
32	4.18	ACRYLIC ACID		CARBARYL		ETHYL ACRYLATE		MOLYBDENUM TRIOXIDE		SELENIUM COMPOUNDS
33	326.91	ACRYLONITRILE	0.01	CARBON DISULFIDE		ETHYL CHLOROFORMATE		MONOCHLOROPENTAFLUOROEHTANE		SILVER
34		ALLYL ALCOHOL	72.11	CARBON TETRACHLORIDE	0.00	ETHYLBENZENE		N,N-DIMETHYLANILINE		SILVER COMPOUNDS
35	4.81	ALLYL CHLORIDE		CARBONYL SULFIDE		ETHYLENE		N-BUTYL ALCOHOL	0.00	STYRENE
36		ALPHA-NAPHTHYLAMINE		CATECHOL	0.24	ETHYLENE GLYCOL		N-DIOCTYL PHTHALATE		STYRENE OXIDE
37		ALUMINUM (FUME OR DUST)	480.74	CHLORDANE	480.74	ETHYLENE OXIDE		N-NITROSODIPHENYLAMINE		SULFURIC ACID
38		ALUMINUM OXIDE (FIBROUS FORM)		CHLORINE		ETHYLENE THIOUREA		NA		TERT-BUTYL ALCOHOL
39	0.50	AMMONIA	24.04	CHLORINE DIOXIDE		ETHYLENEIMINE		NAPHTHALENE	35.58	TETRACHLOROETHYLENE
40		AMMONIUM NITRATE (SOLUTION)		CHLOROACETIC ACID		FLUOMETURON	0.19	NICKEL		TETRACHLORVINPHOS
41		AMMONIUM SULFATE (SOLUTION)	0.24	CHLOROBENZENE	62.50	FORMALDEHYDE	0.19	NICKEL COMPOUNDS		THALLIUM COMPOUNDS
42	4.81	ANILINE		CHLOROETHANE		FREON 113		NITRIC ACID		THIOUREA
43	0.10	ANTHRACENE	1.87	CHLOROFORM		GLYCOL ETHERS		NITRILOTRIACETIC ACID		THORIUM DIOXIDE
44	0.20	ANTIMONY	8.65	CHLOROMETHANE	6,249.67	HEPTACHLOR	0.46	NITROBENZENE		TITANIUM TETRACHLORIDE
45	24.04	ANTIMONY COMPOUNDS		CHLOROMETHYL METHYL ETHER		HEXACHLORO-1,3-BUTADIENE		NITROGLYCERIN	0.01	TOLUENE
46	20,671.98	ARSENIC		CHLOROPHENOLS	12,499.34	HEXACHLOROBENZENE		O-ANISIDINE	68.68	TOLUENE-2,4-DIISOCYANATE
47	20,671.98	ARSENIC COMPOUNDS		CHLOROPRENE	68.68	HEXACHLOROCYCLOPENTADIENE		O-CRESOL	68.68	TOLUENE-2,6-DIISOCYANATE
48	1,105,710.64	ASBESTOS (FRIABLE)		CHLOROTHALONIL	19.23	HEXACHLOROETHANE		O-DINITROBENZENE		TOLUENEDIISOCYANATE (MIX
49	9.61	BARIUM	57,689.25	CHROMIUM	23,556.44	HYDRAZINE		O-TOLUIDINE		TRICHLORFON
50	9.61	BARIUM COMPOUNDS		CHROMIUM COMPOUNDS	23,556.44	HYDRAZINE SULFATE		O-XYLENE	10.84	TRICHLOROETHYLENE
51		BENZAL CHLORIDE		COBALT		HYDROCHLORIC ACID		P-ANISIDINE	0.00	TRICHLOROFLUOROMETHANE
52	39.90	BENZENE		COBALT COMPOUNDS	1.60	HYDROGEN CYANIDE		P-CRESIDINE		TRIFLURALIN
53		BENZOIC TRICHLORIDE		COPPER		HYDROGEN FLUORIDE		P-CRESOL		URETHANE
54		BENZOYL CHLORIDE		COPPER COMPOUNDS		HYDROQUINONE		P-DINITROBENZENE		VANADIUM (FUME OR DUST)
55		BENZOYL PEROXIDE		CREOSOTE		ISOBUTYRALDEHYDE		P-NITROSODIPHENYLAMINE	0.02	VINYL ACETATE
56		BENZYL CHLORIDE		CRESOL (MIXED ISOMERS)		ISOPROPYL ALCOHOL 1		P-PHENYLENEDIAMINE	153.84	VINYL BROMIDE
57	11,537.85	BERYLLIUM	0.01	CUMENE		ISOPROPYL ALCOHOL 2		P-XYLENE	403.82	VINYL CHLORIDE
58	11,537.85	BERYLLIUM COMPOUNDS		CUMENE HYDROPEROXIDE		LEAD		PARATHION		VINYLIDENE CHLORIDE
59		BIPHENYL		CUPFERRON		LEAD COMPOUNDS	107.07	PENTACHLOROPHENOL		XYLENE (MIXED ISOMERS)
60	48.07	BIS(2-CHLORO-1-METHYLETHYL) ETHER	1,045,222.22	CYANIDE COMPOUNDS	13,936.30	LINDANE		PERACETIC ACID		ZINC (FUME OR DUST)
61	1,586.45	BIS(2-CHLOROETHYL) ETHER		CYCLOHEXANE		M-CRESOL	0.00	PHENOL		ZINC COMPOUNDS
62	48.07	BIS(2-ETHYLHEXYL) ADIPATE		DECABROMODIPHENYL OXIDE		M-DINITROBENZENE		PHOSGENE		1,1,1-TRICHLOROETHANE
63	298,061.93	BIS(CHLOROMETHYL) ETHER		DI(2-ETHYLHEXYL) PHTHALATE		M-XYLENE	0.48	PHOSPHORIC ACID		1,1,2,2-TETRACHLOROETHAN
64		BROMOCHLORODIFLUOROMETHANE		DI(2-ETHYLHEXYL) PHTHALATE (DEHP)		MALEIC ANHYDRIDE		PHOSPHORUS (YELLOW OR WHITE)		1,1,2-TRICHLOROETHANE
65		BROMOFORM		DIAMINOTOLUENE (MIXED ISOMERS)		MANEB		PHTHALIC ANHYDRIDE		1,1-DIMETHYL HYDRAZINE
66	0.96	BROMOMETHANE		DIBENZOFURAN	96.15	MANGANESE		PICRIC ACID		1,2,4-TRICHLOROBENZENE
67		BROMOTRIFLUOROMETHANE		DIBROMOTETRAFLUOROEHTANE		MANGANESE COMPOUNDS		POLYBROMINATED BIPHENYLS		1,2,4-TRIMETHYLBENZENE

APPENDIX I Per Unit Externality Values Used in This Study 2 of 2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
68		BUTYL ACRYLATE				DIBUTYL PHTHALATE			16.02	MERCURY				POLYCHLORINATED BIPHENYLS				1,2-BUTYLENE OXIDE	
69	0.17	BUTYL BENZYL PHTHALATE			0.34	DICHLOROBENZENE (MIXED ISOMERS)				MERCURY COMPOUNDS				PROPANE SULTONE				1,2-DIBROMO-3-CHLOROPROF	
70		BUTYRALDEHYDE			1,057.64	DICHLOROBROMOMETHANE				METHANOL				PROPIONALDEHYDE				1,2-DIBROMOETHANE	
71		C.I. BASIC GREEN 4				DICHLORODIFLUOROMETHANE				METHOXYCHLOR				PROPOXUR				1,2-DICHLOROBENZENE	
72		C.I. BASIC RED 1			0.01	DICHLOROMETHANE			6.87	METHYL ACRYLATE				PROPYLENE				1,2-DICHLOROETHANE	
73		C.I. DISPERSE YELLOW 3				DICHLOROTETRAFLUOROETHANE			0.00	METHYL ETHYL KETONE			17.79	PROPYLENE OXIDE				1,2-DICHLOROETHYLENE	
74					9.61	DICHLORVOS				METHYL HYDRAZINE				PROPYLENEIMINE				1,2-DICHLOROPROPANE	
75						DICOFOL				METHYL IODIDE				PYRIDINE				1,3-BUTADIENE	
76						DIETHANOLAMINE												1,3-DICHLOROBENZENE	
77																		1,3-DICHLOROPROPYLENE	
78																		1,4-DICHLOROBENZENE	
79																		1,4-DIOXANE	
80																		2,3-DICHLOROPROPENE	
81																		2,4,5-TRICHLOROPHENOL	
82																		2,4-D	
83																		2,4-DIAMINOTOLUENE	
84																		2,4-DICHLOROPHENOL	
85																		2,4-DIMETHYLPHENOL	
86																		2,4-DINITROPHENOL	
87																		2,4-DINITROTOLUENE	
88																		2,6-XYLIDINE	
89																		2-ETHOXYETHANOL	
90																		2-METHOXYETHANOL	
91																		2-NITROPHENOL	
92																		2-NITROPROPANE	
93																		2-PHENYLPHENOL	
94																		3,3'-DICHLOROBENZIDINE	
95																		3,3'-DIMETHOXYBENZIDINE	
96																		4,4'-DIAMINODIPHENYL ETHER	
97																		4,4'-ISOPROPYLIDENEDIPHEN	
98																		4,4'-METHYLENEBIS(2-CHLOR	
99																		4,4'-METHYLENEDIANILINE	
100																		4,6-DINITRO-O-CRESOL	
101																		4-AMINOAZOBENZENE	
102																		4-AMINOBIPHENYL	
103																		4-NITROPHENOL	
104																		5-NITRO-O-ANISIDINE	

APPENDIX J Hydro Externality Estimates per Megawatt Hour 1 of 3

Year 2000 $/ MWh																				
FERC Dam #	VOCs	NOx	CO	SO2	PM10	Cost D&T	CO2 Con.	Total Up,no	Upstream T	Total Upstre	Operations (	Operations I	Total Operat	Total$$ Imp	Total Impact	Upstream nc	Operations r	Total Impact	Total Impact	Total Impact
7,591	$0.01	$0.04	$0.00	$0.20	$0.02	$0.00	$0.14	$0.40	$15.07	$15	$0.044	0.0000	$0.0433	$15.51	$0.448	$0.405	$0.043	$0.448	$0.448	$0.448
4,253	$0.08	$0.34	$0.00	$1.68	$0.14	$0.00	$1.13	$3.37	$125.43	$129	$1.361	0.0009	$1.3563	$130.16	$4.727	$3.371	$1.356	$4.727	$4.727	$4.727
7,961	$0.03	$0.15	$0.00	$0.75	$0.06	$0.00	$0.50	$1.50	$55.95	$57	$0.284	0.0000	$0.2827	$57.73	$1.786	$1.504	$0.283	$1.786	$1.786	$1.786
11,168	$0.06	$0.25	$0.00	$1.26	$0.11	$0.00	$0.84	$2.52	$93.60	$96	$7.662	0.0037	$7.6310	$103.74	$10.147	$2.516	$7.631	$10.147	$10.147	$10.147
7,888	$0.01	$0.04	$0.00	$0.19	$0.02	$0.00	$0.12	$0.37	$13.90	$14	$0.036	0.0000	$0.0361	$14.31	$0.410	$0.374	$0.036	$0.410	$0.410	$0.410
7,464	$2.42	$10.82	$0.02	$53.76	$4.63	$0.00	$35.95	$107.60	$4,003.40	$4,111	$2.859	0.0015	$2.8475	$4,113.84	$110.444	$107.596	$2.847	$110.444	$1.125	$1.125
10,163	$0.02	$0.10	$0.00	$0.50	$0.04	$0.00	$0.33	$0.99	$36.95	$38	$0.132	0.0000	$0.1313	$38.08	$1.125	$0.993	$0.131	$1.125	$4.708	$4.708
5,362	$0.05	$0.20	$0.00	$1.02	$0.09	$0.00	$0.68	$2.04	$75.77	$78	$2.680	0.0026	$2.6719	$80.48	$4.708	$2.036	$2.672	$4.708	$17.538	$17.538
8,791	$0.38	$1.68	$0.00	$8.34	$0.72	$0.00	$5.58	$16.68	$620.78	$637	$0.858	0.0001	$0.8536	$638.32	$17.538	$16.684	$0.854	$17.538	$3.066	$3.066
10,934	$0.06	$0.29	$0.00	$1.44	$0.12	$0.00	$0.96	$2.88	$107.23	$110	$0.185	0.0000	$0.1838	$110.29	$3.066	$2.882	$0.184	$3.066	$4.027	$4.027
6,474	$0.09	$0.39	$0.00	$1.93	$0.17	$0.00	$1.29	$3.86	$143.48	$147	$0.172	0.0000	$0.1707	$147.51	$4.027	$3.856	$0.171	$4.027	$12.452	$12.452
8,450	$0.18	$0.82	$0.00	$4.09	$0.35	$0.00	$2.73	$8.18	$304.31	$312	$4.288	0.0034	$4.2736	$316.76	$12.452	$8.179	$4.274	$12.452	$0.306	$0.306
2,897	$0.00	$0.02	$0.00	$0.11	$0.01	$0.00	$0.07	$0.21	$7.98	$8	$0.092	0.0000	$0.0915	$8.29	$0.306	$0.215	$0.091	$0.306	$6.613	$6.613
6,132	$0.05	$0.22	$0.00	$1.08	$0.09	$0.00	$0.72	$2.17	$80.56	$83	$4.467	0.0014	$4.4474	$87.17	$6.613	$2.165	$4.447	$6.613	$2.023	$2.023
4,718	$0.01	$0.06	$0.00	$0.32	$0.03	$0.00	$0.21	$0.64	$23.86	$24	$1.387	0.0004	$1.3813	$25.88	$2.023	$0.641	$1.381	$2.023	$1.614	$1.614
3,265	$0.02	$0.07	$0.00	$0.34	$0.03	$0.00	$0.23	$0.69	$25.53	$26	$0.931	0.0007	$0.9280	$27.15	$1.614	$0.686	$0.928	$1.614	$3.795	$3.795
9,100	$0.06	$0.27	$0.00	$1.34	$0.12	$0.00	$0.90	$2.68	$99.70	$102	$1.119	0.0013	$1.1157	$103.49	$3.795	$2.680	$1.116	$3.795	$34.519	$34.519
6,752	$0.05	$0.21	$0.00	$1.04	$0.09	$0.00	$0.69	$2.08	$77.32	$79	$32.518	0.0422	$32.4410	$111.84	$34.519	$2.078	$32.441	$34.519	$2.076	$2.076
7,410	$0.05	$0.20	$0.00	$1.00	$0.09	$0.00	$0.67	$2.01	$74.70	$77	$0.069	0.0001	$0.0685	$76.78	$2.076	$2.008	$0.068	$2.076	$0.218	$0.218
3,342	$0.00	$0.02	$0.00	$0.09	$0.01	$0.00	$0.06	$0.17	$6.36	$7	$0.047	0.0000	$0.0466	$6.58	$0.218	$0.171	$0.047	$0.218	$0.370	$0.370
2,556	$0.01	$0.03	$0.00	$0.14	$0.01	$0.00	$0.09	$0.28	$10.51	$11	$0.088	0.0001	$0.0873	$10.88	$0.370	$0.283	$0.087	$0.370	$17.096	$17.096
5,274	$0.20	$0.87	$0.00	$4.35	$0.37	$0.00	$2.91	$8.70	$323.64	$332	$2,010.347	0.9403	$2,002.2553	$2,334.59	$2,010.953	$9.762	$7.334	$17.096	$12.464	$12.464
4,254	$0.22	$0.98	$0.00	$4.88	$0.42	$0.00	$3.26	$9.76	$363.22	$373	$7.351	0.0098	$7.3341	$380.31	$17.096	$11.743	$0.721	$12.464	$9.057	$9.057
8,486	$0.26	$1.18	$0.00	$5.87	$0.51	$0.00	$3.92	$11.74	$436.92	$449	$0.724	0.0006	$0.7213	$449.39	$12.464	$7.133	$1.925	$9.057	$21.247	$21.247
8,242	$0.16	$0.72	$0.00	$3.56	$0.31	$0.00	$2.38	$7.13	$265.39	$273	$1.930	0.0023	$1.9247	$274.45	$9.057	$13.048	$8.199	$21.247	$5.367	$5.367
9,411	$0.29	$1.31	$0.00	$6.52	$0.56	$0.00	$4.36	$13.05	$485.50	$499	$8.224	0.0079	$8.1987	$506.74	$21.247	$7.332	$168.648	$175.980	$2.147	$2.147
7,473	$0.16	$0.74	$0.00	$3.66	$0.32	$0.00	$2.45	$7.33	$272.81	$280	$169.379	0.0548	$168.6481	$448.79	$175.980	$3.034	$2.334	$5.367	$1.792	$1.792
8,736	$0.07	$0.30	$0.00	$1.52	$0.13	$0.00	$1.01	$3.03	$112.87	$116	$2.339	0.0031	$2.3336	$118.24	$5.367	$1.952	$0.195	$2.147	$14.684	$14.684
7,411	$0.04	$0.20	$0.00	$0.98	$0.08	$0.00	$0.65	$1.95	$72.62	$75	$0.196	0.0001	$0.1954	$74.76	$2.147	$1.596	$0.196	$1.792	$4.459	$4.459
9,340	$0.04	$0.16	$0.00	$0.80	$0.07	$0.00	$0.53	$1.60	$59.39	$61	$0.195	0.0009	$0.1958	$61.18	$1.792	$14.342	$0.342	$14.684	$6.491	$6.491
5,563	$0.32	$1.44	$0.00	$7.17	$0.62	$0.00	$4.79	$14.34	$533.65	$548	$0.343	0.0002	$0.3418	$548.33	$14.684	$4.258	$0.201	$4.459	$4.665	$4.665
3,309	$0.10	$0.43	$0.00	$2.13	$0.18	$0.00	$1.42	$4.26	$158.41	$163	$0.202	0.0002	$0.2011	$162.87	$4.459	$3.926	$2.566	$6.491	$75.191	$9.912
5,912	$0.09	$0.39	$0.00	$1.96	$0.17	$0.00	$1.31	$3.93	$146.07	$150	$2.573	0.0027	$2.5656	$152.56	$6.491	$3.310	$1.354	$4.665	$9.912	$5.149
4,318	$0.07	$0.33	$0.00	$1.65	$0.14	$0.00	$1.11	$3.31	$123.17	$126	$1.358	0.0015	$1.3542	$127.84	$4.665	$0.815	$74.376	$75.191	$5.149	$2.016
3,126	$0.02	$0.08	$0.00	$0.41	$0.04	$0.00	$0.27	$0.82	$30.34	$31	$74.630	0.0582	$74.3760	$105.53	$75.191	$4.956	$4.955	$9.912	$2.016	$3.951
5,824	$0.11	$0.50	$0.00	$2.48	$0.21	$0.00	$1.66	$4.96	$184.42	$189	$4.976	0.0019	$4.9555	$194.33	$9.912	$4.035	$1.115	$5.149	$3.951	$7.425
2,445	$0.09	$0.41	$0.00	$2.02	$0.17	$0.00	$1.35	$4.03	$150.12	$154	$1.119	0.0004	$1.1146	$155.27	$5.149	$1.831	$0.186	$2.016	$7.425	$1.489
6,597	$0.04	$0.18	$0.00	$0.91	$0.08	$0.00	$0.61	$1.83	$68.11	$70	$0.186	0.0001	$0.1858	$70.13	$2.016	$2.626	$1.326	$3.951	$1.489	$6.688
2,396	$0.06	$0.26	$0.00	$1.31	$0.11	$0.00	$0.88	$2.63	$97.69	$100	$1.332	0.0004	$1.3259	$101.64	$3.951	$5.284	$2.141	$7.425	$6.688	$1.481
5,362	$0.12	$0.53	$0.00	$2.64	$0.23	$0.00	$1.77	$5.28	$196.60	$202	$2.144	0.0038	$2.1411	$204.03	$7.425	$0.977	$0.513	$1.489	$1.481	$1.593
11,482	$0.02	$0.10	$0.00	$0.49	$0.04	$0.00	$0.33	$0.98	$36.34	$37	$0.515	0.0003	$0.5126	$37.83	$1.489	$5.379	$1.309	$6.688	$1.593	$0.805
8,012	$0.12	$0.54	$0.00	$2.69	$0.23	$0.00	$1.80	$5.38	$200.14	$206	$1.312	0.0019	$1.3090	$206.83	$6.688	$1.378	$0.102	$1.481	$0.805	$3.508
8,615	$0.03	$0.14	$0.00	$0.69	$0.06	$0.00	$0.46	$1.38	$51.29	$53	$0.103	0.0001	$0.1025	$52.77	$1.481	$1.195	$0.398	$1.593	$3.508	$30.991
2,400	$0.03	$0.12	$0.00	$0.60	$0.05	$0.00	$0.40	$1.20	$44.46	$46	$0.399	0.0002	$0.3976	$46.06	$1.593	$0.776	$0.028	$0.805	$30.991	$0.538
8,405	$0.02	$0.08	$0.00	$0.39	$0.03	$0.00	$0.26	$0.78	$28.88	$30	$0.029	0.0000	$0.0285	$29.69	$0.805	$1.566	$1.943	$3.508	$0.538	$8.702
2,555	$0.04	$0.16	$0.00	$0.78	$0.07	$0.00	$0.52	$1.57	$58.26	$60	$1.944	0.0041	$1.9425	$61.77	$3.508	$1.949	$29.042	$30.991	$8.702	$11.283
4,293	$0.04	$0.20	$0.00	$0.97	$0.08	$0.00	$0.65	$1.95	$72.53	$74	$29.159	0.0140	$29.0422	$103.52	$30.991	$0.495	$0.043	$0.538	$11.283	$9.051
2,966	$0.01	$0.05	$0.00	$0.25	$0.02	$0.00	$0.17	$0.50	$18.42	$19	$0.043	0.0000	$0.0427	$18.96	$0.538	$7.888	$0.814	$8.702	$9.051	$2.740
5,638	$0.18	$0.79	$0.00	$3.94	$0.34	$0.00	$2.64	$7.89	$293.51	$301	$0.817	0.0004	$0.8136	$302.21	$8.702	$4.055	$7.229	$11.283	$2.740	$6.276
5,735	$0.09	$0.41	$0.00	$2.03	$0.17	$0.00	$1.35	$4.05	$150.86	$155	$7.257	0.0040	$7.2287	$162.14	$11.283	$8.129	$0.922	$9.051	$6.276	$1.058
3,320	$0.18	$0.82	$0.00	$4.06	$0.35	$0.00	$2.72	$8.13	$302.46	$311	$0.924	0.0014	$0.9217	$311.51	$9.051	$2.270	$0.470	$2.740	$1.058	$12.884
11,547	$0.05	$0.23	$0.00	$1.13	$0.10	$0.00	$0.76	$2.27	$84.46	$87	$0.472	0.0004	$0.4702	$87.20	$2.740	$5.496	$0.780	$6.276	$12.884	$38.914
10,163	$0.12	$0.55	$0.00	$2.75	$0.24	$0.00	$1.84	$5.50	$204.49	$210	$0.772	0.0058	$0.7795	$210.77	$6.276	$0.769	$0.289	$1.058	$38.914	$4.990
3,051	$0.02	$0.08	$0.00	$0.38	$0.03	$0.00	$0.26	$0.77	$28.62	$29	$0.290	0.0003	$0.2888	$29.68	$1.058	$7.115	$5.768	$12.884	$4.990	$1.311
6,240	$0.16	$0.72	$0.00	$3.56	$0.31	$0.00	$2.38	$7.12	$264.75	$272	$5.789	0.0040	$5.7683	$277.63	$12.884	$19.104	$19.810	$38.914	$1.311	$4.850
7,920	$0.43	$1.92	$0.00	$9.55	$0.82	$0.00	$6.38	$19.10	$710.81	$730	$19.852	0.0280	$19.8098	$749.73	$38.914	$3.928	$1.061	$4.990	$4.850	$21.239
2,490	$0.09	$0.39	$0.00	$1.96	$0.17	$0.00	$1.31	$3.93	$146.16	$150	$1.065	0.0008	$1.0614	$151.15	$4.990	$1.203	$0.108	$1.311	$21.239	$1.073
2,932	$0.03	$0.12	$0.00	$0.60	$0.05	$0.00	$0.40	$1.20	$44.75	$46	$0.109	0.0001	$0.1082	$46.06	$1.311	$4.208	$0.642	$4.850	$1.073	$1.065
5,362	$0.09	$0.42	$0.00	$2.10	$0.18	$0.00	$1.41	$4.21	$156.58	$161	$0.643	0.0009	$0.6418	$161.43	$4.850	$19.575	$1.664	$21.239	$1.065	$9.096
11,566	$0.08	$0.37	$0.00	$1.85	$0.16	$0.00	$1.24	$3.70	$137.55	$141	$216.747	1.0672	$217.8057	$359.05	$221.503	$0.948	$0.125	$1.073	$9.096	$2.695
7,921	$0.44	$1.97	$0.00	$9.78	$0.84	$0.00	$6.54	$19.57	$728.33	$748	$1.668	0.0024	$1.6642	$749.57	$21.239	$1.053	$0.013	$1.065	$2.695	$7.157
6,689	$0.02	$0.10	$0.00	$0.47	$0.04	$0.00	$0.32	$0.95	$35.26	$36	$0.126	0.0001	$0.1254	$36.33	$1.073	$6.686	$2.410	$9.096	$7.157	$8.938
2,941	$0.02	$0.11	$0.00	$0.53	$0.05	$0.00	$0.35	$1.05	$39.17	$40	$0.013	0.0000	$0.0126	$40.24	$1.065	$2.634	$0.061	$2.695	$8.938	$0.945
7,254	$0.15	$0.67	$0.00	$3.34	$0.29	$0.00	$2.23	$6.69	$248.79	$255	$2.417	0.0025	$2.4099	$257.88	$9.096	$4.989	$2.168	$7.157	$0.945	$1.372
6,756	$0.06	$0.26	$0.00	$1.32	$0.11	$0.00	$0.88	$2.63	$98.00	$101	$0.061	0.0001	$0.0612	$100.70	$2.695	$7.073	$1.866	$8.938	$1.372	$0.905
3,254	$0.11	$0.50	$0.00	$2.49	$0.21	$0.00	$1.67	$4.99	$185.64	$191	$2.173	0.0032	$2.1682	$192.79	$7.157	$0.566	$0.379	$0.945	$0.905	$3.805
5,379	$0.16	$0.71	$0.00	$3.53	$0.30	$0.00	$2.36	$7.07	$263.16	$270	$1.871	0.0019	$1.8656	$272.10	$8.938	$1.137	$0.235	$1.372	$3.805	$2.984

APPENDIX J Hydro Externality Estimates per Megawatt Hour 2 of 3

FERC Dam #	VOCs	NOx	CO	SO2	PM10	Cost D&T	CO2 Con.	Total Up,no	Upstream T	Total Upstre	Operations	Operations	Total Operat	Total$$ Imp	Total Impact	Upstream nc	Operations r	Total Impact	Total Impact	Total Impact
2,731	$0.01	$0.06	$0.00	$0.28	$0.02	$0.00	$0.19	$0.57	$21.06	$22	$0.380	0.0006	$0.3791	$22.00	$0.945	$0.543	$0.362	$0.905	$2.984	$3.049
7,528	$0.03	$0.11	$0.00	$0.57	$0.05	$0.00	$0.38	$1.14	$42.32	$43	$0.235	0.0004	$0.2345	$43.69	$1.372	$3.556	$0.249	$3.805	$3.049	$7.407
10,677	$0.01	$0.05	$0.00	$0.27	$0.02	$0.00	$0.18	$0.54	$20.22	$21	$0.362	0.0006	$0.3615	$21.12	$0.905	$1.604	$1.380	$2.984	$51.428	$6.527
6,597	$0.08	$0.36	$0.00	$1.78	$0.15	$0.00	$1.19	$3.56	$132.29	$136	$0.250	0.0002	$0.2493	$136.10	$3.805	$1.946	$1.103	$3.049	$55.814	$2.329
2,556	$0.04	$0.16	$0.00	$0.80	$0.07	$0.00	$0.54	$1.60	$59.69	$61	$1.382	0.0025	$1.3799	$62.68	$2.984	$50.450	$0.978	$51.428	$7.407	$1.653
11,163	$0.04	$0.20	$0.00	$0.97	$0.08	$0.00	$0.65	$1.95	$72.40	$74	$1.105	0.0016	$1.1031	$75.45	$3.049	$0.725	$55.088	$55.814	$6.527	$1.782
8,505	$1.13	$5.07	$0.01	$25.21	$2.17	$0.00	$16.86	$50.45	$1,877.12	$1,928	$0.980	0.0016	$0.9784	$1,928.54	$51.428	$3.316	$4.091	$7.407	$2.329	$4.336
3,133	$0.02	$0.07	$0.00	$0.36	$0.03	$0.00	$0.24	$0.73	$26.98	$28	$55.182	0.0898	$55.0885	$82.79	$55.814	$4.071	$2.456	$6.527	$1.653	$26.084
3,025	$0.07	$0.33	$0.00	$1.66	$0.14	$0.00	$1.11	$3.32	$123.37	$127	$4.097	0.0069	$4.0909	$130.78	$7.407	$2.286	$0.043	$2.329	$1.782	$3.968
3,464	$0.09	$0.41	$0.00	$2.03	$0.18	$0.00	$1.36	$4.07	$151.47	$156	$2.467	0.0006	$2.4558	$158.00	$6.527	$1.513	$0.140	$1.653	$4.336	$5.186
6,116	$0.05	$0.23	$0.00	$1.14	$0.10	$0.00	$0.76	$2.29	$85.07	$87	$0.043	0.0001	$0.0428	$87.40	$2.329	$1.734	$0.048	$1.782	$26.084	$4.106
2,489	$0.03	$0.15	$0.00	$0.76	$0.07	$0.00	$0.51	$1.51	$56.31	$58	$0.140	0.0002	$0.1401	$57.96	$1.653	$4.076	$0.260	$4.336	$3.968	$6.975
2,809	$0.04	$0.17	$0.00	$0.87	$0.07	$0.00	$0.58	$1.73	$64.53	$66	$0.048	0.0003	$0.0480	$66.32	$1.782	$21.616	$4.468	$26.084	$5.186	$5.758
9,282	$0.09	$0.41	$0.00	$2.04	$0.18	$0.00	$1.36	$4.08	$151.67	$156	$0.260	0.0004	$0.2600	$156.01	$4.336	$3.504	$0.463	$3.968	$4.106	$5.138
4,320	$0.49	$2.17	$0.00	$10.80	$0.93	$0.00	$7.22	$21.62	$804.28	$826	$4.483	0.0036	$4.4679	$830.36	$26.084	$4.407	$0.778	$5.186	$6.975	$3.742
2,397	$0.08	$0.35	$0.00	$1.75	$0.15	$0.00	$1.17	$3.50	$130.38	$134	$0.465	0.0003	$0.4635	$134.34	$3.968	$3.969	$0.137	$4.106	$5.758	$2.951
11,313	$0.10	$0.44	$0.00	$2.20	$0.19	$0.00	$1.47	$4.41	$163.98	$168	$0.780	0.0013	$0.7784	$169.17	$5.186	$5.790	$1.186	$6.975	$5.138	$0.642
5,613	$0.09	$0.40	$0.00	$1.98	$0.17	$0.00	$1.33	$3.97	$147.68	$152	$0.137	0.0001	$0.1366	$151.79	$4.106	$2.554	$3.203	$5.758	$3.742	$8.182
4,609	$0.13	$0.58	$0.00	$2.89	$0.25	$0.00	$1.93	$5.79	$215.42	$221	$1.187	0.0022	$1.1855	$222.40	$6.975	$3.349	$1.789	$5.138	$2.951	$0.267
11,365	$0.06	$0.26	$0.00	$1.28	$0.11	$0.00	$0.85	$2.55	$95.04	$98	$3.216	0.0015	$3.2032	$100.80	$5.758	$2.419	$1.323	$3.742	$0.642	$1.497
11,574	$0.08	$0.34	$0.00	$1.67	$0.14	$0.00	$1.12	$3.35	$124.62	$128	$1.796	0.0007	$1.7889	$129.75	$5.138	$1.024	$1.928	$2.951	$8.182	$2.712
4,202	$0.05	$0.24	$0.00	$1.21	$0.10	$0.00	$0.81	$2.42	$90.02	$92	$1.325	0.0021	$1.3226	$93.76	$3.742	$0.380	$0.262	$0.642	$0.287	$2.111
3,442	$0.02	$0.10	$0.00	$0.51	$0.04	$0.00	$0.34	$1.02	$38.09	$39	$1.932	0.0025	$1.9279	$41.04	$2.951	$3.906	$4.276	$8.182	$1.497	$3.799
2,558	$0.01	$0.04	$0.00	$0.19	$0.02	$0.00	$0.13	$0.38	$14.12	$15	$0.263	0.0002	$0.2625	$14.77	$0.642	$0.226	$0.061	$0.287	$73.119	$0.359
11,433	$0.09	$0.39	$0.00	$1.95	$0.17	$0.00	$1.31	$3.91	$145.33	$149	$4.288	0.0048	$4.2764	$153.51	$8.182	$1.381	$0.117	$1.497	$2.712	$13.550
2,323	$0.01	$0.02	$0.00	$0.11	$0.01	$0.00	$0.08	$0.23	$8.41	$9	$0.061	0.0001	$0.0611	$8.69	$0.287	$43.693	$29.427	$73.119	$2.111	$12.537
2,808	$0.03	$0.14	$0.00	$0.69	$0.06	$0.00	$0.46	$1.38	$51.37	$53	$0.117	0.0002	$0.1168	$52.87	$1.497	$1.973	$0.739	$2.712	$3.799	$2.710
8,640	$0.98	$4.39	$0.01	$21.83	$1.88	$0.00	$14.60	$43.69	$1,625.69	$1,669	$29.480	0.0461	$29.4265	$1,698.81	$73.119	$1.114	$0.996	$2.111	$0.359	$0.890
3,777	$0.04	$0.20	$0.00	$0.99	$0.08	$0.00	$0.66	$1.97	$73.42	$75	$0.741	0.0009	$0.7389	$76.13	$2.712	$2.328	$1.470	$3.799	$13.550	$0.696
2,931	$0.03	$0.11	$0.00	$0.56	$0.05	$0.00	$0.37	$1.11	$41.46	$43	$0.999	0.0011	$0.9964	$43.57	$2.111	$0.333	$0.026	$0.359	$12.537	$1.891
11,478	$0.05	$0.23	$0.00	$1.16	$0.10	$0.00	$0.78	$2.33	$86.64	$89	$1.464	0.0066	$1.4702	$90.44	$3.799	$9.620	$3.930	$13.550	$2.710	$3.634
2,528	$0.01	$0.03	$0.00	$0.17	$0.01	$0.00	$0.11	$0.33	$12.38	$13	$0.026	0.0000	$0.0260	$12.74	$0.359	$11.308	$1.229	$12.537	$0.890	$5.286
11,132	$0.22	$0.97	$0.00	$4.81	$0.41	$0.00	$3.21	$9.62	$357.93	$368	$3.940	0.0049	$3.9299	$371.48	$13.550	$2.457	$0.253	$2.710	$0.696	$5.540
6,338	$0.25	$1.14	$0.00	$5.65	$0.49	$0.00	$3.78	$11.31	$420.75	$432	$1.225	0.0049	$1.2289	$433.28	$12.537	$0.720	$0.170	$0.890	$1.891	$14.696
2,608	$0.06	$0.25	$0.00	$1.23	$0.11	$0.00	$0.82	$2.46	$91.40	$94	$0.254	0.0004	$0.2533	$94.11	$2.710	$0.574	$0.122	$0.696	$3.634	$1.389
2,375	$0.02	$0.07	$0.00	$0.36	$0.03	$0.00	$0.24	$0.72	$26.80	$28	$0.171	0.0002	$0.1700	$27.69	$0.890	$0.822	$1.070	$1.891	$5.286	$1.891
2,323	$0.01	$0.06	$0.00	$0.29	$0.02	$0.00	$0.19	$0.57	$21.37	$22	$0.122	0.0001	$0.1217	$22.06	$0.696	$3.143	$0.491	$3.634	$5.540	$1.149
2,194	$0.02	$0.08	$0.00	$0.41	$0.04	$0.00	$0.27	$0.82	$30.58	$31	$1.074	0.0004	$1.0695	$32.47	$1.891	$2.349	$2.937	$5.286	$14.696	$1.467
4,451	$0.07	$0.32	$0.00	$1.57	$0.14	$0.00	$1.05	$3.14	$116.93	$120	$0.492	0.0007	$0.4912	$120.57	$3.634	$4.685	$0.854	$5.540	$1.389	$0.828
2,721	$0.05	$0.24	$0.00	$1.17	$0.10	$0.00	$0.79	$2.35	$87.42	$90	$2.940	0.0059	$2.9369	$92.70	$5.286	$14.429	$0.267	$14.696	$1.891	$2.446
7,590	$0.11	$0.47	$0.00	$2.34	$0.20	$0.00	$1.57	$4.69	$174.33	$179	$0.858	0.0005	$0.8544	$179.87	$5.540	$0.365	$1.024	$1.389	$1.149	$7.643
6,597	$0.32	$1.45	$0.00	$7.21	$0.62	$0.00	$4.82	$14.43	$536.86	$551	$0.264	0.0023	$0.2671	$551.56	$14.696	$0.994	$0.897	$1.891	$1.467	$4.309
1,893	$0.01	$0.04	$0.00	$0.18	$0.02	$0.00	$0.12	$0.36	$13.57	$14	$1.028	0.0007	$1.0243	$14.96	$1.389	$1.051	$0.098	$1.149	$0.828	$4.081
2,300	$0.02	$0.10	$0.00	$0.50	$0.04	$0.00	$0.33	$0.99	$36.98	$38	$0.900	0.0007	$0.8973	$38.87	$1.891	$1.359	$0.108	$1.467	$2.446	$1.898
2,326	$0.02	$0.11	$0.00	$0.53	$0.05	$0.00	$0.35	$1.05	$39.10	$40	$0.098	0.0001	$0.0981	$40.25	$1.149	$0.424	$0.404	$0.828	$7.643	$3.935
2,334	$0.03	$0.14	$0.00	$0.68	$0.06	$0.00	$0.45	$1.36	$50.57	$52	$0.108	0.0000	$0.1080	$52.04	$1.467	$1.878	$0.568	$2.446	$4.309	$1.378
2,530	$0.01	$0.04	$0.00	$0.21	$0.02	$0.00	$0.14	$0.42	$15.76	$16	$0.406	0.0003	$0.4045	$16.59	$0.828	$3.076	$4.567	$7.643	$4.081	$2.775
5,073	$0.04	$0.19	$0.00	$0.94	$0.08	$0.00	$0.63	$1.88	$69.87	$72	$0.569	0.0010	$0.5683	$72.32	$2.446	$4.176	$0.133	$4.309	$1.898	$2.383
2,552	$0.07	$0.31	$0.00	$1.54	$0.13	$0.00	$1.03	$3.08	$114.44	$118	$4.572	0.0088	$4.5669	$122.08	$7.643	$2.407	$1.673	$4.081	$3.935	$0.709
2,488	$0.09	$0.42	$0.00	$2.09	$0.18	$0.00	$1.40	$4.18	$155.39	$160	$0.133	0.0001	$0.1327	$159.70	$4.309	$1.548	$0.350	$1.898	$1.378	$1.610
2,375	$0.05	$0.24	$0.00	$1.20	$0.10	$0.00	$0.80	$2.41	$89.57	$92	$1.677	0.0023	$1.6735	$93.65	$4.081	$3.817	$0.118	$3.935	$2.775	$1.198
2,422	$0.03	$0.16	$0.00	$0.77	$0.07	$0.00	$0.52	$1.55	$57.60	$59	$0.351	0.0005	$0.3499	$59.50	$1.898	$1.012	$0.366	$1.378	$2.383	$2.944
11,475	$0.09	$0.38	$0.00	$1.91	$0.16	$0.00	$1.28	$3.82	$142.02	$146	$0.118	0.0001	$0.1180	$145.96	$3.935	$1.971	$0.804	$2.775	$0.709	$9.738
2,666	$0.02	$0.10	$0.00	$0.51	$0.04	$0.00	$0.34	$1.01	$37.64	$39	$0.366	0.0007	$0.3659	$39.02	$1.378	$2.184	$0.198	$2.383	$1.610	$0.874
2,710	$0.04	$0.20	$0.00	$0.98	$0.08	$0.00	$0.66	$1.97	$73.32	$75	$0.807	0.0007	$0.8044	$76.09	$2.775	$0.577	$0.132	$0.709	$1.198	$1.378
2,288	$0.05	$0.22	$0.00	$1.09	$0.09	$0.00	$0.73	$2.18	$81.27	$83	$0.199	0.0003	$0.1984	$83.65	$2.383	$0.650	$0.961	$1.610	$2.944	$1.440
2,574	$0.01	$0.06	$0.00	$0.29	$0.02	$0.00	$0.19	$0.58	$21.47	$22	$0.132	0.0002	$0.1315	$22.18	$0.709	$0.891	$0.307	$1.198	$9.738	$0.434
2,077	$0.01	$0.07	$0.00	$0.32	$0.03	$0.00	$0.22	$0.65	$24.17	$25	$0.960	0.0028	$0.9609	$25.78	$1.610	$1.239	$1.705	$2.944	$0.874	$1.342
2,458	$0.02	$0.09	$0.00	$0.45	$0.04	$0.00	$0.30	$0.89	$33.16	$34	$0.307	0.0007	$0.3067	$34.36	$1.198	$9.493	$0.245	$9.738	$1.378	$0.519
2,457	$0.03	$0.12	$0.00	$0.62	$0.05	$0.00	$0.41	$1.24	$46.10	$47	$1.709	0.0024	$1.7050	$49.04	$2.944	$0.675	$0.199	$0.874	$1.440	$1.977
7,887	$0.21	$0.95	$0.00	$4.74	$0.41	$0.00	$3.17	$9.49	$353.22	$363	$0.245	0.0005	$0.2448	$362.96	$9.738	$1.029	$0.349	$1.378	$0.434	$1.847
8,277	$0.02	$0.07	$0.00	$0.34	$0.03	$0.00	$0.23	$0.68	$25.12	$26	$0.199	0.0005	$0.1990	$25.99	$0.874	$0.465	$0.975	$1.440	$1.342	$0.456
2,531	$0.02	$0.10	$0.00	$0.51	$0.04	$0.00	$0.34	$1.03	$38.30	$39	$0.340	0.0051	$0.3490	$39.68	$1.378	$0.225	$0.210	$0.434	$0.519	$2.160
2,368	$0.81	$3.62	$0.01	$18.00	$1.55	$0.00	$12.04	$36.03	$1,340.73	$1,377	$420.306	0.8522	$419.9251	$1,796.69	$455.959	$0.767	$0.575	$1.342	$1.977	$5.178
2,325	$0.01	$0.05	$0.00	$0.23	$0.02	$0.00	$0.16	$0.46	$17.29	$18	$0.973	0.0031	$0.9748	$18.73	$1.440	$0.376	$0.143	$0.519	$1.847	$1.105
2,333	$0.01	$0.02	$0.00	$0.11	$0.01	$0.00	$0.08	$0.22	$8.36	$9	$0.210	0.0002	$0.2098	$8.79	$0.434	$1.736	$0.241	$1.977	$0.456	$1.013
2,403	$0.02	$0.08	$0.00	$0.38	$0.03	$0.00	$0.26	$0.77	$28.53	$29	$0.577	0.0008	$0.5755	$29.88	$1.342	$1.502	$0.346	$1.847	$2.160	$2.448
2,302	$0.01	$0.04	$0.00	$0.19	$0.02	$0.00	$0.13	$0.38	$13.98	$14	$0.144	0.0002	$0.1433	$14.50	$0.519	$0.449	$0.007	$0.456	$5.178	$1.351
2,323	$0.04	$0.17	$0.00	$0.87	$0.07	$0.00	$0.58	$1.74	$64.58	$66	$0.242	0.0002	$0.2411	$66.56	$1.977	$1.331	$0.829	$2.160	$1.105	$0.857

APPENDIX J Hydro Externality Estimates per Megawatt Hour 3 of 3

FERC Dam #	VOCs	NOx	CO	SO2	PM10	Cost D&T	CO2 Con.	Total Up,no	Upstream T	Total Upstre	Operations (	Operations M	Total Operat	Total$$ Imp	Total Impact	Upstream nc	Operations r	Total Impact	Total Impact	Total Impact
2,727	$0.03	$0.15	$0.00	$0.75	$0.06	$0.00	$0.50	$1.50	$55.87	$57	$0.345	0.0011	$0.3457	$57.72	$1.847	$4.425	$0.753	$5.178	$1.013	$2.165
2,287	$0.01	$0.05	$0.00	$0.22	$0.02	$0.00	$0.15	$0.45	$16.72	$17	$0.007	0.0000	$0.0066	$17.18	$0.456	$0.632	$0.473	$1.105	$2.448	$0.988
2,513	$0.03	$0.13	$0.00	$0.67	$0.06	$0.00	$0.44	$1.33	$49.54	$51	$0.831	0.0007	$0.8285	$51.70	$2.160	$0.607	$0.406	$1.013	$1.351	$1.284
2,519	$0.10	$0.44	$0.00	$2.21	$0.19	$0.00	$1.48	$4.42	$164.64	$169	$0.754	0.0016	$0.7534	$169.82	$5.178	$2.344	$0.104	$2.448	$0.857	$33.693
1,893	$0.01	$0.06	$0.00	$0.32	$0.03	$0.00	$0.21	$0.63	$23.52	$24	$0.474	0.0007	$0.4729	$24.62	$1.105	$0.264	$1.087	$1.351	$2.165	$2.996
2,335	$0.01	$0.06	$0.00	$0.30	$0.03	$0.00	$0.20	$0.61	$22.59	$23	$0.407	0.0007	$0.4062	$23.60	$1.013	$0.292	$0.565	$0.857	$0.988	$7.588
2,323	$0.05	$0.24	$0.00	$1.17	$0.10	$0.00	$0.78	$2.34	$87.22	$90	$0.104	0.0002	$0.1037	$89.67	$2.448	$1.079	$1.086	$2.165	$1.284	$2.221
1,855	$0.01	$0.03	$0.00	$0.13	$0.01	$0.00	$0.09	$0.26	$9.81	$10	$1.089	0.0019	$1.0874	$11.16	$1.351	$0.731	$0.256	$0.988	$33.693	$3.311
2,458	$0.01	$0.03	$0.00	$0.15	$0.01	$0.00	$0.10	$0.29	$10.85	$11	$0.567	0.0005	$0.5652	$11.71	$0.857	$1.239	$0.046	$1.284	$2.996	$2.620
2,365	$0.02	$0.11	$0.00	$0.54	$0.05	$0.00	$0.36	$1.08	$40.16	$41	$1.088	0.0015	$1.0859	$42.32	$2.165	$1.396	$32.296	$33.693	$7.588	$2.299
2,611	$0.02	$0.07	$0.00	$0.37	$0.03	$0.00	$0.24	$0.73	$27.21	$28	$0.256	0.0006	$0.2565	$28.20	$0.988	$2.783	$0.214	$2.996	$2.221	$2.894
2,327	$0.03	$0.12	$0.00	$0.62	$0.05	$0.00	$0.41	$1.24	$46.09	$47	$0.046	0.0001	$0.0455	$47.38	$1.284	$5.631	$1.958	$7.588	$3.311	$3.594
2,458	$0.03	$0.14	$0.00	$0.70	$0.06	$0.00	$0.47	$1.40	$51.96	$53	$32.256	0.1002	$32.2962	$85.65	$33.693	$1.020	$1.201	$2.221	$2.620	$1.809
2,323	$0.06	$0.28	$0.00	$1.39	$0.12	$0.00	$0.93	$2.78	$103.54	$106	$0.214	0.0002	$0.2137	$106.53	$2.996	$1.720	$1.591	$3.311	$2.299	$3.824
2,712	$0.13	$0.57	$0.00	$2.81	$0.24	$0.00	$1.88	$5.63	$209.51	$215	$1.961	0.0032	$1.9576	$217.10	$7.588	$0.746	$1.874	$2.620	$2.894	$8.112
2,600	$0.02	$0.10	$0.00	$0.51	$0.04	$0.00	$0.34	$1.02	$37.94	$39	$1.206	0.0006	$1.2012	$40.16	$2.221	$0.934	$1.365	$2.299	$3.594	$32.723
2,534	$0.04	$0.17	$0.00	$0.86	$0.07	$0.00	$0.57	$1.72	$63.99	$66	$1.594	0.0025	$1.5909	$67.30	$3.311	$2.261	$0.633	$2.894	$1.809	$18.166
2,283	$0.02	$0.07	$0.00	$0.37	$0.03	$0.00	$0.25	$0.75	$27.74	$28	$1.872	0.0058	$1.8745	$30.36	$2.620	$1.768	$1.826	$3.594	$3.824	$11.655
2,520	$0.02	$0.09	$0.00	$0.47	$0.04	$0.00	$0.31	$0.93	$34.75	$36	$1.357	0.0073	$1.3651	$37.05	$2.299	$0.601	$1.208	$1.809	$8.112	$19.836
2,529	$0.05	$0.23	$0.00	$1.13	$0.10	$0.00	$0.76	$2.26	$84.13	$86	$0.635	0.0007	$0.6330	$87.02	$2.894	$2.662	$1.162	$3.824	$32.723	$3.770
2,322	$0.04	$0.18	$0.00	$0.88	$0.08	$0.00	$0.59	$1.77	$65.77	$68	$1.833	0.0011	$1.8259	$69.36	$3.594	$7.119	$0.994	$8.112	$18.166	$9.683
1,904	$0.01	$0.06	$0.00	$0.30	$0.03	$0.00	$0.20	$0.60	$22.35	$23	$1.212	0.0014	$1.2084	$24.16	$1.809	$5.182	$27.541	$32.723	$11.655	$2.849
2,456	$0.06	$0.27	$0.00	$1.33	$0.11	$0.00	$0.89	$2.66	$99.05	$102	$1.162	0.0031	$1.1623	$102.87	$3.824	$17.649	$0.516	$18.166	$19.836	$4.043
2,942	$0.16	$0.72	$0.00	$3.56	$0.31	$0.00	$2.38	$7.12	$264.86	$272	$0.994	0.0023	$0.9936	$272.98	$8.112	$0.616	$11.038	$11.655	$58.903	$5.489
4,026	$0.12	$0.52	$0.00	$2.59	$0.22	$0.00	$1.73	$5.18	$192.81	$198	$27.444	0.1167	$27.5408	$225.53	$32.723	$18.471	$1.365	$19.836	$3.770	$3.815
2,631	$0.40	$1.77	$0.00	$8.82	$0.76	$0.00	$5.90	$17.65	$656.68	$674	$0.512	0.0033	$0.5163	$674.85	$18.166	$9.879	$49.024	$58.903	$9.683	$5.320
2,572	$0.01	$0.06	$0.00	$0.31	$0.03	$0.00	$0.21	$0.62	$22.92	$24	$11.008	0.0427	$11.0385	$34.58	$11.655	$1.933	$1.837	$3.770	$2.849	$4.289
3,180	$0.42	$1.86	$0.00	$9.23	$0.79	$0.00	$6.17	$18.47	$687.26	$706	$1.360	0.0057	$1.3649	$707.10	$19.836	$9.031	$0.652	$9.683	$4.043	
2,615	$0.22	$0.99	$0.00	$4.94	$0.42	$0.00	$3.30	$9.88	$367.58	$377	$48.934	0.1660	$49.0237	$426.48	$58.903	$2.454	$0.394	$2.849	$5.489	
2,458	$0.04	$0.19	$0.00	$0.97	$0.08	$0.00	$0.65	$1.93	$71.93	$74	$1.834	0.0060	$1.8366	$75.70	$3.770	$2.256	$1.787	$4.043	$3.815	
2,323	$0.20	$0.91	$0.00	$4.51	$0.39	$0.00	$3.02	$9.03	$336.02	$345	$0.651	0.0017	$0.6516	$345.70	$9.683	$5.246	$0.243	$5.489	$5.320	
2,527	$0.06	$0.25	$0.00	$1.23	$0.11	$0.00	$0.82	$2.45	$91.32	$94	$0.390	0.0032	$0.3942	$94.17	$2.849	$3.497	$0.319	$3.815	$4.289	
1,892	$0.05	$0.23	$0.00	$1.13	$0.10	$0.00	$0.75	$2.26	$83.93	$86	$1.786	0.0051	$1.7874	$87.97	$4.043	$4.148	$1.172	$5.320		
2,284	$0.12	$0.53	$0.00	$2.62	$0.23	$0.00	$1.75	$5.25	$195.18	$200	$0.245	0.0000	$0.2434	$200.67	$5.489	$3.496	$0.793	$4.289		
2,077	$0.08	$0.35	$0.00	$1.75	$0.15	$0.00	$1.17	$3.50	$130.10	$134	$0.316	0.0022	$0.3186	$133.92	$3.815					
2,077	$0.09	$0.42	$0.00	$2.07	$0.18	$0.00	$1.39	$4.15	$154.35	$158	$1.157	0.0106	$1.1720	$159.67	$5.320					
2,329	$0.08	$0.35	$0.00	$1.75	$0.15	$0.00	$1.17	$3.50	$130.08	$134	$0.780	0.0080	$0.7926	$134.37	$4.289					
								Total Up,no tc	Upstream To	Total Upstrea	Operations CC	Operations Me	Total Operatic	Total$$ Impa	Total Impact-l	Upstream no	Operations nc	Total Impact-r	Total Impact-no	outliersNo T
							Average	$4.83	$179.57	$184.40	$19.45	$0.02	$19.40	$203.80	$24.22	$4.63	$4.21	$8.84	$7.24	$5.53
							Median	$2.26	$83.93	$86.19	$0.82	$0.00	$0.81	$87.97	$3.63	$2.17	$0.80	$3.55	$3.41	$3.05
							Smallest	$0.17	$6.36	$6.53	$0.01	$0.00	$0.01	$6.58	$0.22	$0.17	$0.01	$0.22	$0.22	$0.22
							Largest	*$107.60*	*$4,003.40*	*$4,110.99*	*$2,010.35*	*$1.07*	*$2,002.26*	*$4,113.84*	*$2,010.95*	*$107.60*	*$166.65*	*$175.98*	*$75.19*	*$38.91*