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The work on which this report is based was supported with funds provided by the State of Utah and by the U.S. Department of the Interior under Project No. B-171-Utah, Grant No. 14-34-0001-9137. Investigation Period March 1, 1979, to August 31, 1981.

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ABSTRACT

The overall objective of the study reported here was to determine to what extent energy accounting could supplement and/or complement economic benefit/cost analyses of water management projects and to specifically examine the energy impacts of water based recreation. The energy accounting literature was carefully reviewed and an energy accounting methodology applicable to water management was devised. Data pertaining to recreation at five reservoirs in Utah were assembled from visitation records and on-site surveys. Energy requirements for site construction, travel to and from the recreation site, and recreation at the site were estimated. It was determined that energy devoted to water based recreation is not inconsequential. As much energy is devoted to recreation at Lake Powell alone as is required for all of production agriculture in Utah. It is suggested that while the models developed in this study could be used with confidence in the preparation of energy impact statements the authors are not persuaded energy accounting provides additional information to water use planners beyond that obtainable from traditional economic analysis.

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The work on which this report is based was supported with funds provided by the State of Utah and by the U.S. Department of the Interior, Project B-171-Utah, Grant No. 14-34-0001-9137. Investigation Period March 1, 1979, to August 31, 1981.

The principal investigators on this project were J. Clair Batty, Professor of Mechanical Engineering; E. Bruce Godfrey, Associate Professor of Economics; and J. Paul Riley, Professor of Civil and Environmental Engineering, all at Utah State University. Other investigators included David A. Bell, Research Associate Mechanical Engineering; Craig Howell, candidate for the M.S. degree in Economics; and Thomas C. Stoddard, candidate for the M.S. degree in Mechanical Engineering at Utah State University.

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CHAPTER 1

INTRODUCTION

This report deals with a form of technology assessment. In its broadest sense, technology assessment provides the decision maker with information which may go far beyond conventional engineering and cost/benefit studies to look at what else might happen in achieving an immediate goal. The assessment addresses the full range of social costs, including impacts on: the family; legal, political, and social institutions; and the environment. Thus, technology assessment might be regarded as an analysis of the total impact of a technology on a society (Coates 1974).

Traditionally, multipurpose water resource development projects are assessed on the basis of an economic analysis in which the costs and benefits associated with the projects are compared. Usually, both direct and indirect costs and benefits are included in these analyses. In addition, recent efforts have been made to address the environmental and, to some extent, the social impacts of the developments. However, to this point assessments may not have included consideration of project impacts on the energy resources of the nation. This report addresses the question of how to apply energy impact assessment to water resource development projects, particularly those involving flat-water recreation. What use can be made of energy impact assessments? What additional information would be provided by energy impact assessment? What techniques are most appropriate for flat-water recreation projects?

Energy conservation is being increasingly advocated as both a prudent and essential component of national policy. The 1974 Non-nuclear Energy Research and Development Act stipulates that the Department of Energy conduct a "net energy analysis" for each non-nuclear project supported by public funds (Burness et al. 1980). Implementation of effective energy conservation strategies requires awareness of the energy use associated with a wide variety of activities, including those associated with water. Some authors have indicated that energy impact statements, similar to or an extension of environmental impact statements, will be required prior to the construction of publically funded water projects. Certainly the energy use implications of millions of people being attracted hundreds and even thousands of miles for recreation on major man-made reservoirs should not be ignored.

Two fundamental approaches to assessing energy impacts have been advocated. The first approach is to express energy costs in traditional monetary terms that are used in economic benefit/cost analyses. This approach assumes the market place captures or reflects the value of energy. The second approach is to express energy costs in units of energy. This energy accounting approach requires the development of an acceptable methodology for tracking the quantity and forms of the myriad flows of energy associated with a particular endeavor. Many different energy accounting methodologies have been proposed in the past few years. Clearly if an energy accounting approach is to be adopted to assess the energy impacts of water projects one must be identified that is widely acceptable and will achieve credibility in the national water management community.

The principal investigators in this study did not assume a priori that energy accounting was inherently superior to economic benefit/cost analysis in comparing alternative water projects. The proposition to be tested is, "does energy accounting provide information that would complement and/or supplement economic analysis"? An evaluation of the worth of this additional information, however, may find that it is not worth the cost of its estimation.

The Rise of the Concept of Energy Accounting

Within the last few years, as public awareness of the energy crisis has spread, significant interest has become manifest in energy accounting as possibly providing a useful supplement to traditional economic analysis. An example of the need for supplemental analysis is found in the controversy surrounding the development of oil shale. Using traditional economic analysis, various estimates have been made concerning the economic feasibility of oil shale development. According to various analysts, when the price of oil reaches \$3.73/bbl (Dinnen and Cook 1972), or \$6.80/bbl (Adelman et al. 1974), or \$15.00/bbl (Rothfield 1975), or \$21.00/bbl (McCormick 1976), or \$25.00/bbl (Wiser 1976) oil shale development will become a reality. These analyses seem to suggest that dollar values provide an unstable bench mark on which to base policy decisions. The dollar value of a given form of energy is dependent upon many factors, including the vagaries of political bodies and foreign cartels, and thus can vary over a wide range especially when rates of inflation vary over time.

The energy accounting approach on the surface seems to provide a basic method of comparing the relative efficiencies with which various power producing options convert basic resources into a commodity such as electric power or gasoline. One apparent advantage of the energy accounting approach is that the magnitude and impact of these energy flows are clearly delineated. Many who consider themselves friends of the environment are actively promoting wind and solar power as being absolutely pollution free having little or no environmental impact. The usual image of these systems excludes soot, smog, heat, and grime. The immense quantities of materials that must be manufactured and assembled to implement wind or solar power production on a significant scale are often forgotten or ignored. A material and energy flow analysis would perhaps show that the environmental impact associated with deployment of such systems will not be zero, and it is not inconceivable that the production of electricity via windmills or solar generators could result in greater environmental degradation than the production of electricity via traditional coal-fired steam generating plants. When told that a solar collector will cost so many dollars, some tend to shrug and think of the cost as being only money. However, if more coal would have to be mined and burned to manufacture the collecting systems than would be required to produce the power by burning the coal directly, the preconceived environmental gain might not exist.

Thus, one possible advantage of the energy accounting may include educational value in improving public awareness of the technical realities of nature. For example, the energy method of accounting has brought a realization that American agriculture owes its awesome productivity to energy inputs on a vast scale, and that in terms of food energy produced per unit of energy input we are relatively inefficient. We learn further through energy accounting that energy inputs to food production are commonly only a small fraction of the energy inputs to the total food system. It appears, for example, that more energy is often used to transport food from the supermarket to the home than is needed to produce the food (Brown and Batty 1976).

Those who are responsible for formulating long range water management policy must constantly assess the relevance of information in the decision making process. The extent to which the information derivable from energy accounting supplements and/or complements economic analysis needs to be evaluated. For example, by carefully tracing the energy flows associated with recreation at existing man-made impoundments (Figure 1), can a better perspective of the impacts of future similar developments be obtained?

Objectives of the Study

The following are specific objectives of this study:

1. To devise a workable methodology for energy accounting as a supplement to economic benefit-cost analysis suitable for evaluating the energy impact of recreation at man-made flat-water sites.

2. To study the hypothesis that relationships exist among certain parameters pertaining to recreation, such as the distance from major population centers to the recreation area, the kind of activity at the area, and the amounts and kinds of energy devoted to recreation.

3. To develop a general predictive model for estimating energy use at man-made flat-water recreation areas from relevant parameters.

4. To suggest guidelines for energy impact statements based on the predictive model developed in objective 3.

5. To carefully assess the validity of energy accounting in the area of water management, and specifically to describe its usefulness as a supplement to traditional economic benefit/cost analysis.

Research Procedure

In order to meet the above objectives, the following specific tasks were accomplished.

1. The various approaches to energy flow analysis were carefully evaluated by both engineers and economists.

2. An energy accounting methodology was developed that seemed appropriate for water based recreation.

3. Relevant data pertaining to recreation at two major Utah reservoirs (Flaming Gorge and Lake Powell) and four smaller Utah reservoirs (Willard Bay, East Canyon, Rockport, Hyrum Dam) were assembled.

4. Questionnaires and on-site surveys were made where necessary to supplement data from existing records. These surveys were designed primarily to provide information regarding the energy associated with travel to and from the recreation site (E_1) and the energy expended while at the recreation site (E_2) for activities such as boating.

5. Information relating to a third energy category (E_3), namely that associated with the construction and maintenance of the site, was derived from construction plans and other official records.

6. Suggestions for writing energy impact statements based on the predictive model were made.

7. The validity of energy accounting in water recreation management was scrutinized based on the experience gained in this study.

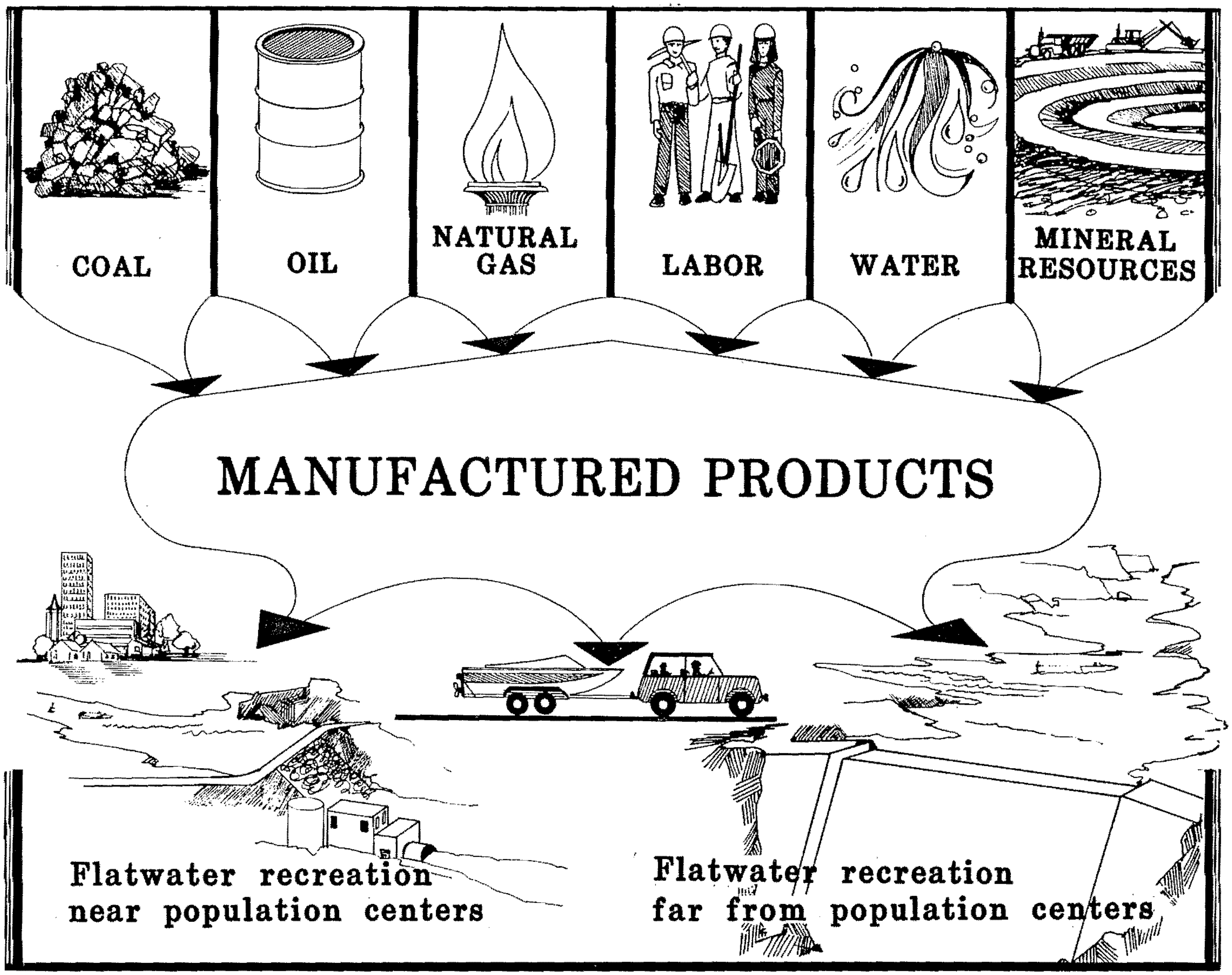

Figure 1. Energy accounting may be useful in helping planners optimally deploy basic resources. For example, constructing more water recreation sites closer to population centers may help conserve the nations energy resources.

CHAPTER 2

CURRENT ENERGY ACCOUNTING TECHNIQUES

The Concept of Net Energy

If one were to single out a pioneer in energy accounting methods, H. T. Odum would probably be first mentioned. It was Odum who defined many of the key concepts accepted today in attempting to develop a consistent energy accounting procedure (Odum 1971).

The starting point in understanding energy accounting or energy flow analysis is the notion of net energy. Odum defined this quantity as the amount of energy available for consumer use after the energy cost of finding, producing, refining, transporting, and so forth, has been subtracted (Odum 1973). For example, each barrel of gasoline requires an input of energy in the extraction and refining processes. Thus, each unit of energy resource output requires a certain quantity of energy input. The net energy is the difference between the two, expressed as follows:

$$\text{Net energy} = \begin{array}{c}\text{Quantity of energy}\\ \text{obtained from the}\\ \text{developed resource}\end{array} - \begin{array}{c}\text{Quantity of energy}\\ \text{spent in develop-}\\ \text{ing the resource}\end{array}$$

Energies summarized in the above equation must all be in the same form or numeraire (e.g., barrels of oil or tons of coal). Though net energy can be a negative number, it should normally be positive for a project to warrant further consideration. Spending one barrel of oil to operate machinery which, in turn, generates two barrels of usable oil for the marketplace is an example of positive net energy. The investment taken from current stock is replaced and the process shows a gain of an additional barrel of available energy supply. Operations with negative net energy require more input energy than is produced.

A second term used in energy accounting is the energy yield ratio. It is defined as a project's useful energy production (or savings) divided by required inputs. The reciprocal of this ratio is termed the energy investment ratio.

$$\text{Energy yield ratio} = \frac{\text{Quantity of energy obtained}}{\text{Quantity of energy spent}}$$

The energy yield ratio can be thought of as a coefficient of performance, where a larger value suggests a preferred choice.

The Importance of Energy Form

It is obvious that net energy and the energy yield ratio must be expressed in terms of a specified form of energy, otherwise the concept would have little meaning. Society is usually willing to maintain processes that have a negative net energy or an energy yield ratio of less than unity if the market value of the energy form produced is greater than the market value of the energy inputs regardless of the quantities of energy involved. For example, a coal fired electrical generating plant uses about three times as much energy in the form of coal as is typically produced by the plant in the form of electricity.

Representative monitary values of various forms of energy are shown in Table 1. This table emphasizes the importance of specifying the energy form in order to give meaning to energy accounting concepts. Furthermore, there are large variations of value within each form of energy listed in Table 1. High sulfur coal is less valuable than low sulfur coal for example. It is not uncommon in energy accounting reports to see energy in the form of human labor added directly to energy in the form of fossil fuels and electricity and the total referred to as units of "energy."

Energy Accounting Terms and Techniques

A major challenge in energy accounting is to first identify and then to quantify all the significant energy flows that cross the project control boundary. Definition of the scope and significance of energy flows is a major source of disagreement in the various existing energy accounting methodologies.

In the Odum model, for example, a "holistic" approach is suggested. Odum

Table 1. Calculated values of various energy forms based on assumptions shown.

	Assumptions	Value ($\$/10^6$ kJ)
Fossil Fuels		
Natural Gas	33 750 kJ/m^3, \$0.08/m^3	\$ 2.40
Coal	22 000 kJ/m^3, \$0.05/m^3	\$ 2.40
Diesel	39 000 kJ/L, \$0.26/L	\$ 6.60
Gasoline	34 800 kJ/L, \$0.31/L	\$ 8.90
Animal Feeds		
Alfalfa Hay	9 670 kJ/kg, \$0.09/kg	\$ 9.30
Grain Corn	14 550 kJ/kg, \$0.15/kg	\$ 10.30
Electricity		
Residential	\$0.06/kW·h	\$ 16.60
Foods		
Rice	15 140 kJ/kg, \$0.75/kg	\$ 48.70
Potatoes	25 700 kJ/kg, \$0.20/kg	\$ 77.80
Bread	11 215 kJ/kg, \$0.88/kg	\$ 78.50
Turkey	10 400 kJ/kg, \$1.50/kg	\$144.20
Beef	10 700 kJ/kg, \$3.30/kg	\$194.10
Mechanical Energy		
Farm Tractor	\$20 000/6000 hr, 7.6 L/hr, 20% eff.	\$ 56.00
Automobile	\$0.20/km, 10 km/L, 15% eff.	\$380.00
Human Labor		
Manual Labor	0.30 kW, \$4.00/hr	\$ 27,800
Skilled Labor	0.10 kW, \$10.00/hr	\$138,900
Professional	0.05 kW, \$15.00/hr	\$416,700

reasons that energy flow is the driving force of all systems and as such should be accounted for wherever an energy transfer is accomplished. In his very detailed procedure, energy inputs are defined as being either direct or indirect. They are further subdivided as natural subsidies or social subsidies. For an impoundment project, examples of these energy categories are described below.

Direct inputs

Direct inputs are those energy sources applied directly to the project. Social subsidies of a direct nature are those energy flows over which man has control such as the fuel used to operate project equipment and the energy spent in processing the materials going to construct the project. Natural subsidies are those over which humans have, as yet, exerted no control such as solar energy irradiating the earth's surface, potential and kinetic energy associated with river systems, and energies associated with biological phenomena such as photosynthesis and chemical potentials.

Indirect inputs

Indirect energy inputs constitute a catch-all category for everything that is not a material or process expenditure. Typically, this category includes energy required for labor, engineering, maintenance, and personnel services. There are also reasons why intermediate products need to be counted as indirect inputs. For example, energy is needed to process the materials used in building the earth-moving equipment employed in the construction of a dam. The energy used for the fabrication of these kinds of intermediate products is classified as indirect energy input to the project development.

Combining energy inputs

Following the holistic approach, an energy budget analysis for a typical reservoir would show not only energy inputs for manufacturing materials and performing construction operations, but also would include the potential photosynthetic energy of the foliage that was removed because of the construction project. Sunlight is diffuse and cannot be captured and used as readily as a concentrated fuel such as coal. Consequently, Odum defines a "quality factor" for each form of energy flow which is intended to convert all inputs to a standard fossil fuel equivalent (SSFE). Odum proposed the energy concentration of bituminous coal to serve as such a standard and this has met with wide theoretical acceptance. The practical problem of quantifying differences in quality and form however remains as one of the significant disadvantages pointed out by energy accounting critics as being difficult and clearly subjective. Even though one could accept any energy form as a standard and express all energy flows in terms of the selected standard, the criticism of subjectivity in conversion still applies.

To account for indirect inputs, such as labor, a factor that converts dollars to kilojoules is often established using gross national product and the total energy use. This conversion ratio is usually standardized by a price index ratio to a base year to correct for the influence of inflation on gross national product (Bayley et al. 1977). In a similar manner, Odum expresses all energy flows associated with a project in kilojoules of coal (Odum 1973).

Since the inception of Odum's methodology, others have tried to develop energy accounting procedures. As indicated earlier, the major criticism of Odum's model is the complexity in determining energy flows. Virtually every succeeding attempt at an energy accounting methodology has tried to make energy flows easier to calculate. An obvious procedure is to restrict the energy flows considered, taking only the primary inputs, for example, and ignoring indirect inputs. Other methods consider indirect inputs but attempt to resolve the issue of which indirect inputs have a significant impact and which ones should not be counted for an approximate analysis. Another approach considers the various sectors of the economy as defined by the Department of Commerce and for a particular project correlates those sectors interfacing with each other in the process. Energy flows between the various economic sectors are traced and arranged in a matrix configuration. Net energy values are then derived from the matrix (Herendeen and Bullard 1974). One advantage of this scheme is that an iteration procedure can be used, with additional inputs being included for each interation until a desired level of accuracy is achieved in the analysis result. This input-output approach is interesting but is complex in practice. Extensive computation is required and the procedure cannot compensate for a lack of basic data on energy flows.

Only a few of the energy accounting methodologies reviewed as part of this study are summarized here. Our conclusions from the review are that the information gained from energy accounting does not warrant a complex procedure that could reduce the credibility of applying the concept to water resource projects. Therefore, the energy accounting methods used in water resources management problems should be simple, straightforward, and unencumbered by undue complexity, specialized jargon, or nomenclature. As suggested previously (Otto 1975), the first of several criteria for applying energy accounting to water resources planning is the methodology must be simple enough for routine work. The validity of energy accounting and the specific kinds of information it provides to managers of water resources systems are further discussed later in this report. However, a simple methodology is first proposed and demonstrated by applying it to water recreation in Utah.

CHAPTER 3

DEVELOPMENT OF ENERGY ACCOUNTING METHODOLOGY FOR WATER-BASED RECREATION

The three principal energy consuming activities involved in developing and using a reservoir for recreation are: 1) facility construction, 2) recreation activities such as boating at the site, and 3) travel to and from major population centers that are generally some distance from the reservoir. Estimates of the amount of energy used in these three activities are based on the following assumptions:

1. Energy flows are expressed in petroleum fuel equivalents. This represents a departure from many methodologies. The energy spent for recreation is primarily in the form of petroleum products used in travel and for operation of recreational vehicles. As a result, the difficulty of determining conversion factors is mitigated if not avoided for direct input energy flows because this is the form in which the largest share of the energy is consumed. Furthermore, it is likely that the political and psychological impact of measuring energy for recreation will be greater upon planners and recreators when expressed in terms of liters or gallons of gasoline because the public is familiar with this form of energy.

2. Natural energy inputs will be ignored. For the most part, society is concerned with expenditures that must be incurred to satisfy its needs. Natural energy inputs have little direct social cost in most instances. As a result, only those inputs which represent a societal allocation of controlled energy resources need be considered because only these inputs involve a change in resource availability.[1]

3. Indirect energy inputs will not be exhaustively sought and included. It is realized that indirect energy inputs are commonly expended but like secondary benefits and costs, their order of magnitude is probably small in most cases. For example, labor is one of the most common indirect inputs on a typical project. As a result, energy accounting proposals have often used economic measures to determine how many fossil fuel equivalents a day's wages represent. To illustrate the effects of this approach, consider a strong person who can produce 1/20 hp (0.0373 kW) continuously. At this rate, the total energy produced during one 8-hour working day amounts to 0.4 hp-hr or about 0.3 kW·hr. If the same work were done with electricity, costing 6¢/kW-hr, the value of the day's labor would be roughly 2 cents. The typical laborer is paid more than 2500 times that amount for an energetically equivalent quantity of work.

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[1] Some energy accounting models include the loss of vegetation and its photosynthetic potential as an energy loss, or cost, chargeable against a project. For water projects in the West, these losses would often be from sagebrush and other plants adapted to steep, rugged and arid land that would generally require greater energy expenditures to collect the stored energy than these plants yield (Litterman et al. 1978).

All this leads to the question of how to appropriately include labor and other similar indirect energy inputs in an energy accounting methodology. Furthermore, indirect inputs can be summed "ad infinitum" and someone must ultimately determine where to draw the line. An attempt to itemize and prioritize the multitude of indirect inputs quickly entangles the analyst in a web of complexity and judgment bias not unlike those encountered in estimating secondary benefits and costs (Eckstein 1958, Prest and Turvey 1965, James and Lee 1971). Thus, we suggest indirect inputs be neglected unless specific conditions make them significant or particularly relevant.

Multiple Purpose Projects and the Allocation of Energy Expenditures

In water-resource management, a project will generally provide many goods and services. For example, a dam may be built to provide flood control, irrigation for nearby farmland, culinary water for neighboring cities, hydroelectric power, flat-water recreation, or any combination thereof. Recreation has historically not been a major reason for constructing reservoirs but current policy includes recreation-related costs and benefits. One of the major problems associated with multiple purpose projects involves the allocation of costs that are not a direct function of a particular purpose (James and Lee 1971, Chapter 23). The standard approach involves the estimation of the costs associated with and without the inclusion of each single purpose (e.g. recreation). The joint costs are then allocated in some manner (Water Resources Council (1973).

Energy accounting methodologies offer few guidelines for allocating joint energy costs amoung the services of multiple-purpose water projects. Furthermore, it is doubtful that a procedure could offer a realistic distribution of energy costs without having to deal with such vagaries as relative energy intensiveness and efficiencies of various project objectives or the quality of different input energy forms. It should be noted that of the three main energy inputs considered in this study, only construction energy need be allocated among different purposes. The on-site and travel energy expenditures are directly associated with recreation.

Methodology Outline

Based on the foregoing assumptions, an approach for evaluating energy expenditures for water recreation areas is developed in this section.

Evaluating construction energy

Construction energy is evaluated by estimating and summing energy inputs required to convert construction materials from a raw state to their final position and function in the project. Previous studies (Batty et al. 1976) have quantified and summarized component values with a fair level of agreement. For example, a kilogram of concrete aggregate requires approximately 46 kilojoules of process energy for extraction, transportation, crushing, batching, screening, and delivery. Similar calculations are made for most common construction components (as shown in Chapter 4). For a given impoundment then, the procedure can become quite routine. One would consider the total mix of construction materials by weight, multiply each quantity by the estimated energy value it represents, and sum to obtain the total energy expended in construction.

An important issue in the construction energy calculation is the matter of replacement and maintenance of components over the life of the project. As various components are replaced at different times, additional energy is needed. In a recycle analysis Bell (1977) estimated the "energy content" of the scrap materials taken out of the structure as the energy required to recycle and use them elsewhere. The difference between the energy cost of the raw material and the energy cost of such products from this recycled scrap represented an energy savings which he credited to the project. This procedure yields a reasonably realistic value for the total social allocation of energy to the project. The total construction energy was then divided by the life of the project (50 years) to reflect an annual energy expenditure for construction (Water Resources Council 1973). It should be noted that this procedure ignores the question of the time value of energy/resource use and assumes a zero discount rate--a procedure used by all energy accountants that may not be valid from a social perspective.

Evaluating travel and on-site energy

A different procedure is needed to predict the energy used on-site and in travel to a particular water recreation site. The greatest uncertainty in energy calculation comes from unpredictable human behavior. Research has shown that there is often little or no correlation between a person's stated recreational desires and the recreational activities actually undertaken (Hancock 1972). Actual variables such as the price of fuel, diversity of activities at the site, and availability of services often do not affect attendance at a particular site nearly as much as does public perception of these variables, as distorted as that perception may be. Following the gasoline shortages of 1974 and 1979 tourism advertising efforts emphasized "plenty of gas," and being able to "do it all in one place," in order to influence public perception.

Another problem relating to predicted attendance at the site involves variables of a subjective nature such as the site's degree of scenic attractiveness and its reputation for being crowded during peak recreation periods. Clearly, opinions and preferences vary on these matters from person to person. It is therefore difficult to accurately predict a site's drawing capacity. For example, if scenic beauty were of prime importance, many recreators would enter a site in spite of the number of people already there. However, at some point a less crowded or less scenic or more remote site might become preferable to arriving recreators.

To compound the difficulty associated with assessing subjective variables, one need look no further than current political trends where a pseudo-demand parallels real demand for development of areas for recreational use and environmental protection (Milstein 1977). Many who support water development projects might never personally avail themselves of ensuing recreational opportunities but base their support on the assurance of knowing that the opportunity for recreation exists. An exhaustive treatment of these factors is beyond the scope of the study. However, the complexity of the situation and the impact it has on accurate energy accounting can be appreciated.

If energy accounting is to provide a useful supplemental planning tool to evaluate the impact of a proposed water management project, it is essential to assess potential recreational trends, and the associated energy use before the project is initiated. It seems appropriate therefore to: 1) study trends in recreation at selected impoundments, 2) examine energy use as a function of site, geography, attendance, types of available activities, and types of vehicles, and 3) develop some empirical formulation that might reasonably approximate the energy consumption. Given the physical and aesthetic parameters for a proposed water-based recreation project, energy use could then be extrapolated for project evaluation and some guidelines could be developed to aid planners in considering the energy-related ramifications of a proposed project.

The methodology for this study, then, was to select a number of impoundments having diverse characteristics. A field survey of actual recreators was chosen as the best way to obtain data for energy expenditures at the sites and for travel. A follow-up, end of the season, survey of these same water recreators was used to obtain data on their recreational habits over the entire year. Thus, data were obtained which considered such factors as multiple trips and extended vacations.

Data for total attendance, total number of boats, campers, and construction plans for each reservoir were obtained from the administering agencies (State Department of Parks and Recreation and the Bureau of Reclamation). All this information provided a basis for estimating the energy required to construct the facility, the energy required to transport recreators and their equipment to and from the site, and the energy devoted to recreation at the site.

CHAPTER 4

ENERGY ACCOUNTING--CASE STUDIES

The above energy accounting concepts were used to estimate the energy expended by recreators at six reservoirs in Utah.

Site Selection

Each site chosen offers a different mix of attractions. The largest recreation site studied was Lake Powell in Southern Utah. The other sites were also in Utah but vary in size and proximity to population centers. Those selected were Flaming Gorge, Willard Bay, Rockport Reservoir, East Canyon Dam, and Hyrum Dam (see Figure 2). The most significant common feature of each site is regular, established recreational traffic with developed and maintained recreational facilities.

Data for this study were based on 1978 information. In 1979, rising fuel prices and other extraneous factors disrupted recreational traffic and the ensuing unsettled condition suggested 1979 or later data would restrict generality. Impacts of price increase on recreation can be inferred from a comparison of the 1978 data with that from 1979.

Construction Energy Expenditures

The construction of dams often requires a vast array of resources, some of which are depicted in Figure 3.

As indicated earlier, the issues of energy inputs into material processing have been fairly well resolved. For example, Figure 4 shows the types of energy inputs that need to be considered for cement. Summing these inputs results in an approximate energy input per installed kilogram of material.

By repeating this analysis for the multiplicity of construction materials, reference input values are calculated for the components included in the construction of a water recreation site. Bell (1977) has summarized approximations for material process energy. These are shown in Table 2.

The energy inputs associated with recycling as proposed by Bell (1977) are estimated and portrayed in Table 3 for a kilogram of aluminum. Note that the savings of energy attributable to recycling are deducted from the energy expense to the raw material and remain with society in terms of available energy to do something else. For this example of three installations (one original and two replacements with recyling of old parts), the saving to society is 829 623 kJ minus 449 423 kJ or 335 200 kJ. This is about 40 percent of the energy expenditure required for installation of a kilogram of aluminum three times. Similar extension of this analysis for all materials that can potentially be recycled results in the recycle values shown in Table 4.

The construction energy for a certain site can then be estimated if the quantity (mass) of each material in the structure is known, given the energy inputs shown in Table 4. An example of this estimation process is shown in Table 5 for Glen Canyon Dam (Lake Powell) and Flaming Gorge Dam. (Note that in each case the values used

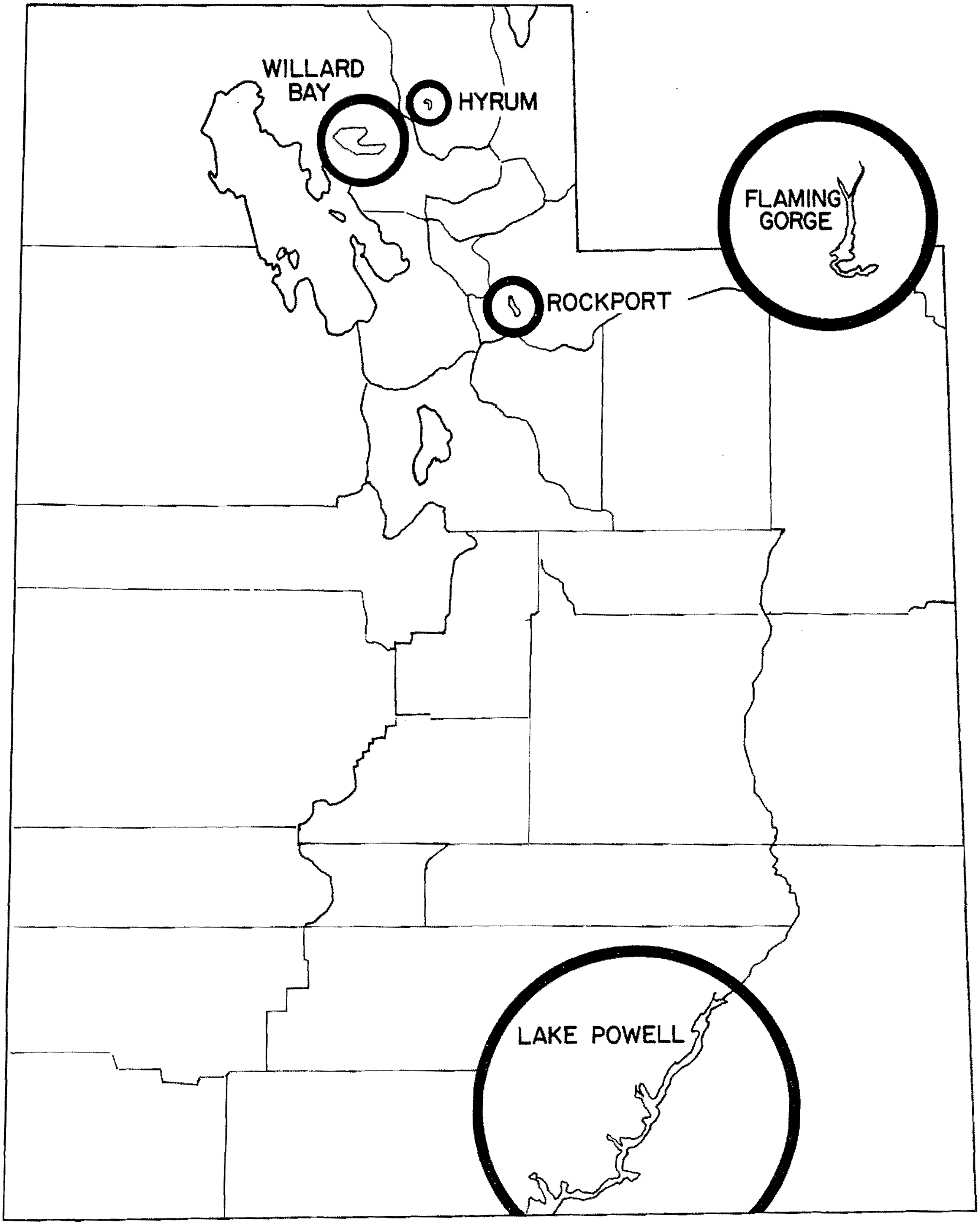


Figure 2. Locations of the recreation sites investigated as part of this study.

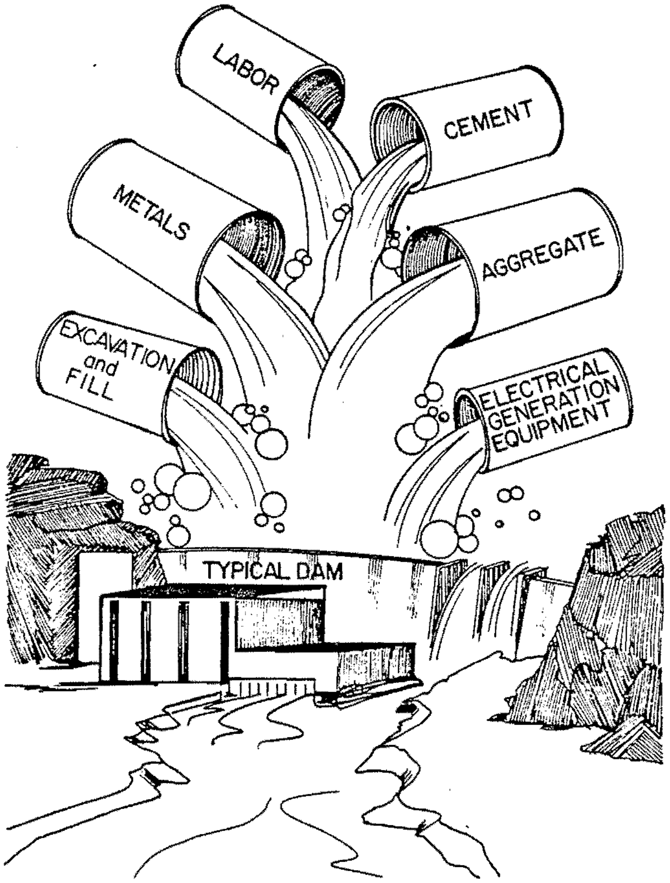


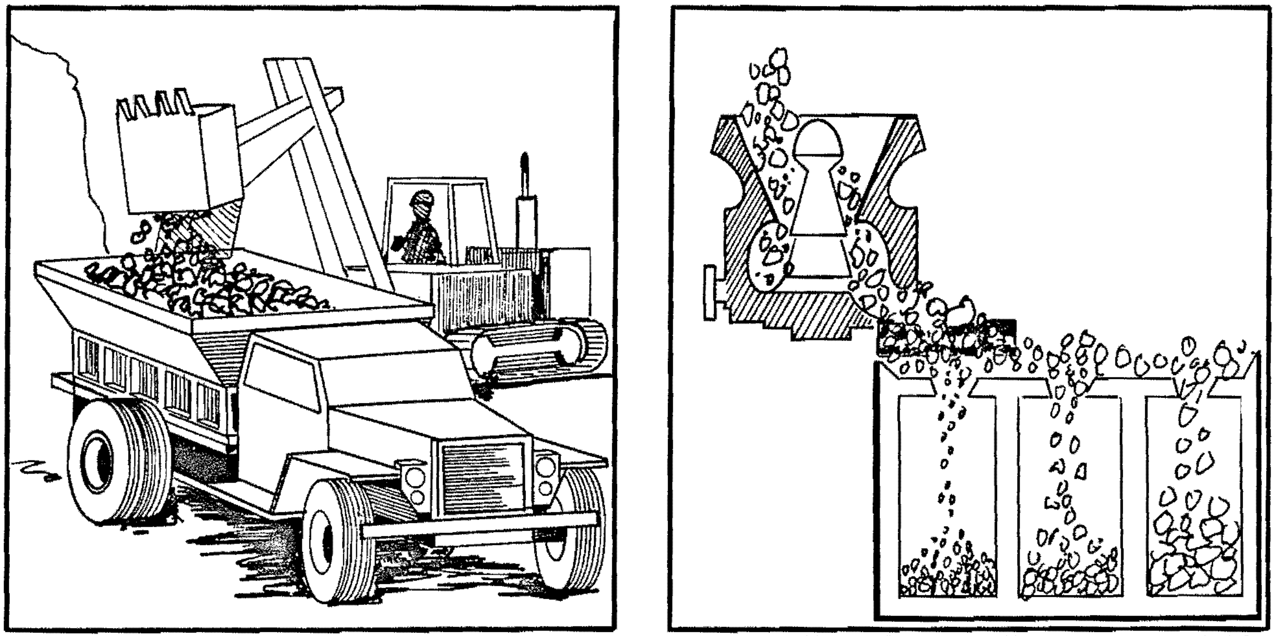
Figure 3. Typical resources devoted to construction of a dam.

Table 2. Energy inputs to major materials or processes on a raw material basis (Bell 1977).

Material	Reference Input Value (kJ/kg)
Steel cast	33 520
Steel rebar	41 900
Carbon steel	58 660
Stainless steel	67 040
Aluminum	276 541
Copper	142 461
Cement	12 570
Excavation and fill	29
Aggregates	46
Diesel fuel	155 031
Gasoline	129 891
PVC	108 941
Polyethylene	125 700
Glass plate	46 090
Electric motors	83 800 - 419 002
Generators	83 800
Hydro-turbines	87 990
Steam turbines	104 750
Pumps	83 800
Engines	83 800 - 14 146 068

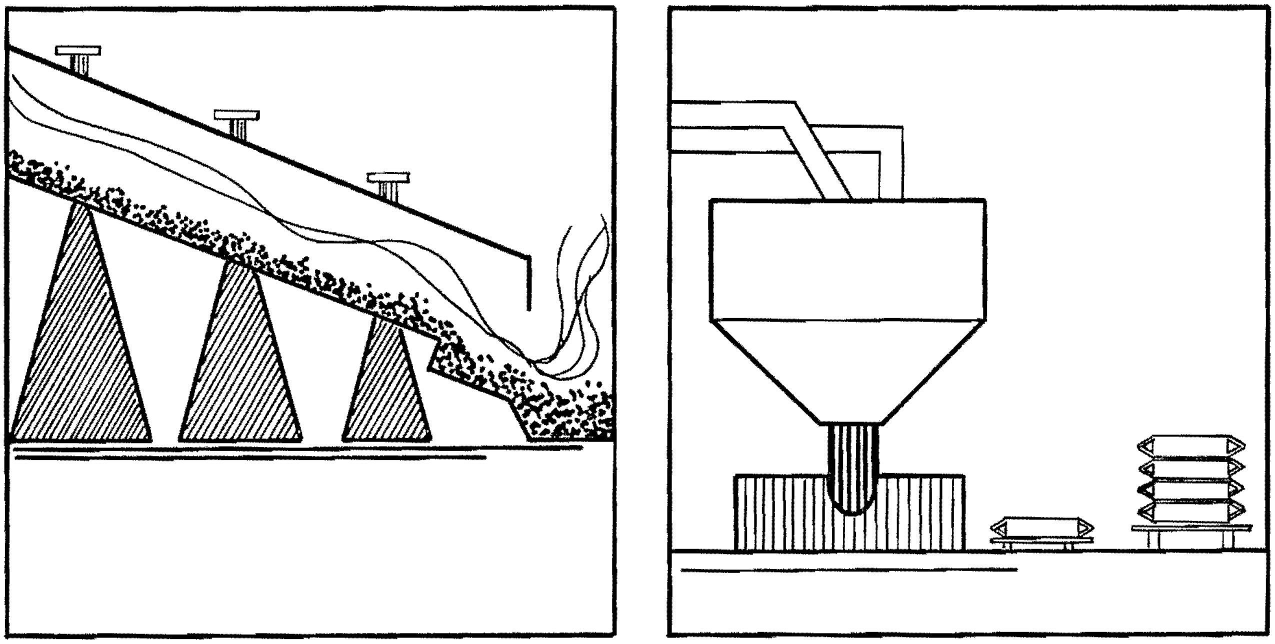
Table 3. Energy investment by society in a kilogram of aluminum (Bell 1977).

Action Taken	Debt (Owed Society) kJ	Credit (Returned to Soc.) kJ	Balance (Society) kJ
Initial install.	276 541		276 541
take out, scrap		167 600	108 941
replace with new part	276 541		385 482
take out, scrap		167 600	217 882
replace with new part	276 541		494 423



MINING and TRANSPORTATION
1 257 $\frac{\text{kJ}}{\text{kg}}$

CRUSHING, BLENDING, GRINDING
2 325 $\frac{\text{kJ}}{\text{kg}}$



KILN DRYING
8 380 $\frac{\text{kJ}}{\text{kg}}$

MIXING and PACKAGING
1 257 $\frac{\text{kJ}}{\text{kg}}$

Figure 4. Energy inputs to cement (Bell 1977).

Table 4. Difference between energy required to manufacture the indicated product from raw material and from recycled material. (See Table 3 for example.)

Product	Energy Difference (kJ/kg)
Steel case	16 760
Steel rebar	20 950
Carbon steel	29 330
Stainless steel	33 520
Aluminum	108 940
Copper	83 800
Cement	not applicable
Excavation and fill	not applicable
Aggregates	not applicable
Diesel fuel	not applicable
Gasoline	not applicable
PVC	not applicable
Polyethylene	not applicable
Glass plate	not applicable
Electric motors	62 850
Generators	62 850
Hydro-turbines	41 900
Steam turbines	62 850
Pumps	188 550
Engines	41 900

represent fossil fuel equivalent in terms of oil). These estimates show that the construction of Glen Canyon Dam and the associated products of power production, flood control, irrigation, and recreation represented by Lake Powell, required an investment by society of 1.82 x 10^{16} joules.

Iterations of this algorithm were routinely accomplished to find the construction energy for each of the other selected sites. Values found through this exercise were then divided by 50 years (estimated life of the dam by Water Resource Council recommendation) to represent an annual energy investment as shown in Table 6. This is done to allow summation and comparison with travel and recreational on-site energy computed annually and assumes a kilojoule today has the same value as a kilojoule yesterday or some time in the future. Thus, none of these values are discounted to reflect a positive rate of social time preference.

Obviously, not all of the energy devoted by society to the construction of a water project should logically be charged to recreation. It seems reasonable to assign the same fraction of construction energy inputs to recreation as are construction costs in an economic benefit/cost analysis. However, for analysis purposes, the total construction energy is shown in Table 6 with the realization that this overestimates the amount of construction energy attributable to recreation.

Travel Energy Expenditures

The next energy expenditure to be estimated is the energy cost associated with travel to and from the impoundment by recreators. The procedure selected to estimate travel energy utilized on-site surveys (see Appendix for questionnaires used). A team of research assistants was sent to each of the study sites. This team ascertained the origin of the recreators and took preliminary data for on-site energy use including types of vehicles (see Figure 5), size and types of boats, and kinds of activities pursued. A post season questionnaire was also sent to users to obtain additional data (see Howell 1981) for an evaluation of these data).

Example of computation

To illustrate the application of this methodology, the computation of travel energy to Willard Bay will be used as an example. The survey data upon which these calculations are based are summarized by Stoddard (1981).

Table 5. Sample computation of construction energy cost expressed in fossil fuel equivalents for Glen Canyon Dam and Flaming Gorge Dam (Batty et al. 1976).

	(a) Installed Mass Or Quantity (Million kg)	(b) Mean Replacement Schedule	(c) Energy Inv. Raw Mat. 10^6 joules/kg	(d) Energy Inv. Recycled Mat. 10^6 joules (kg)	$\frac{bxd+c}{c}$ Evaluation Factor	$a \frac{(bxd+c)}{c} c$ Net Mat. Energy Invest. TJ (10^{12} joules)
PROJECT: Glen Canyon Dam (Lake Powell)						
Steel Rebar	12.998	0.0	41 900	20 950	1.0	544.606
Steel Carbon	46.392	0.0	58 660	29 330	1.0	2 721.372
Aluminum	0.950	1.1	276 541	108 940	1.433	376.494
Copper	0.250	1.3	142 461	83 800	1.765	62.754
Cement	969.834	0.0	12 570	12 570	1.0	12 191.206
Aggregate	9 298.408	0.0	46	46	1.0	428.564
Excavation & Fill	11 997.946	0.0	29	29	1.0	351.526
Turbines Hydro.	4.426	1.2	87 990	41 894	1.6	612.028
Generators	5.625	1.3	83 800	62 840	2.0	931.018
					Total Energy Investment	18 219.652
PROJECT: Flaming Gorge Dam						
Steel Rebar	2.300	0.0	41 900	20 950	1.0	96.354
Steel Carbon	6.699	0.0	58 660	29 330	1.0	392.957
Aluminum	0.005	1.1	276 541	108 940	1.433	1.982
Copper	0.005	1.3	142 461	83 800	1.765	1.257
Cement	179.969	0.0	12 570	12 570	1.0	2 262.225
Aggregate	1 699.709	0.0	46	46	1.0	78.341
Excavation & Fill	1 399.760	0.0	29	29	1.0	41.054
Turbines Hydro.	0.550	1.2	87 990	41 894	1.6	76.036
Generators	0.680	1.3	83 800	61 840	2.0	112.523
					Total Energy Investment	3 062.730

Investigators found that during evaluation periods, the recreators entering Willard Bay State Park resided at various nearby communities in the proportion shown in Table 7. Also shown is the one-way distance from the point of origin to the site. Multiplying these two values gives the one-way vehicle kilometers in travel from each location and this is summed to one-way vehicle kilometers traveled by the sample group to reach the site. Doubling this amount accounts for the return trip and represents total vehicle kilometers traveled.

Table 6. Annual construction energy input.

	GJ (10^9 Joules Oil Equivalent)
Lake Powell	364 393
Flaming Gorge	61 244
Rockport Res.	12 252
Willard Bay	9 143
East Canyon Res.	7 919
Hyrum Dam	1 827

The distances used are point to point mileage figures from standard highway road maps. Some of the respondents live either closer or further from the site than the mileages indicated. However, this variation will generally be averaged out with a large population. As a result this should be a reasonable approximation of the actual mileage traveled.

Figure 5. Recreators travel to the site in various kinds of vehicles.

Table 7. Calculation of vehicle kilometers by recreators sampled in this study to Willard Bay.

Point of Origin	No. of Vehicles From Origin	Approx. Distance of Site from Origin	Vehicle-Kilometers
Cache Co. (Logan)	18	48.3	869.0
Salt Lake City	1216	73.5	89 433.2
Ogden	1023	19.3	19 756.3
Provo	13	157.6	2 048.2
Brigham City	334	10.5	3 493.9
S.W. Utah	0		0.0
S.E. Utah	4	381.6	1 526.3
Northern Utah	0		0.0
Out of state	78	112.0[a]	8 736.0
	Total One-Way Vehicle Kilometers		125 913.9
	x 2 for Return Trip		251 827.9

[a] Distance to nearest significant community across nearest state line, in this case, Preston, Idaho.

It was assumed that out-of-state users were from the nearest out of state community of significant size. The slightly increased accuracy of further subdividing out-of-state points of origin does not appear to justify the increased complexity of computation. It is recognized that this procedure may underestimate the actual energy expenditures but it is doubtful that the differences would be large given the relatively small number of users from out of state that use most of the study sites. The major exceptions may include Flaming Gorge and Lake Powell where out of state users represent a major portion of the use at these sites (the degree of bias is not known).

State Parks and Recreation records were used to extrapolate the sample to the total recreation visits. For example, the sample included 2686 vehicles, and state agencies report some 116 537 vehicles traveling to Willard Bay in 1978. Assuming the same geographic distribution in visitors as the sample, the overall total in vehicle kilometers is

(251 827.9 vehicle-kms) x (116 537/2686)

= 10 926 011 vehicle kilometers

Data obtained from the questionnaires were used to compute a weighted average fuel consumption rate for the vehicles. For example, 13 percent of the vehicles using Willard Bay were classified as small cars. These cars were assumed to obtain a mileage of 11 kilometers per liter (26 mpg). Other mileage rates were assumed for four-wheel drive vehicles (5.5 km/L or 13 mpg), mid-sized cars (7.65 km/L or 18 mpg), pickups (5.95 km/L or 14 mpg), motor homes (5.53 km/L or 13 mpg), vans (5.1 km/L or 12 mpg), and cycles (14.88 km/L or 35 mpg). Dividing average fuel consumption into vehicle-kilometers gives total liters which is easily converted into joule equivalents as follows:

Vehicle
Type:

$$\overset{\text{Small}}{0.133\ (11.05)} + \overset{\text{Intermed.}}{0.073\ (7.65)}$$

$$+ \overset{\text{Large}}{0.181\ (6.38)} + \overset{\text{Pickup}}{0.384\ (5.95)}$$

$$+ \overset{\text{Van}}{0.052\ (5.10)} + \overset{\text{4-W.D.}}{0.105\ (5.53)}$$

$$+ \overset{\text{Motorhome}}{0.057\ (3.40)} + \overset{\text{Cycles}}{0.006\ (14.88)}$$

$$= 6.61\ \text{km/liter}$$

$$\frac{10\ 967\ 011\ \text{km}}{6.61\ \text{km/liter}} = 1\ 652\ 952\ \text{liters}$$

$$(1\ 652\ 952\ \text{liters}) \times (33\ 316\ 615\ \text{J/liter})$$

$$= 5.507 \times 10^{13}\ \text{J}$$

Similar calculations were performed for the other sites to result in the travel energy approximations for each as summarized in Table 8.

Procedure generalization

The impoundments studied vary significantly with respect to size and distances traveled by visiting recreators. For example Lake Powell is a regional recreation site while Willard Bay is primarily used by local residents. Most of the data collected from the questionnaires were from Utah residents. As a result, Utah Parks and Recreation personnel provided estimates of the origin of users from other states for Lake Powell. These estimates indicate that 35 percent of the visitors are from Utah, 25 percent from California, 20 percent from Arizona, and 20 percent from Colorado. To simplify the calculations involved, it was assumed that recreators resided at the most concentrated metropolitan area of the state--Phoenix, Arizona; Salt Lake City, Utah; Denver, Colorado; and Los Angeles, California. Obviously, more data would improve these estimates but the metropolitan points-of-origin assumed would dominate because more recreation visitors will be from these areas. Furthermore, people coming from farther away will tend to balance those from points nearer so the average distances from the metropolitan centers may be a reasonable estimate (see Figure 6).

Complications associated with multipurpose travel and stopping at more than one site are ignored in this analysis because the data from users indicated that most recreators are single purpose and site visitors. Thus, travel to and from the site is all that is considered in the first attempt to

Table 8. Estimated annual energy expenditure (1978) for six reservoirs in Utah.

	TJ (10^{12} Joules)		
	Construction	Travel	On-Site
Lake Powell	364.4	2927.9	976.0
Flaming Gorge	61.2		a
Willard Bay	9.1	55.1	55.3
Rockport	12.3	38.0	27.9
East Canyon	7.9	23.6	30.4
Hyrum Dam	1.8	57.3	26.1

[a] Insufficient data.

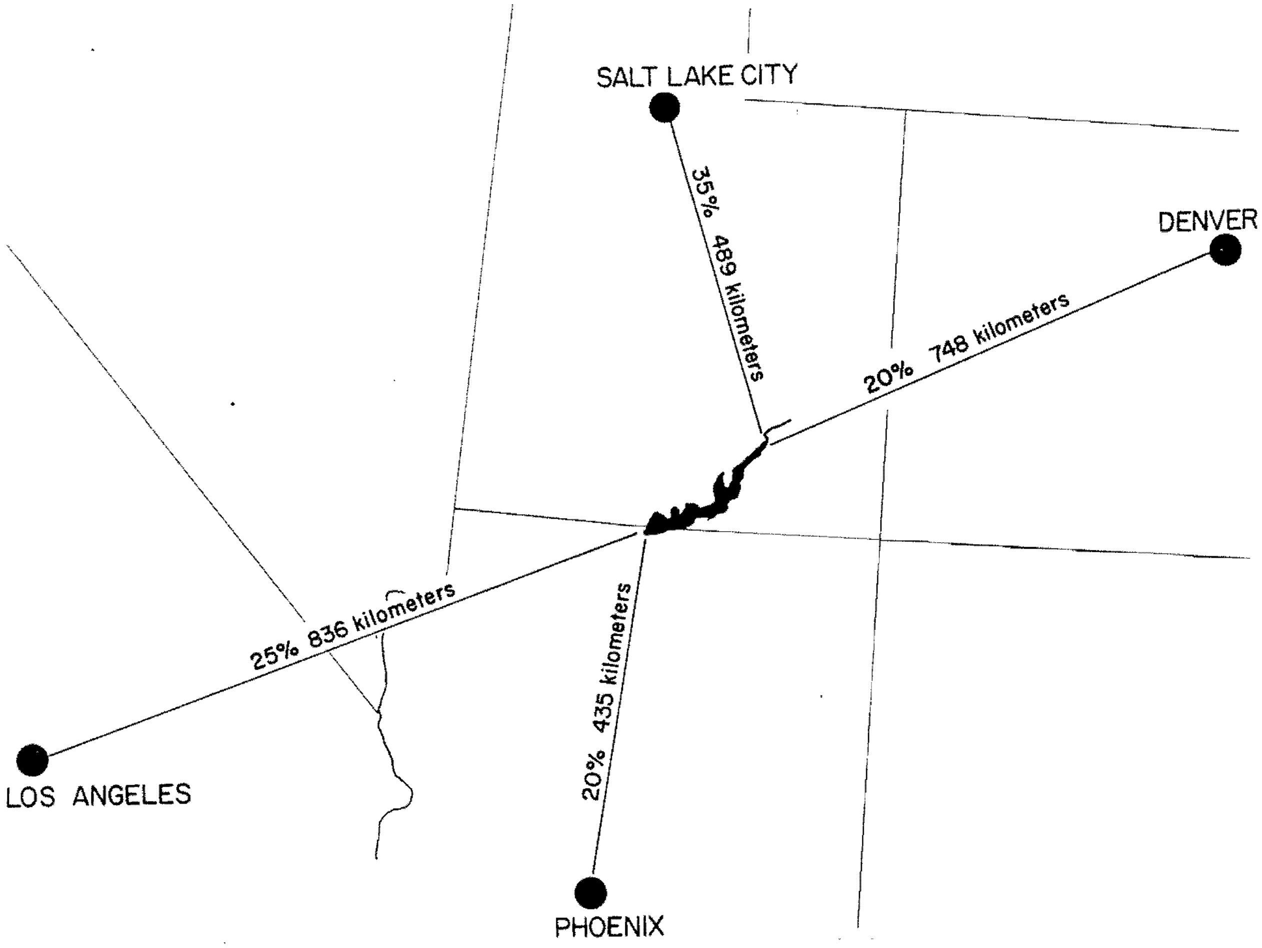


Figure 6. Travel energy assumption for Lake Powell.

quantify this energy account. Resulting travel energy values are summarized in Table 8.

On-Site Energy Expenditure

Estimation of the on-site energy was based on questionnaires. The responses from those returning a questionnaire on the followup survey of activities actually undertaken paralleled very closely the responses given by recreators quizzed at the site. This indicated these recreators have a concept of the costs of recreation and consciously make those decisions to spend the amount of energy, money, and time to pursue their chosen activities with an awareness of the trade-offs involved. Thus, the data from the survey were considered to be sufficiently accurate to reflect energy usage on-site.

Example of computation

On-site energy for the Rockport Reservoir will be presented to illustrate the procedures used. Data were first sought to quantify the amount of energy used by a typical recreation craft. Fuel conservation in boat motors, as with automobiles, is currently a major concern. Consequently, motor fuel economy test data such as the plots in Figure 7 are obtainable from manufacturers.

It was futile to ask recreators about the fuel economy consumption of their boat motors. Most do not know how many gallons of fuel their craft consume per hour. The survey was successful in determining the horse power rating of the motor and the length of time the recreators spent at the site. Thus, the task was to relate power rating of the

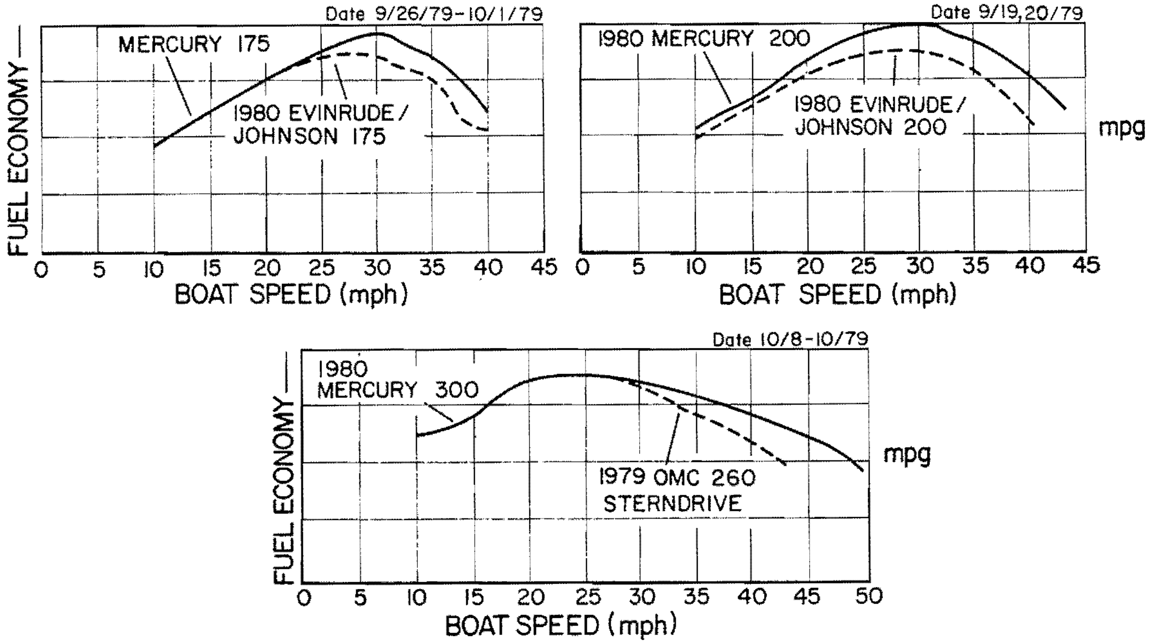


Figure 7. Representative plots of motor fuel consumption from manufacturer tests on standard boat sizes (Mecury 1979).

motor to average fuel consumption rate and multiply this rate by the amount of time on the water.

A collection of motors were investigated, representing trade names commonly available in Utah. The horse-power rating of these motors was plotted versus their average fuel consumption rate in liters per hour in Figure 8.

For outboard motors the average fuel consumption rate in liters per hour is estimated as:

FCR (L/h) = 0.084 hp - 3.36

And for inboard motors we estimate

FCR (L/h) = 0.158 hp - 5.05

From the recreator responses to the questionnaire at Rockport Reservoir we calculated an average boat motor rating of 167.4 hp on the average and an average fuel consumption rate per boat at that site of 16.1 L/h.

A distinction was needed between day-recreators and overnight campers. According to the survey data, virtually no one stayed between 12 and 20 hours. A natural break of 12 hours was taken for analysis purposes. Those who spent less time at the site were considered day-recreators and were given credit for spending most (90 percent was assumed) of their time operating the boat. Those spending more time were assumed to also camp, sleep, eat, etc., during the day and to spend only a fraction (25 percent was assumed) of their site time

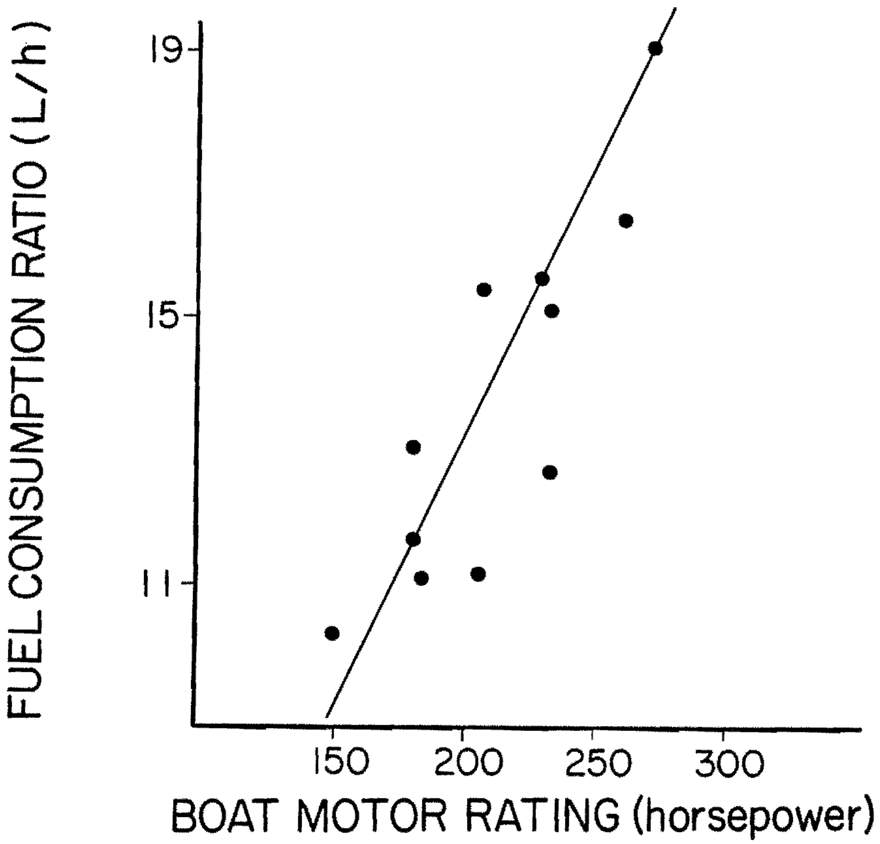


Figure 8. Average fuel consumption rate (liter/hr) as a function of horse-power rating for outboard motors.

boating. These fractions can be made more exact by further observation, but, for a first approximation, they seem adequate. We then extrapolated the survey sample results to estimate the total annual energy devoted to boating at Rockcreek.

$$\text{Hours spent at site by survey groups staying longer than 12 hours } 0.25 + \text{Hours spent by survey groups staying less than 12 hours } 0.90$$

$$= \text{Boat hours in survey sample}$$

or

$$(1672)\ (0.25) + (50)\ (0.9) = 463$$

$$= \text{estimated boat hours from survey sample}$$

then

$$\text{Boat hours in survey sample} \ \frac{\text{Total number of boats brought to site during year}}{\text{Number of boats in survey}} = \text{Total boat hours at site during year}$$

or

$$463 \ \frac{(10\ 947)}{(97)} = 52\ 252 \text{ total boat hours at site during year}$$

Fuel consumption is calculated as:

$$(52\ 252 \text{ boat hours})\ (16.1 \text{ L/h}) = 841\ 257 \text{ L of fuel}$$

or

$$(841\ 257 \text{ L})\ (33\ 316\ 000 \text{ J/L}) = 2.802 \times 10^{13} \text{ J}$$

Consideration should be given, of course, to other on-site energy expenses. Fuel to cook meals, to heat water or illuminate a lantern are all legitimate energy accounts. These amounts are small compared to the boat operation energy expenditures. Furthermore, it may be argued that cooking food and lighting lamps would still occur if the recreators were home and so probably should not be included in a net expenditure analysis exclusively for recreation.

Similar procedures were followed for the other sites. The results are shown in Table 8 along with the construction and travel energies for each site.

Procedure generalization

Lake Powell is a major attraction located a considerable distance from population centers. As might be expected, the energy devoted to travel by recreators at Lake Powell greatly exceeds the construction energy and the energy expended on site. At the smaller sites located closer to population centers, the energy devoted to travel is comparable to the energy expended at the site.

To gain a perspective of the energies shown in Table 8, it may be helpful to compare the amount of energy devoted to recreation at the five sites for which we have data with another major energy using activity in the State of Utah--agricultural production. The results shown in Table 8 suggest that approximately 30 million gallons of liquid fuels are expended each year for recreation at Lake Powell including travel to and from the site but excluding construction energy. In comparison, the Economic Research Service of the U.S. Department of Agriculture estimated the amount of energy used on Utah farms for crop and livestock production including field operations, irrigation, crop drying, mechanized feeding, space heating, farm business, truck and auto use, etc. The reported values are shown in Table 9.

Comparison of the values shown in Table 9 with those of Table 8 suggest that the liquid fuel energy devoted to recreation [(2927.9 + 976) x 10^{12} joules = 3903 x 10^{12} joules] at Lake Powell alone (not counting the construction energy) is roughly equivalent to the total liquid fuel energy required for all of agricultural production [(1960 + 1760 + 400) x 10^{12} joules = 4120 x 10^{12} joules] in Utah. The on site and travel energy [(55.1 + 55.3 + ... + 57.3 + 26.1) x 10^{12} joules = 313.7 x 10^{12} joules] for the four small reservoirs, however, represents only about 10 percent of the energy expended at Lake Powell. This is also approximately equal to the LP gas used in agricultural production in Utah. These figures suggest that remote recreation sites may be heavy users of energy and that energy expenditures for travel generally represent the largest portion of the energy associated with using impoundments.

Table 9. Energy used on Utah farms for crop and livestock production including field operations, irrigation, crop drying, mechanized feeding, space heating, farm business, truck and auto use. (Economic Research Service, USDA, 1977).

Gasoline		Diesel & Fuel Oil		LP Gas	
1000 gal	10^{12} joules	1000 gal	10^{12} joules	1000 gal	10^{12} joules
14 831	1960	11 817	1760	3014	400

CHAPTER 5

ENERGY ACCOUNTING AS A PREDICTIVE MECHANISM

A second objective of this research was to evaluate energy accounting methodologies as a mechanism for predicting the energy impacts of water development alternatives. This evaluation is based on the analysis and data outlined in Chapter 4.

Development of a Preproject Energy Model

Construction of a water development project may be based on actual or perceived demands for flat-water recreation, irrigation, power, and flood control or other purposes. However, it is not always obvious to planners that the expenditures needed to obtain these benefits can be justified. If energy analysis can help clarify these impacts, then it may become an important tool for water planners.

A first step for development of a general energy strategy is to predict the per capita energy use for a site. It is interesting to examine the per capita energy expenditures for the five sites evaluated.

Travel energy

The order of listing in Table 10 is intentional. One can look at the top three numbers in the travel energy column and observe that they fall within a narrow envelope and are lower than the others. Of greater importance is the fact that these three water recreation sites are geographically closest to the Salt Lake City-Ogden population center. Travel to any of the three would represent only about one hour of driving time. Hypothetically assuming a relation between distance and energy, take the Rockport value of 76.30 (MJ/visitor per hour driving time) and consider that the distance from the dominant population center (Salt Lake City) to Hyrum Dam represents approximately a 2-hour drive.

$$(76.30 \text{ MJ/visitor-year/hour}) \times (2 \text{ hours driving time}) = 152.60$$

This value is very close to the value of 150.59 from Table 10.

The Lake Powell figure would represent about a 10 hour drive, which is not very far off the actual, further supporting such a correlation. Herein is the justification for computation of travel energy for Lake Powell as was done in Chapter 4. Geographic distance to the site from population centers appears to be a definite factor in recreation. Smaller facilities located close to population centers would seem to be more energy efficient for providing the same recreation.

For development of a predictive model, some relationship would have to be accepted and used. We are suggesting that relationship could be:

$$\text{Annual Travel Energy} = 75 \text{ MJ/visitor}\cdot\text{hr} \times \begin{matrix}\text{Driving time}\\ \text{in hours}\end{matrix} \quad \begin{matrix}\text{No. of visitors}\\ \text{per year}\end{matrix}$$

On-site energy

It is observed from Table 10 that the on-site energy per capita for

Willard Bay, Rockport Reservoir, and Hyrum Dam falls within a ± 10 percent span (123, 111, and 137 MJ/visitor, respectively). The data in this column are influenced heavily by the type of activity in which the recreators engage. At the three mentioned sites, a similar mix of fishing, waterskiing, and pleasure boating is reported.

The exceptional figures for East Canyon Dam and Lake Powell are partially explained in the same context. The long straight shape of East Canyon Reservoir makes it popular for hydroplanes and power boat racing. The motors of boats at East Canyon typically were rated at higher horsepower than at the other sites and this accounts for the greater per capita on-site energy. In the instance of Lake Powell, larger pleasure crafts (yachts, cruisers) are found in greater numbers and the activity is more oriented to sight-seeing and visitors stay longer. Though this may not explain the total extent of the figure it provides a reasonable rationale for the on-site energy expenditure at Lake Powell being greater than at the other sites.

Development of an on-site factor for the ensuing model is, at best, imprecise. It can be concluded that activities of the recreators do play a significant role in energy accounting. However, this relates to the attractions of the site and the public perception (real or imagined) of those attractions.

There appears to be a relationship between distance traveled and the predominant recreation activity at a site (Table 11). For example, sites that are close to the origin of users appear to be used most heavily for high energy activities such as waterskiing,

Table 10. Energy expenditures per visitor for five reservoirs in Utah.

	Visitors (May-Nov.)	Travel		On Site	
		MJ / Visitor	Liters of Fuel[a] / Visitor	MJ / Visitor	Liters of Fuel[a] / Visitor
Willard Bay	447 318	61.22	1.84	123.52	3.71
East Canyon	170 389	69.26	2.08	178.49	5.36
Rockport Res.	248 727	76.30	2.29	111.79	3.36
Hyrum Dam	190 190	150.59	4.52	137.01	4.11
Lake Powell	1 816 514	805.74	24.18	537.58	16.14

[a] 1 gallon = 3.7854 liters.

Table 11. Most probable activity at site according to origin.

	SLC	Ogden	Cache	Brigham	Morgan	Provo
Willard Bay	Ski	Ski	Ski	Ski	Fish	Boat
Hyrum Dam	Ski	Ski	Ski	Ski	--	--
East Canyon	Ski	Fish	Fish	--	Ski	Fish
Rockport	Ski	Fish	Other	--	--	Boat
Flaming Gorge	Fish	Fish	Fish	Fish	Fish	Fish
Lake Powell	Boat	Boat	Boat	Boat	--	Boat

while more distant sites appear to be used most heavily for boating. However, specific characteristics of some sites make some uses dominant (e.g., fishing at Flaming Gorge, skiing at Hyrum Dam, and boating at Lake Powell).

Planners involved in preparing an energy impact statement for a proposed recreation site must estimate the mix of activities that will probably occur at the proposed water impoundment and relate this to the energy per visitor assessed to the project by on-site accounts. Once these probable activities have been identified, the energy conversion factors outlined below can be used to estimate the fuel that will be used in recreating at a particular site. For example, for water skiing:

$$\begin{matrix}\text{On site}\\ \text{energy}\end{matrix} = \left(130\ \frac{\text{MJ}}{\text{visitor}}\right)\left(\begin{matrix}\text{Expected no.}\\ \text{of visitors}\\ \text{per year}\end{matrix}\right)$$

For speed boating and racing activities:

$$\begin{matrix}\text{On site}\\ \text{energy}\end{matrix} = \left(200\ \frac{\text{MJ}}{\text{visitor}}\right)\left(\begin{matrix}\text{Expected no.}\\ \text{of visitors}\\ \text{per year}\end{matrix}\right)$$

For larger boats, cabin cruisers, etc.:

$$\begin{matrix}\text{On site}\\ \text{energy}\end{matrix} = \left(500\ \frac{\text{MJ}}{\text{visitor}}\right)\left(\begin{matrix}\text{Expected no.}\\ \text{of visitors}\\ \text{per year}\end{matrix}\right)$$

Estimate of attendance

The above outlines how the preceding analysis can be used to estimate the amount of energy that will be used per capita at a particular site. However, it is necessary to estimate the total number of people that will utilize a particular water development project before the total amount of energy that will be expended by recreators can be estimated. Therefore, the second step in estimating the amount of energy that will be used must include an estimation of the visitation to the site. Numerous studies (Boyet and Tolley 1966; Dyer and Whaley 1968; Kalter and Gosse 1969; Gillespie and Brewer 1969; Myles 1970; Cicchetti 1973; Dyer, Kelly, and Bowes 1977; Wetzstein, Green, and Elsnor 1981) have developed procedures that can be used in estimating the level of visitation. Therefore, this issue will not be discussed in this report although an interesting correlation between surface area and visitation was developed by SL.

It is seen then, that energy accounting principles can be used to extrapolate energy expenditures into the future. The utility of this result is that energy usage can be forecast even before the project is initiated. The information gathered from these energy accounting exercises will make comparisons possible between water recreation options as well as comparison with other kinds of recreation which may be in competition for the same energy commitment.

Water Recreation Response to Fuel Price

After 1978, the year for which the data used in this study were obtained, major disruptions in traditional recreational patterns at flat-water sites were evident. The plot of Figure 9 shows the 1979 monthly attendance at Lake Powell as a percentage of the 1978 attendance for corresponding months. Superimposed on this is the national monthly average price for various grades of fuels. Although a number of factors may cause variances, the general downward trend in visitation suggests rising fuel prices tend to dampen recreational activity. This confirms other studies suggesting recreational activity at relatively remote sites is inversely related to the price of fuel (Burke and Williams 1974).

A plot of 1979 and 1980 attendance as a percentage of attendance of the same month in the previous year at three of the smaller sites is shown in Figure 10. Faced with higher costs for recreation, enthusiasts apparently chose to forego a long trip to Lake Powell, opting instead for shorter trips to closer sites. These results seem to substantiate the thesis that more water recreation areas closer to urban population centers may be needed if fuel prices escalate.

As part of the survey and in this study, recreators were asked what their responses would be to increased recreation costs. Their responses are tabulated in Table 12. It is clear that some changes would be made. It is not

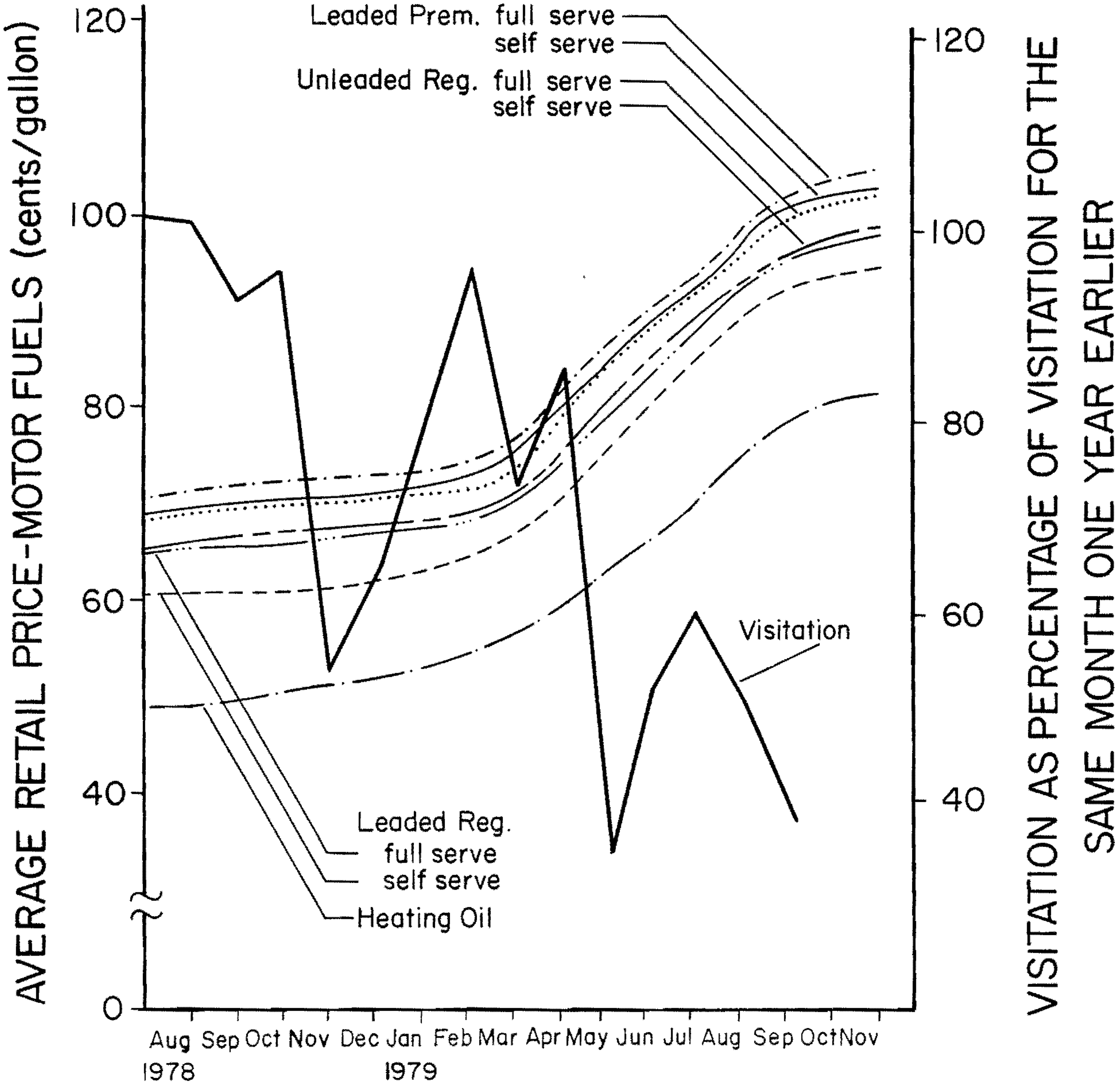


Figure 9. 1979 fuel prices and Lake Powell attendance as percentage of the same month the previous year.

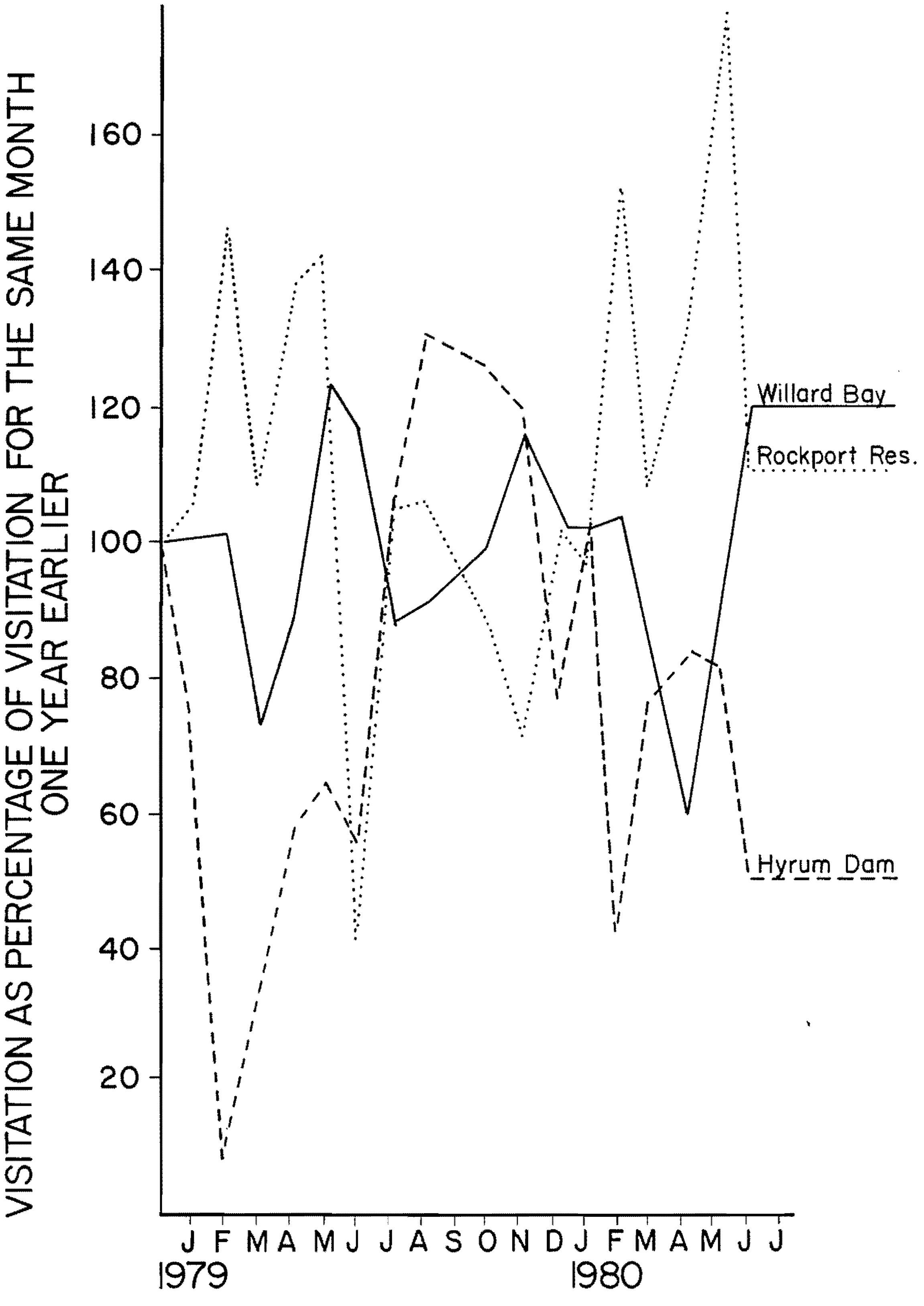


Figure 10. Attendance 1979-1980 at Willard Bay, Rockport Reservoir, and Hyrum Dam as percentage of previous year's attendance for the same month.

clear, however, what other recreational activities would be substituted. It would be interesting to compare energy costs of different activities, comparing water recreation for example, with energy costs of golf, hunting, motorcycle racing, etc., because water related activities (e.g., boating, fishing) may be a more or less intensive user of energy than would be the alternative recreational activities. This suggests that more work is needed to estimate the net energy use of particular activities; i.e., what are the energy expenditures with versus without the activity being considered. Furthermore, policies can be formulated and evaluated as to their potential energy impacts. For example, 3-day weekends tend to encourage water oriented recreation (and increased energy consumption) as indicated by data plotted in Figure 11.

Table 12. Recreator reaction, by percent of sample, to increased fuel costs.

	%
Not go as often	41
Not go	21
Go closer to home	16
Fewer trips but with longer stays	13
Restrict boat use	4
No response	5

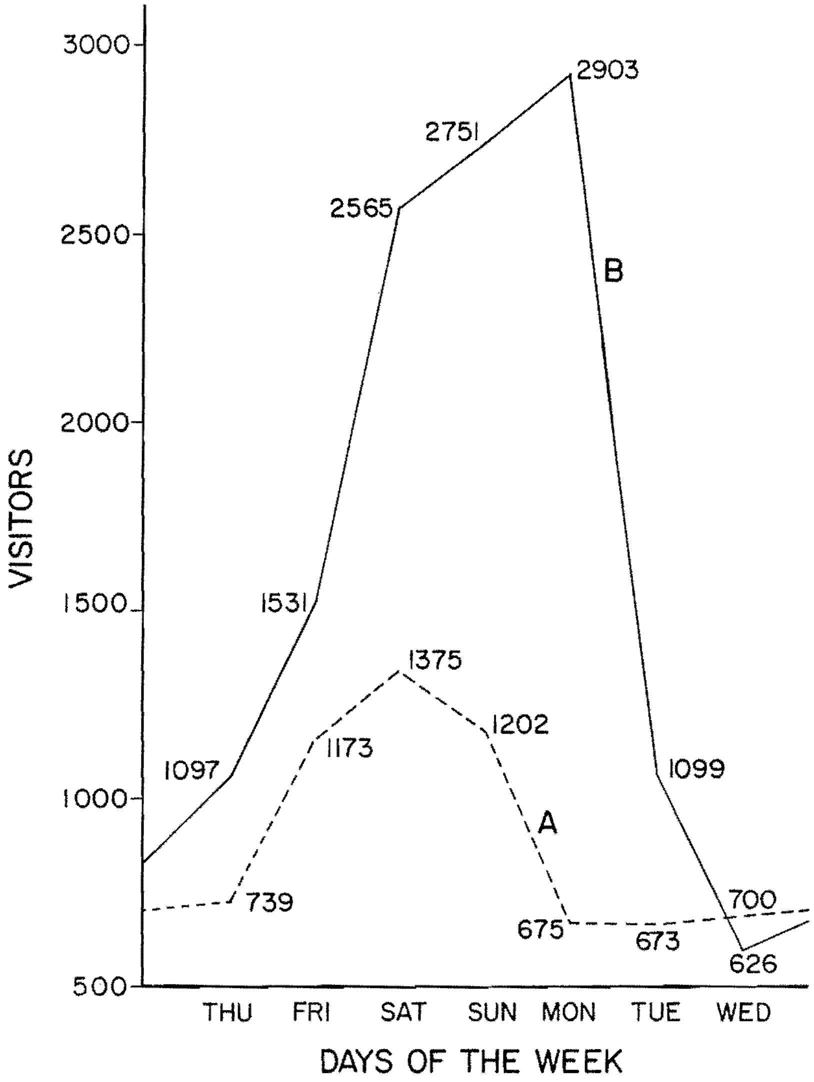


Figure 11. Comparison of average Rockport Reservoir attendance on 3-day weekends (B) vs regular weekends (A).

CHAPTER 6

ENERGY ACCOUNTING AND ECONOMIC ANALYSIS

One of the primary objectives of this study was to devise an energy accounting methodology that would "supplement economic benefit-cost (B/C) analysis." The major reason why this study was undertaken stemmed from a perceived weakness, by some people, of B/C analysis that energy impacts were not correctly or fully evaluated. The preceding analysis outlines the energy accounting methodology developed but it does not evaluate this methodology with respect to the similarities and differences it has with B/C analysis. Many of these similarities and differences are suggested in the previous analysis but are not made explicit. The following explicitly outlines similarities and differences between B/C and energy accounting methodologies.

Techniques

Essentially every energy accounting technique outlined in Chapter 2 has an analogous parallel in B/C analysis. For example, net energy is similar to net benefits where the energy (costs) needed to develop a resource is subtracted from the energy (benefits) obtained from that resource. Another important area involves the "holistic" approach suggested by Odum. This approach would count all energy inputs and is essentially analogous to counting all pecuniary and technical externalities (Prest and Turvey 1965). However, the most troublesome issue for both B/C analysis and energy accounting generally involves the subjective selection of a numeraire; dollars vs francs vs pesos or oil vs gas vs coal equivalents. This issue is commonly solved in B/C analysis by accepting the medium of exchange that exists in the area being studied, but energy accountants continue to argue over which is the "best" numeraire.

Methodology/Assumptions

Each of the methodological assumptions outlined in Chapter 3 can be related to similar issues that have been resolved in B/C analysis. The selection of a numeraire (petroleum fuel equivalents) is troublesome but resolvable. However, whatever numeraire chosen will involve some problems when energy equivalents of different resources must be estimated (e.g., coal vs gas vs hydro). The decision to ignore natural energy impacts and indirect energy inputs is essentially analogous to the decision to ignore secondary and tertiary monetary costs. This does not mean that these inputs or costs don't exist, it only suggests that their order of magnitude is such that the information provided by including them is not worth the effort required for their determination.

Perhaps the one area where B/C analysis and energy accounting differ is the evaluation of construction inputs. This stems from two basic differences in the methodologies. First, the numeraire chosen (e.g., dollars vs petroleum equivalents) would tend to weight the various inputs differently. For example, energy accounting accounts for the energy inputs of a resource while B/C analysis weights inputs according to their relative scarcity. This illustrates a basic philosophical difference between the two approaches. Energy accounting assumes that energy is the most limiting input form while B/C analysis does not make this assumption. There are some logical reasons why energy could be the limiting input form (Georgescu-Roegen 1975) but if this position is taken to the extreme it yields an "energy theory of value" that is subject to the same weaknesses as the "labor theory of value" suggested by Karl Marx (Blaug 1968).

The methods used to estimate the energy expended in traveling to/from and at a recreation site are essentially equivalent to the methodology used to estimate the expenditures incurred by recreators (Howell 1981). This suggests that essentially every step used in this study to determine the energy traveling and on site is equivalent to the procedures used in B/C analysis except a different numeraire is emphasized. Thus, one could take the energy expenditures shown in Table 11, multiply them by the cost per joule or unit volume of fuel and find the costs spent by recreators. Similarly, expenditures per capita that are available from other studies could easily be converted to energy equivalents.

Prediction

The predictive mechanism outlined in this study is equivalent to the methodology one would use in B/C analysis to determine the benefits of providing recreation at some water development except in the interpretation of results.

In estimating economic benefits from outdoor recreation the cost of travel to a reservoir and for on-site activities is usually regarded as a surrogate of willingness to pay for the experience and hence becomes a tool for estimating benefits of a water project rather than cost. According to this interpretation, recreation at more distant reservoirs might tend to be accounted a higher benefit than recreation at not so distant sites. Thus the process of maximizing net economic benefits tends to increase energy use. Energy analysis on the other hand accounts for energy inputs to travel and for on-site activities as a cost rather than a benefit.

Another difference seems to be that energy accounting reflects only the energy costs of activities while ignoring other costs (time, satisfaction foregone, etc.) while economic analysis at least in part incorporates these factors. Furthermore, energy accounting does not provide a mechanism for evaluating whether the expenditure of these energies is beneficial in the aggregate because these decisions must involve social rather than physical evaluations.

CHAPTER 7

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In summary the following accomplishments were made as part of this project.

1. A large amount of energy accounting literature was carefully reviewed by an interdisciplinary team that included both economists and thermodynamicists. A simple workable methodology was devised for energy accounting.

2. Relevant data pertaining to recreation at Lake Powell, Willard Bay, East Canyon Reservoir, Rockport Reservoir, and Hyrum Reservoir were obtained from visitation records and questionnaires and on-site surveys.

3. Values for the energy associated with travel to and from the recreation site, the energy expended at the recreation site, and the energy associated with construction and maintenance of the site were estimated.

4. A tentative model was developed that can be used to predict the amount of energy that would be expended in recreation activities at a proposed water development project.

A number of interesting conclusions may be drawn from the study. Even though the societal energy inputs to the construction of water impoundments such as Glen Canyon Dam are large, that energy input is generally relatively small compared to the energy devoted to recreation at the site over the expected life of the project.

The energy requirements to sustain recreation at the sites studied is not inconsequential. About as much energy is devoted to recreation at Lake Powell alone as is devoted to all of production agriculture in Utah. This helps place in perspective the impact that water based recreation has on our energy resources but does not suggest that these expenditures cannot be justified.

The models used to predict the travel and on-site energy expenditures per visitor should be reasonably reliable and could be used with some confidence in the preparation of energy impact statements.

The perceived need for energy accounting appears to be based almost entirely on the suspicion that current market prices do not reflect the value of future energy inputs and that future energy prices will shift dramatically upwards relative to other goods and services. For example, it appears to have a greater emotional impact to say that as much liquid petroleum fuel is burned annually in pursuit of recreation at Lake Powell as is used by all of Utah's agriculture than to compare the dollars devoted to fueling those two activities. Yet precisely the same information is implied in both statements. Certainly that information could be derived from an economic analysis as well as an energy analysis.

We, therefore, recommend to the water management community that energy accounting analyses need not be deliberately called for in connection with proposed water projects. If energy impact analysis is imposed by legislative mandate then every effort should be made to keep that analysis simple and understandable. The guidelines developed in this study are recommended.

The complex "holistic" energy accounting methodologies should be rejected on the grounds that they distort the basic issues. These kinds of analyses are subjective in general and thus reflect the particular biases of the investigators. Because they are so difficult to understand and have an associated esoteric jargon there seems to be a certain mystic that implies they are conveying more information than they really do. We have seen no real evidence that environmental impacts, for example, are more realistically assessed by energy accounting than by economic analysis.

We further suggest that a suitable perspective of the energy impacts associated with a particular project can be obtained from traditional economic analysis simply by careful delineation and interpretation of the costs associated with energy use. Energy accounting clearly assigns energy inputs to recreation as a "cost" rather than a "benefit" whereas traditional economic B/C analysis sometimes does just the opposite depending on interpretation. Thus energy analysis could help provide a countering factor in considering whether construction of additional recreation facilities at large distant reservoirs is really in the nation's best interests.

Furthermore, energy accounting does tend to lift the level of energy consciousness which is desirable in a society that must become more energy conservative. Certainly society in general and water use planners in particular must be aware of the demands on basic resources generated by activities such as water based recreation.

SELECTED BIBLIOGRAPHY

Adelman, M. A., et al. 1974. Energy self-sufficiency: An economic evaluation. Technology Review, 76(45).

Adelson, P. D., Ed. 1974. Energy: Use conservation and supply. American Association for Advancement of Science, Washington, D.C.

Ayres, R. U., and M. Narkus-Kramer. 1976. An assessment of methodologies for estimating national energy efficiency. ASME 76-WA/TS-4.

Banks, William F. 1977. An energy study of pipeline transportation systems. Systems Science and Software, La Jolla, California.

Baron, S. 1980. The economic vs. energetic techniques of forecasting the true cost of solar energy. ASME publication 80-CZ/Sol-24, presented at Century 2 Solar Energy Conference, San Franciso, California.

Barton, John A., and Thomas J. Lutton. 1979. Energy accounting in the food processing industry. U.S. Department of Agriculture, Economics, Statistics, and Cooperative Services, Washington, D.C.

Batty, J. C., et al. 1975. Energy inputs to irrigation. Irrigation and Drainage Division, Journal of ASCE, Vol. 101, No. IR4, Prog. Paper 11810.

Batty, J. C., D. A. Bell, and B. C. Jensen. 1976. Energy accounting perspectives and guidelines. Utah State University, Logan, Utah.

Batty, J. C., J. P. Riley, W.J. Grenney, and D. A. Bell. 1976. An energy accounting evaluation of several alternatives for hydropower and geothermal development. Final Report Project A-031, Utah Water Research Laboratory, Utah State University, Logan, Utah.

Bayley, S., et al. 1977. Energetics and systems modeling: A framework study for energy evaluation of alternative transportation modes. Engineering and Industrial Experiment Station, University of Florida. (Available from NTIS.)

Bell, D. A. 1977. The development of a thermodynamic energy accounting system and its application to power project evaluation. Master's thesis, Utah State University, Logan, Utah.

Berry, R. S. 1972. Recycling - thermodynamics and environmental thrift. Bulletin of the Atomic Scientists, 28:9-15.

Berry, R. S. 1973. Recycling - thermodynamics and environmental thrift. Bulletin of Atomic Scientists, 29:11-17, 58-60.

Berry, B. R., and M. F. Fels. 1973. The energy cost of automobiles. Bulletin of the Atomic Scientists. 29:10-11-17 and 58-60.

Berry, B. R., and H. Makino. 1974. Energy thrift in packaging and marketing. Technology Review, 76(4):33-43.

Blaug, Mark. 1968. Economic theory in retrospect. Irwin.

Boyet, Wayne E., and George S. Tolley. 1966. Recreation projection based on demand analysis. Journal of Farm Economics 48(4,part 1):484-1002.

Brown, Richard E., and William J. Hansen. 1978. (I) Evaluation of operational effectiveness of recreation sites and II investment analysis of recreation facility development. IWR78-R3. Report submitted to U.S. Army Engineer Institute for Water Resources, Kingman Building, Fort Belvoir, Virginia.

Brown, S. J., and J. C. Batty. 1976. Energy allocation in the food system: A microscale view. Transactions of ASAE, 19:758-761.

Bullard, C. W., P. S. Penner, and D. A. Pirati. 1976. Energy analysis: Handbook for combining process and input-output analysis. Energy Research Group, University of Illinois.

Burke, James F., and Peter W. Williams. 1979. Gasoline prices and availability: What do they mean for tourism? Volume 8, No. 3. Institute for the Study of Outdoor Recreation and Tourism, Utah State University, Logan.

Burness, Stuart, et al. 1980. Thermodynamics and economic concepts as related to resource-use policies. Land Economics, 56(1).

Carlson, T. C. G., and W. P. Goss. 1980. OTEC-A comprehensive energy analysis. Mechanical Engineering, p. 32. January.

Cervinka, V., et al. 1974. Energy requirements for agriculture in California. Joint study: California Department of Food and Agriculture and University of California, Davis.

Cicchetti, Charles J. 1973. Forecasting recreation in the United States: An economic review of methods and applications to plan for the required environmental resources. Lexington Books, D. D. Heath and Company, Lexington, Massachusetts.

Clark, W. 1974. It takes energy to get energy: the law of diminishing returns is in effect. Smithsonian 5(9):84-91.

Coates, J. F. 1974. Technology assessment. Yearbook of Science and Technology.

Connor, Larry J. 1976. Agricultural policy implications of changing energy prices and supplies. Report prepared for National Science Foundation by Michigan State University, East Lansing.

Cornwell, B., and C. Sullam. 1978. Energy efficient recreation travel, energy conservation: Policy issues and fuel-use scenarios of savings potential, Part 4. Lawrence Berkeley Laboratory, University of California, Berkeley.

Dinnen, G. U., and L. Cook. 1972. Oil shale and the energy crisis. Paper presented at the Winter Annual Meeting of American Society of Mechanical Engineers, New York.

Dwyer, John F., John R. Kelly, and Michael D. Bowes. 1977. Improved procedure for valuation of the contribution of recreation to national economic development. UILU-WRC-77-0128, Research Report No. 128, Department of Forestry, Leisure Studies, and Economics. University of Illinois, Champaign.

Dyer, A. Allen, and R. S. Whaley. 1968. Predicting use of recreation sites. Bulletin 477. Utah Agricultural Experiment Station, Utah State University, Logan, Utah.

Eckstein, Otto. 1958. Water resource development. Harvard University Press.

Economic Research Service. 1977. Energy and U.S. agriculture 1974 data base, FEA/D-77/140. U.S. Department of Agriculture. U.S. Gov. Printing Office, Washington, D.C.

Energy and U.S. Agriculture. 1974. Data base volume 2. Commodity series of energy tables (1977). U.S. Dept. of Agriculture, Economic Research Service. Supt. of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Finney, J. P., F. J. Miller, and D. B. Mills. 1972. Geothermal power project of Pacific Gas and Electric Company at Geysers, California. Paper submitted for presentation at summer meeting of IEEE Power Engineering Society.

Frabetti, Alton J., et al. 1977. Application of net energy analysis to consumer technologies. Development Sciences Incorp., East Sandwich, Mass.

Gardner, B. D. 1975. Energy models and market prices. Paper presented at the annual meeting of the Operations Research Society of America, Chicago, Illinois.

Georgescu-Roegen, N. 1975. Energy and economic myths. Southern Economic Journal, 41:347-381.

Gillespie, Glenn A., and Durward Brewer. 1969. An econometric model for predicting water-oriented outdoor recreation demand. EOS 402, Agricultural Economist, Natural Resource Economics Division, Economic Research Service in cooperation with Missouri Agricultural Experiment Station.

Gilliland, M. W. 1975. Energy analysis and public policy. Science, 189:1051-1056.

Gramm, W. P., and R. R. Davison. 1973. The common sense way to more oil. Wall Street Journal.

Greaves, M. J. 1975. Merchant iron plants: The case for importing energy in the form of direct reduced iron. Engineering and Mining Journal. McGraw-Hill, Inc.

Hancock, H. K. 1972. There is a difference between saying and doing. Utah Science, p. 1-6.

Hannon, B. 1972. System energy and recycling: A study of the container industry. The American Society of Mechanical Engineers, publication No. 72-WA/Ener-3.

Hannon, B. 1972. System energy and recycling: A study of the beverage industry. Center for Advanced Computation Document No. 23. University of Illinois, Urbana.

Hannon, B. 1974. Options for energy conservation. Technology Review, 63:2531.

Hannon, B. 1975. Energy conservation and the consumer. Science, 189:95-101.

Harl, Neil E. 1980. The energy crisis: The adequacy of economic models. National Forum LX(4):42-43.

Heichel, G. H. 1976. Agricultural production and energy resources. American Scientist, 64:64-72.

Henderson, H. as quoted by C. Holden. 1975. Hazel Henderson: Nudging society off its macho trip. Science, 190:862-864.

Herendeen, R., and J. Tanaka. 1975. Energy cost of living, (CAC-171). Center for Advanced Computation, University of Illinois.

Herendeen, R. A., and C. W. Bullard III. 1974. Energy costs of goods and services, 1963 and 1967, (CAC-140). Center for Advanced Computation, University of Illinois.

Heuttner, D. 1976. Net energy analysis: An economic assessment. Science 4235:101-106.

Hirst, Eric. 1973. Energy intensiveness of passenger and freight transport modes. Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830.

Howell, C. S. 1981. An ecnomic analysis of energy accounting. Master's thesis, Utah State University, Logan.

Hunt, John D. 1976. What direction tourism? A plea for planning. Tourism and Recreation Review Vol. 5, No. 3, Institute for the Study of Outdoor Recreation and Tourism, Utah State University, Logan, Utah 84322.

Hurst, E. 1974. Food related energy requirements. Science, 184:134-138.

James, L. Douglas, and Robert R. Lee. 1971. Economics of water resources planning. McGraw Hill.

Kemp, N. B. 1971. The flow of energy in an agricultural society. Scientific American, 224(3).

Lavine, Mitchell J., and Arnim H. Meyburg. (No date). Highway planning with energy flow analysis. A report submitted on National Cooperative Highway Research Program Project 20-11A to the Transportation Research Board of the National Research Council, Cornell University.

Litterman, Mary, Vernon Edman, and Harold Jensen. 1978. Economics of gasahol. Dept. of Agriculture and Applied Economics, University of Minnesota, ER 78-10.

Lounsbury, Margaret, Sandra Hebenstreit, and R. Stephen Berry. 1978. Resource analysis: Water and energy as linked resources. Report No. 134, Water Resources Center, University of Illinois at Urbana-Champaign.

McCormick, M. 1976. Proceedings of the Technology Subcommittee. Energy R & D, Speech, Washington, D.C.

Makhijani, A., and A. Poole. 1974. Energy and agriculture in the third world. Ballinger, Cambridge, Massachusetts.

McCool, Stephen F., et al. 1974. The energy shortage and vacation travel. Tourism and Recreation Review, 3(2), Utah State University, Logan.

Mercury Outboard Motor Division Testing Center. 1979. Fuel conservation tests. Pamphlet.

Milstein, J. S. 1977. Energy conservation and travel behavior. Department of Energy.

Mitchell, E. J. 1972. U.S. Energy Policy: A primer. Enterprise Institute for Public Policy Research.

Myers, C. D. 1977. Energetics: Systems analysis with applications to water resources planning and decision-making. U.S. Army Engineering Institute for Water Resources, Kingman Building, Fort Belvoir, Virginia 22060.

Myers, J. G., et al. 1974. Energy consumption in manufacturing. Ballinger Publishing Co., Cambridge, Massachusetts.

Myles, George A. 1970. Effect of quality factors on water based recreation in Western Nevada. Desert Research Institute, No. 3E, Progress Report Series, Reno, Nevada.

Non-Nuclear Energy Research and Development Act of 1974 (PL 93-577), 93rd Congress. 1974.

Odum, H. T. 1971. Environment, power, and society. John Wiley Interscience.

Odum, H. T. 1973. Energy, ecology, and economics. Ambio 2:220-227.

Odum, Howard T., and Chester Kylstra. 1976. Energy models for environment, power, and society. A Report to U.S. Energy Research and Development Administration, University of Florida, Gainesville.

Odum, H. T., and E. C. Odum. 1976. Energy basis for man and nature. McGraw-Hill.

Office of the State Planning Coordinator. 1974. Some effects of the fuel shortage on travel and recreation in Utah. February.

Oser, Jacob. 1963. The evolution of economic thought. Harcourt, Brace and World Inc., New York.

Otto, A. C. 1979. Energetics: A proposition for change. Water Spectrum. 6(1):42-46.

Outdoor Recreation Action. 1974. Bureau of Outdoor Recreation. U.S. Dept. of the Interior, Washington, D.C. Report #31.

Pacific Gas and Electric. Information supplied on their Geyser units 5 and 6 power plant per letter and booklet received.

Pigman, J., J. A. Deacon, and L. R. C. Deen. 1972. Characteristics of outdoor recreation travel, Kentucky. Department of Research, report for Kentucky Highways.

Pilati, David, and Richard Rosen. 1978. Energy use modeling of the iron and steel industry. Paper presented at the 1978 Summer Computer Simulation Conference, Newport Beach, California.

Pimentel, D., et al. 1973. Food production and the energy crisis. Science, 193-434-949.

Pimentel, David, and Marcia Pimentel. 1979. Food, energy and society. John Wiley and Sons, New York.

Pimentel, D. 1974. Energy use conservation and supply. P. H. Albelson, Ed. (AAAS, Washington, D.C.)

Pimentel, D., et al. 1974. Workshop on research methodologies for studies of energy, food, man and environment. Cornell University, Phase I, June 18-20, Phase II, November 11.

Prest, A. R., and Ralph Turvey. 1965. Benefit cost analysis: A survey. Economic Journal, 75(300):683-705.

Revelle, R. 1976. Energy use in rural India. Science, 192:969-974.

Rothfield, L. B. 1975. Waste and energy requirements for the oil shale industry. Proceedings at the Conference on Water Requirements for Lower Colorado River Basin Energy Needs. Tucson, Arizona.

Rotty, R. M., A. M. Perry, and D. B. Reister. 1975. Net energy from nuclear power. Institute for Energy Analysis, Oak Ridge, Tenn.

Shechter, Mordechai, and Robert C. Lucas. 1978. Simulation of recreational use for park and wilderness management. Published for Resources For The Future by the Johns Hopkins University Press, Baltimore and London.

Shipka, Beverly D. 1974. Tourism and energy. Office of Research and Analysis, U.S. Travel Service.

Shurr, Sam H., and Joel Darmstadter. 1976. The energy connection. Resources for the Future. No. 53.

Simonson, Ernst. 1971. Physiology of work capacity and fatigue. Charles C. Thomas, Springfield, Illinois.

Staff, Chauncey, and Chris Whipple. 1978. Application of the risk/-benefit approach to the energy/environment conflict. Paper presented at the Conference on Environmental Risk/Energy Benefits and the Implications for Education, Lake George, New York.

Steinhart, John S., and Carol E. Steinhart. 1974. Energy use in the U.S. Food System Science, Vol. 184, April.

Stoddard, Thomas C. 1981. Energy accounting as a tool for evaluating man-made water recreation. M.S. thesis, Dept. of Mechanical Engineering, Utah State University, Logan.

Tien, J. K., et al. 1975. Reducing the energy investment in automobiles. Technology Review.

Union Oil's Geothermal Division. 1976. Information concerning their steam field adjacent to the geyser's power plant. Per letter received February 13.

United Nations. 1965. The use of gas in the cement industry. No. St/EZE/GAS/13, New York.

U.S. Department of the Interior, Bureau of Reclamation. 1969. Replacement factors and depreciation rates. Office of Chief Engineer.

U.S. Travel Data Center. 1974. Energy shortage impact survey. Summary Report 1150. Washington, D.C.

Utah State Tax Commission. 1978. Report of gasoline tax refunds for agricultural off-road vehicles. Utah State Printing Office.

Water Resources Council. 1973. Water and related land resources-establishment of principles and standards for planning. Federal Register, 38, Part III.

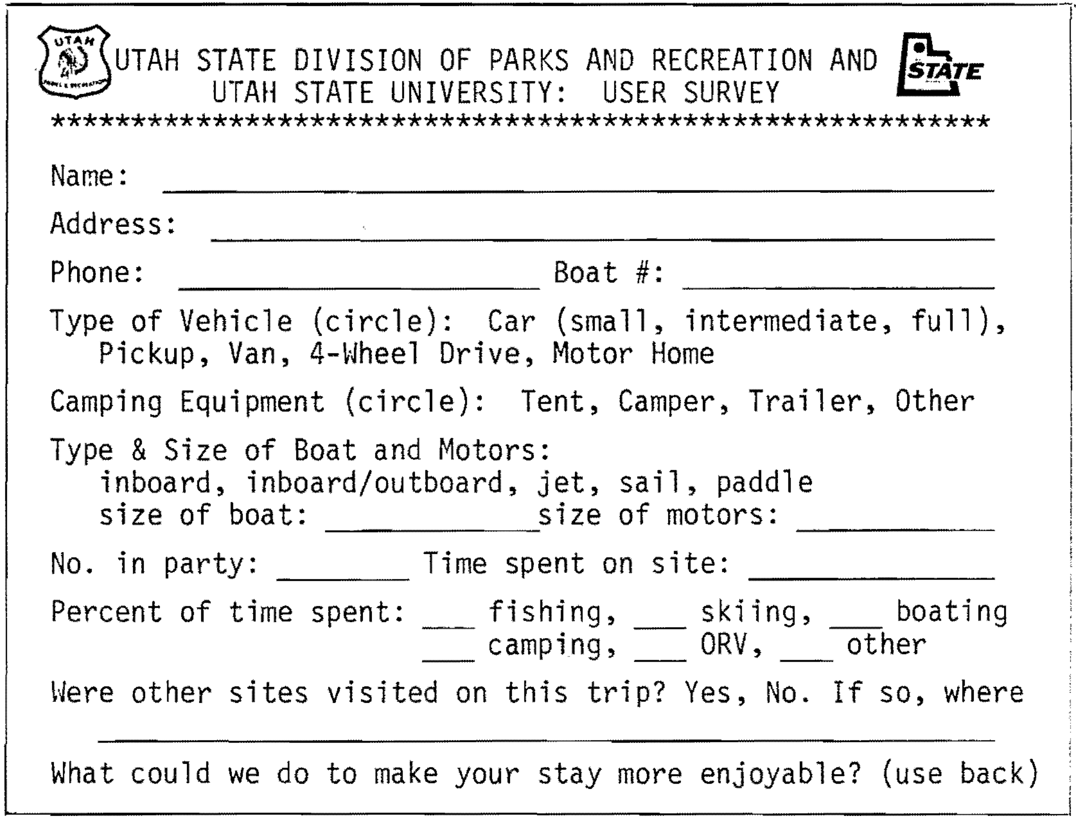
Watson, D. S. 1972. Price theory and its uses. 3rd Ed., Houghton Mifflin Co., Boston, Massachusetts.

Wensink, Robert B., John W. Wolfe, Michael A. Kizer. 1976. Simulating farm irrigation system energy requirements. Water Resources Research Institute, Oregon State University, Corvallis, Oregon.

Wetzstein, Michael E., Richard D. Green, and Gary Elsner. 1981. Estimation of wilderness use functions for Californian analysis of covariance approach. A paper presented at the annual meeting of the Western Ag Econ Assn. Held at Lincoln, Nebraska.

Wiser, W. H. 1980. College of Science Distinguished Guest Lecture Series, Address, Utah State University, Logan.

APPENDIX



UTAH STATE DIVISION OF PARKS AND RECREATION AND
UTAH STATE UNIVERSITY: USER SURVEY

****

Name: ______________________________

Address: ______________________________

Phone: ______________ Boat #: ______________

Type of Vehicle (circle): Car (small, intermediate, full), Pickup, Van, 4-Wheel Drive, Motor Home

Camping Equipment (circle): Tent, Camper, Trailer, Other

Type & Size of Boat and Motors:
inboard, inboard/outboard, jet, sail, paddle
size of boat: ____________ size of motors: ____________

No. in party: ________ Time spent on site: ____________

Percent of time spent: ___ fishing, ___ skiing, ___ boating
___ camping, ___ ORV, ___ other

Were other sites visited on this trip? Yes, No. If so, where

____

What could we do to make your stay more enjoyable? (use back)

I. RECREATION ACTIVITIES

1. Approximately how many days will (did) you spend in recreation activities associated with lakes and reservoirs during 1979? ____________

2. In what other major recreational activities do you or your family participate?
____

3. Has or will the current energy situation alter your participation in any of the recreation activities listed in 1 or 2 above? ______ If so, briefly explain.
____
____

4. How many free hours do you have, on the average for outdoor recreation on each day of the week: ____ Sunday, ____ Monday, ____ Tuesday, ____ Wednesday, ____ Thursday, ____ Friday, ____ Saturday, ____ Holidays.

II. RECREATION EQUIPMENT

1. What types and size of boats and motors did you own and use during 1979? (e.g. 20 foot 120 horse outboard) ____________________
____

2. What primary vehicles were used to transport your boat (e.g. 3/4 ton pickup and camper)? ____________________

3. What other recreation vehicles are owned (e.g. snowmobile, Jeep)? __________
____

III. USER CHARACTERISTICS

1. City or town of residence: ____________________

2. Occupation of head of home: ____________________ spouse: ____________

3. Annual family income before taxes (circle closest amount):

over $40,000
$30,000 - $39,999
$25,000 - $29,999
$20,000 - $24,999

$18,000 - $19,999
$16,000 - $17,999
$14,000 - $15,999
$12,000 - $13,999

$10,000 - $11,999
$ 7,000 - $ 9,999
$ 5,000 - $ 6,999
below $5,000

4. Education of (circle highest year completed):

Head of house: less than 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, more than 17

Spouse: less than 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, more than 17

5. How many children are living at home: _____ pre-teen _____ teenagers _____ other

IV. BOATING

1. Which, if any, of the following sites were visited by members of the family during 1979 (circle): Bear Lake, Deer Creek Reservoir, East Canyon, Fish Lake, Flaming Forge Reservoir, Gunnison Reservoir, Hyrum Reservoir, Otter Creek Reservoir, Pine View Reservoir, Lake Powell, Rockport Reservoir, Great Salt Lake, Starvation Reservoir, Steinaker Reservoir, Strawberry Reservoir, Utah Lake, Willard Bay, Reservoirs in Idaho.

2. Which of the above sites were most often used: ____________________
____

3. Please describe the average or typical trip taken to the sites listed below during 1979.

Site	Travel time (hrs.) one way	Approximate percent of time spent:				Cost of gas & oil	Number in party	When were most visits made (Please check)		Comments on site, if any
		Fishing	Skiing	Boating	Other			Weekend & Holiday	Week-days	
East Canyon										
Flaming Gorge										
Hyrum										
Lake Powell										
Rockport										
Willard Bay										