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Selected human aspects of water development in the Columbia River Basin/U.S.A.

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SUMMARY

The development of water resources causes unitentional as well as intentional hydrologic alterations, both of which may have significant socioeconomic ramifications. Case one considers selected impacts of the rapid development of irrigated land upstream from large hydroelectric plants. This development is causing concern about the viability of industries that depend on large blocks of inexpensive hydroelectric energy. Studies indicate however that regional economic benefits from new irrigation outweigh induced losses by industry. Case two discusses selected aspects of the plan to develop a hydro-thermal system. Implementation of this plan would increase water fluctuations as the Columbia system is used increasingly for peaking energy. Energy oriented interests support the plan while a loose coalition of interests favoring water use for fish and wildlife habitat and/or leisure time-aesthetic uses oppose it.

1 INTRODUCTION

There are many facets of hydrology that have socio-economic significance. Man has a long history of purposefully altering the spatial, temporal, quantiative, and/or qualitative characteristics of water in order to derive various benefits therefrom. Many of the benefits (water related goods and services) and the actions involved in developing the benefits have socio-economic implications. In addition to the intended effects of these hydrologic alterations, unitended effects often accompany water developments.

This paper presents two cases of selected planned and unplanned effects of water development in the Columbia River Basin. The first case discusses the evolving impacts of irrigation development on the generation of hydroelectric energy and aluminum production. The second case deals with some implications of converting from a hydroelectric to a hydrothermal system.

The man-water system (Fig. 1) is a convenient abstraction by which to view some of the complexities associated with socio-economic aspects of the hydrosphere. Water, the raw material in the input subsystem, is transformed into various combinations of water related goods and services by the management subsystem. The latter subsystem has three components:

1) institutions, whose function is to facilitate the attainment of societal goals related to water;
2) technology, which alters the utility of water from the input subsystem-often by altering its spatial, temporal, qualitative, and/or quantitative characteristics; and
3) capital, which makes both institutions and technology functional.

Hydrologic feedback in Fig. 1 represents planned and unplanned alterations usually associated with water developments. Institutional feedback is more gradual /"institutional lag") and usually more difficult to quantify than the former type of feedback. It is, however, an important part of the man-water system, representing adjustments in the management subsystem throurgh legislative, judicial, and administrative processes.

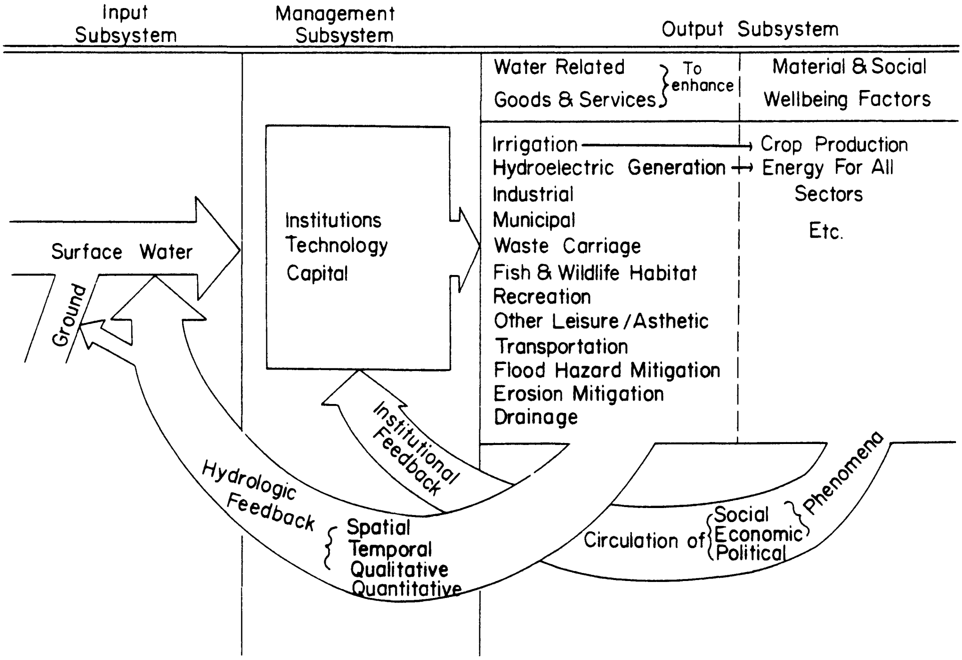

Fig. 1: Man-Water System

2 SELECTED IMPACTS OF IRRIGATION DEVELOPMENT ON HYDRO-ELECTRIC GENERATION AND THE REGIONAL ALUMINUM INDUSTRY

There is a long history of irrigation development in the Columbia Basin reflecting in part the dry summers common to the region and the expansive tracts of semi-arid and arid lands. By 1939 over 1.2 million hectares had been brought under irrigation. Irrigation development has become more rapid in recent decades. By 1975 approximately 3 million hectares were being irrigated; while projections for the year 2o2o range from between 3.8 and 4.5 million hectares.

The goal of markedly increasing the output of crops has been realized through irrigation, but when the circulation of water is altered on a very large scale, as it has been in the Columbia Basin, changes in the circulation of related phenomena are significant. Selected effects of these alterations on the production of hydropower and aluminum are now considered.

The first effect is a reduction in hydroelectric generation. The reduction is already noteworthy and potentially substantial. This is significant to all energy users in the region because the thermal-electric sources to replace the hydrogeneration are at least several times as expensive. While it is axiomatic that consumptive use by irrigation development upstream reduces the generating output of existing hydroelectric plants downstream, this relationship frequently experienced elsewhere on a small scale has become increasingly significant in the Pacific Northwest. The magnitude of existing and projected losses results from the large volume of upstream depletions coupled with the very large capacity of existing hydroelectric plants downstream from the irrigated areas.

The effect of irrigation on the generation of hydroelectric energy in the Columbia Basin varies according to:

1) the point of diversion within the system,
2) the elevation and distance of the irrigated land from the source of water, and
3) the type of distribution system used.

Fig. 2 illustrates three principal areas of recent and projected irrigation development and the location of the diversion points shown in Table 1. Table 1 (Columns 1, 2, and 3) indicates that losses of hydroelectric energy within the system become progressively larger at diversion points further upstream.. For example, a consumptive loss of one thousand cubic meters diverted at John Day reservoir, which has three dams and powerhouses below it, causes an energy loss of approximately 185 kwh; this loss is only about 24 and 14 percent of hydroelectric energy losses resulting from the consumptive use of an equal amount of water diverted at Grand Coulee and Palisades reservoirs, respectively.

In addition to the hydroelectric energy not generated due to upstream consumptive use, recent and projected irrigation techniques require considerable energy for pumping and pressurization. Center pivot technology, which accounts for most of the recent and projected irrigation development in the Columbia Basin, requires over ten times more energy per unit of irrigated land than conventional surface techniques. Moreover, much of the irrigable land lies high above the deeply incised Columbia-Snake system which further increases energy requirements.

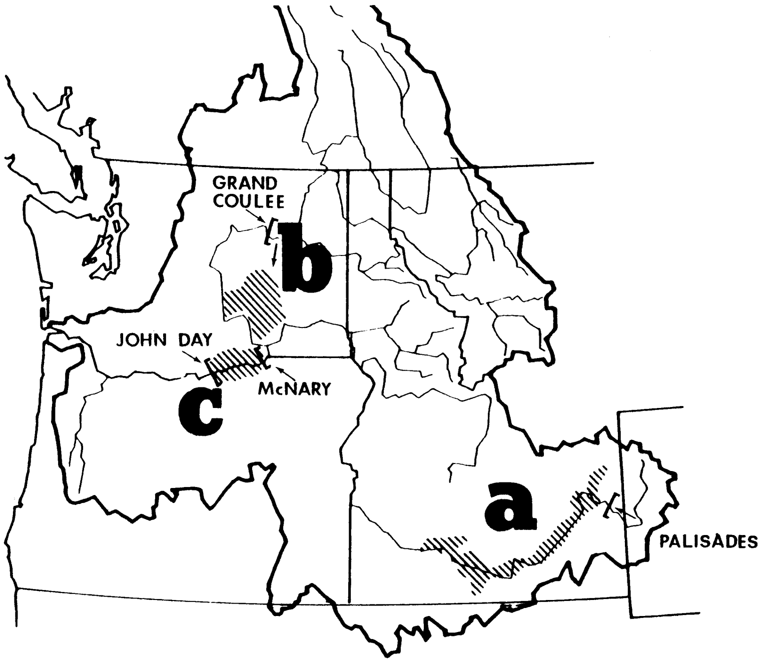

Fig. 2: Columbia River Basin-Primary Areas of Future Irrigation Development

(Source: Midified from U.S. Army Corps of Engineers-Walla Walla District, Irrigation Depletions/Instream Flow Study, December, 1976, p. IV-2)

To irrigate land in the Horse Heavan Hills (Area c, Fig. 2) at 91, 122, 275 meters above the Columbia, energy requirements for pumping and distributing one thousand cubic meters are 491, 596, and 1,123 kwh, respectively, WHITTELSEY (1976). Column 4, Table 1 illustrates energy consumed by pumping and distribution. The quantity of energy required varies with the reange of lifts necessary. With the exception of irrigation diversions at Grand Coulee, potential elevational differences of irrigable lands results in a wide range of required energy per unit of water applied. Column 5 in Table 1 presents the combined energy use from consumptive use and energy requirements per unit of water used for irrigation from each of the four reservoirs.

The energy requirements would be immense for large future developments. For example, full irrigation development of approximately 13o,ooo hectares in the Horse Heavan Hills may require 93o MW, STATE OF WASHINGTON

(1) Location of Diversion	(2) Number of Powerhouses Below Diversion	(3) Hydropower Loss KWH/m^3x10^3	(4) Energy Consumed: Pumping & Distribution KWH/m^3x10^3	(5) Total Energy (3 + 4)	(6) Increased Energy Cost/Hectare $/Hectare
John Day Reservoir	3	185	596-1123	781-1308	167-288
McNary Reservoir	4	234	491-1432	724-1666	152-366
Grand Coulee Reservoir	12	762	434-526	1195-1287	227-257
Palisades Reservoir	26	1276	406-1379	1681-2654	306-529

Tab. 1: Energy Losses, Consumption and Costs from Irrigation at Selected Diversion Points on the Columbia System

(Source: Modified from Charles River, Northwest Energy Policy Project (Final Report), 1978, p.358)

(1975). This is about 95 percent of the present peak capacity of the generating facilities at McNary Dam. Full implemenation of the second phase of the Columbia Basin Irrigation Project (Area b in Fig. 2) would irrigate an additional 2oo,ooo hectares. The diversion point would be from the reservoir behind Coulee Dam, with significant losses of energy.

Because the thermal generated replacement energy is so much more expensive than that generated by hydro, irrigation of new lands results in higher energy costs to all energy consumers in the region. For example, Column 6 of Table 1 illustrates that for every hectare irrigated by water diverted from the John Day reservoir, energy consumers in the region annually must pay between $ 167 and $ 288 in higher energy costs. Column 6 also demonstrates that the amount of the additional energy costs borne by regional consumers per unit of newly irrigated lands varies with the distance upstream that the diversion takes place and the energy consumed by pumping and distribution.

The socio-economic ramifications of more expensive electrical energy in the region are of course difficult to predict. Most attempts to assess such impacts focus on the aluminum industry which is sensitive to the supply and cost of electrical energy. This industry presently uses about one-quarter of the electrical energy consumed in the region, which it buys at very low rates. One of the principal reasons rates are very low is that contracts provide for interruptible service. Thus, when the generation of hydroelectric energy decreases appreciably - due to substantially lower levels of runoff - the aluminum industry may loose access to all or significant portions of its low cost energy source. If the industry elects to continue full production, it must purchase higher cost energy if it is available.

In a study of potential impacts that irrigation depletions would cause the Corps of Engineers projected that by the year 2o2o, 966 MW of hydroelectric generation would be lost yearly from the consumptive use by 1.8 million additional hectares of irrigated lands (Fig. 3) U.S. CORPS OF ENGINEERS (1976). The study also concluded that this reduction of hydro-energy would result in an annual loss by industry of $ 1.8 billion. This loss, most of which would be borne by the aluminum industry, would however be more than offset by an annual increase of $ 2.7 billion in regional income from the sale and processing of crops from the additional irrigated lands. The net annual gain of $ 9oo million results from much higher increases of reginal income per unit of energy used. The Study only included the impacts of hydroelectric energy foregone by consumptive use upstream (Column 3, Table 1), not the higher use for pumping and distribution (Column 4).

Another study using a multi-regional (three state) input-output approach to assess some of the impacts of irrigating and additional one million acres in the region between 1972-1985, concluded that for every dollar of crop derived output gained, between 4 and 7 cents would be lost by the aluminum and related industries, WILKINS (1979). According to the model, the range of 4 to 7 cents depends on whether replacement energy was available to the aluminum industry. If replacement energy is unavailable, the higher loss results. On the average for every new hectare brought under irrigation, about $ 4,324 would be gained due to crop export and processing, while from $ 173 to $ 272 would be lost by the

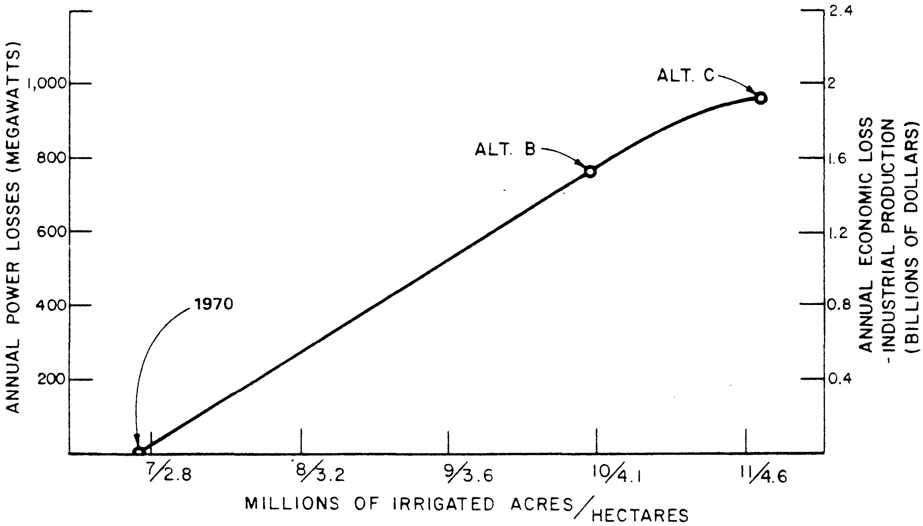

Fig. 3: Impact of Power Losses from Irrigation Depletions on Industry Beyond the 197o Level.

(Source: Midified from U.S. Army Corps of Engineers - Walla Walla District, Irrigation Depletions/Instream Flow Study, December, 1976, p. IV-42)

the aluminum and related industries. The study also concluded that for each MW of hydroelectric generation lost for use in aluminum production and dependet economic activities, 4-7 jobs and from between $ 276,ooo - 476,ooo output are lost to the economy of the region. These losses are more than offset however by 17o-19o new jobs (some of which would be seasonal) and by from $ 6.5-7.2 million dollars of irrigation-generated output in the regional economy.

All of the above figures are for an average water year. Low water years intensify the negative effect of upstream irrigation on downstream hydrogeneration and aluminum production while higher than average flows offset projected losses from additional irrigation. Based on a 4o year record of flows, there is a 18% chance of flows low enough to at least triple hydroelectric energy losses from irrigation depletions over those experienced in an average water year; but, on the other hand, there is a 46% probability that higher than average flows would results in no reduction of hydroelectric generation relative to an average water year.

The study does not consider the national significance of projected losses by the regional aluminum industry, nor the negative impacts that such losses would have on cities within the region whose labor forces are heavily dependet on aluminum production.

3 SELECTED IMPACTS OF THE HYDRO-THERMAL PROGRAM

The plan to develop a hydro-thermal program of generation has many socio-economic ramifications. Such a mode of operations would require the Columbia System to carry progressively less of the base load and increasingly larger proportions of the peak load. This in turn would affect a number of users within the Columbia System.

Fig. 4 illustrates the recent past and projected relative loads carried by hydro and thermal sources of generation during a twenty-four hour period on selected Mondays in 1975, 1985, and 1995. Weekdays in January - especially Mondays - are periods of typically heavy energy demands in the Pacific Northwest. It is evident that in 1975 hydroelectric generation carried most of the base load as well as the peak loads. Fig. 4 indicates that thermal sources of energy are expected to carry an increasing proportion of the base load while hydro will be depended upon to provide peaking energy. Such a mode of operation will concentrate generation of hydroelectric energy in shorter periods of time, causing greater fluctuations of water levels than in the past. Fig. 5 illustrates the different hydraulic capacities of powerhouses associated with increased peaking operation, which add to peaking related problems. Fig. 6 demonstrates how discharge rates at three dams on the Lower Snake River may change in accordance with the evolving hydro-thermal program. Such operations could further jeopardize the already threatened runs of anadromous fish in that reach of the Columbis System.

Increasing numbers of generators are being installed to provide the greater generating capacity required by the hydro-thermal program. Fig. 5 indicates three levels of full gate flows at eleven dams on the main stem of the Columbia. The 1975 gate flows, those planned for 1983, and the flows resulting from the possible ultimate installation in 1995.

Concern about increased reservoir fluctuations is being expressed by water related interests not involved with the generation of energy.

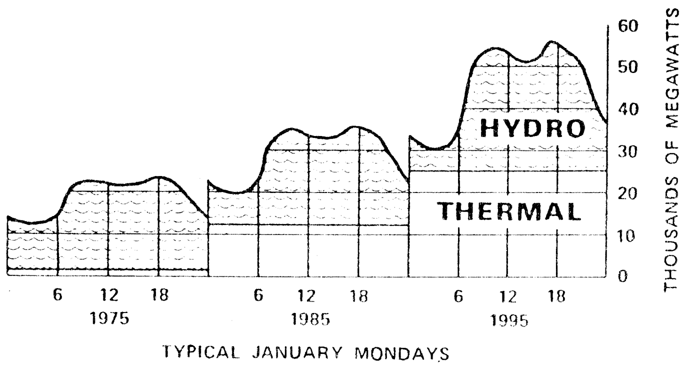

Fig. 4: Estimated Hydro-Thermal Generation

(Source: Modified from U.S. Department of Interior's Bonneville Power Administration, The Role of the Bonneville Power Administration in the Pacific Northwest Power Supply System, Draft, A Program Environmental Statement and Planning Report, Part 2 The Role of BPS, July 22, 1977, p. VII-38)

Particular concern is being expressed about fluctuations that would result if Grande Coulee is developed to its ultimate capacity. In this instance daily reservoir fluctuations of up to 9.75 meters could result from projected peaking operations on weekdays during the winter, BUERAU OF RECLAMATION (1975). The thirty turbines at this ultimate level of output would discharge 12,744 cubic meters per second. Advocates of such operations assure concerned parties that the resulting fluctuations would decrease significantly at reservoirs downstream and be markedly less during the spring and summer seasons.

If the hydro-thermal program develops as planned, growing criticism of and opposition to greater water fluctuations may be expected. Those interest groups associated with the generation, marketing, and use of large blocks of electrical energy will defend the increasing fluctuations as a minor inconvenience associated with the necessary development of the river system. The viewpoint of those groups will be vigorously contested by a combination of special interest groups concerned with deriving greater leisure time/aesthetic benefits from the waters of the Columbia System. They will be joined by groups favoring commercial and/ or tribal harvest of fish from the waters of the Columbia.

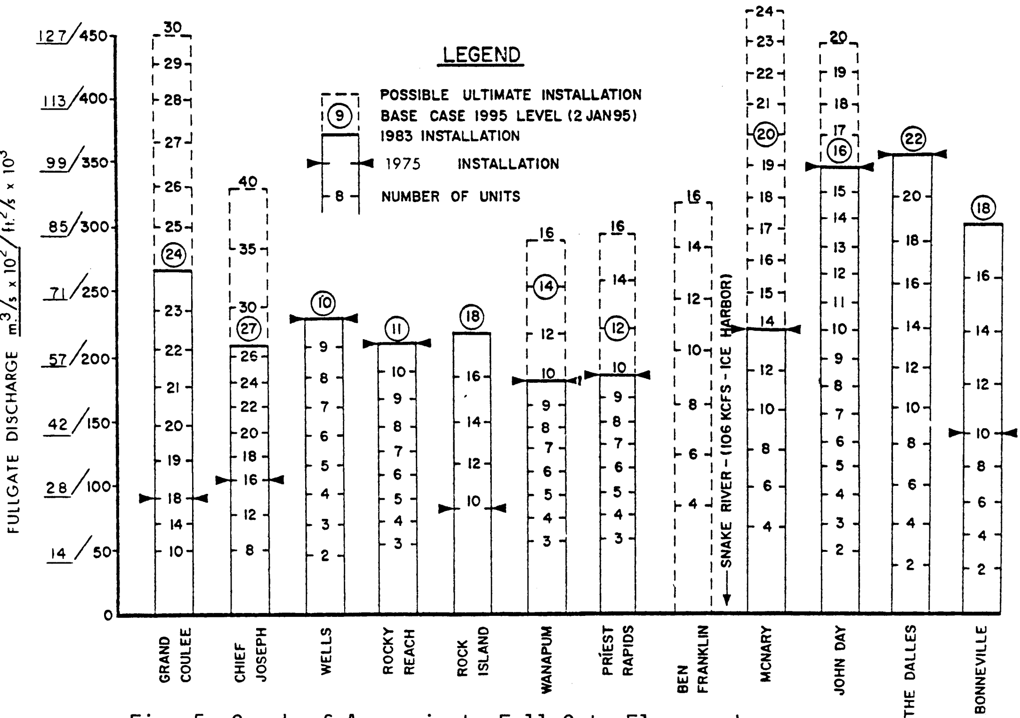

Fig. 5: Graph of Approximate Full Gate Flows and Corresponding Number of Units.

(Source: Modified from Bureau of Reclamation - Pacific Northwest Region (1975), Background of Studies Investigating Desirability of Enlarging the Third Powerplant at Grand Coulee Dam Washington, Boise, Idaho, Fig.5, n.p.)

A common complaint against greater fluctuations will be that an artifical hydrologic environment that has already become an inferior habitat for fish and wildlife and a degraded setting for leisure time/aesthetic uses of the system, will decrease further in quality as fluctuations increase. Special concern is already being expressed about nesting grounds for waterfowl and habitat for aquatic furbearers. These concerns apply to much of the system but many be expected to focus on the last free flowing stretch of the Columbia River between the U.S.-Canadian border and Bonneville Dam - the Hanford Reach.

The diverse and growing number of interest groups favoring the preservation and enhancement of runs of anadromous fish view with alarm projected fluctuations associated with the hydro-thermal program. Their contention is that fish passage over and through the numerous dams on the system is already hazardous for anadromous fish but may become even

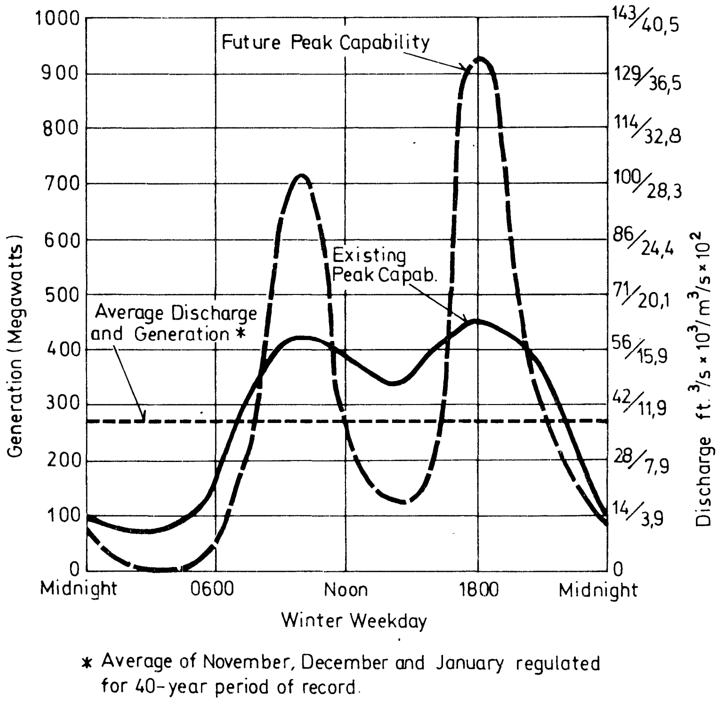

Fig. 6: Example of Shaping Average Generation to Peak Capacity - Lower Granite, Little Goose, and Monumental Dams

(Source: Modified from U.S. Department of Interior, op cit., p. VIII-1o)

more so if fluctuations become greater.

An increasingly influential interest group favoring enhancement of anadromous fish are the several Indian tribes that have fishing treaties with the U.S. federal government. These treaties antedate statehood and guarantee continued rights to fish and to harvest a significant percent of runs entering the Lower Columbia.

Outdoor recreationists - whether favoring slack water or white water - are generally opposed to greater fluctuations because, in general, recreational suitabilitiy of water and its riparian lands are negatively impacted by marked changes in water level. Interests favoring inland water transport also have expressed some reservations about the possible effect of large fluctuations on barge access to locks during hours of peaking operations.

Interests concerned principally with irrigation, municipal and industrial supply, and waste carriage would be affected relatively little by the emerging hydro-thermal program and therefore have not voiced opposition.

4 Conclusion

The cases discussed above are but two of many the world over that could have been used to illustrate the increasing complexity of developing large river systems for a variety of water related gooods and services. As more attention is paid to quality environments and to nontraditional leisure time-aesthetic aspects of water use, societies will be increasingly challenged to implement management strategies that accommodate to a maximum degree possible both traditional-utilitarian and emergent types of water oriented interests.

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