THE POTENTIAL FOR NUCLEAR AND GEOTHERMAL POWER PLANT SITING IN IDAHO AS RELATED TO WATER RESOURCES

A Thesis
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ABSTRACT

The basic purpose of this study is to determine the availability of cooling water in the State of Idaho for use in nuclear and geothermal power production and uranium enrichment facilities.

The first part of the study investigates the physical requirements for cooling water in nuclear and geothermal power production and uranium enrichment facilities. Charts and graphs are presented showing the cooling water requirements for various cooling systems. Cooling water requirement for a 1000 MWe nuclear facility cooled with an evaporative tower is shown to be approximately 33 cfs. The cooling water requirement for the same facility using cooling ponds is shown to be approximately 18 cfs with a pond area requirement of approximately 1500 acres. Cooling water requirements for various other sized plants using both closed cycle and once-through cooling are also shown.

The effects of water quality standards and water rights laws on cooling water supplies are also investigated. It is shown that Idaho's thermal effluent standards and regulations of the Environmental Protection Agency will severely limit if not eliminate completely the use of once-through cooling in the state. It is also shown that State Water Rights Laws will allow an appropriation or a change of appropriation from another use to be made for

power plant cooling. A survey of existing supplies of water that could be used for cooling purposes in energy facilities is made. The Snake River at King Hill, Weiser and the Salmon River at White Bird are shown to be possible sites for facilities in the 1000 MWe range using once-through cooling if today's effluent standards were relaxed. Table 1 and Figures 17 and 18 show the various study sites, locations and plant cooling capacity using once-through cooling.

The above mentioned sites plus the Salmon River at Salmon, Clearwater River at Orofino, Coeur d'Alene River at Cataldo, Pend Orielle River at Albeni Falls and the Kootenai River at Bonners Ferry are all shown to have adequate supplies of cooling water for evaporative tower and pond cooling systems for plants in the 1000 MWe range. Some sites are shown to have capacities for supplying water for tower cooling of power plants the sizes of which are far in excess of 1000 MWe. Table 2 and Figures 19 and 20 show the different sites and approximate water availability, location and power plant cooling capacity for tower or pond cooling systems.

The availability of water to be used in cooling schemes not normally used in conventional power plants is also explored. The use of pumped storage reservoirs as cooling ponds is investigated. Sinker Creek Butte Site and Rabbit Creek Sites near King Hill, various sites around Cascade Reservoir and the combination of Anderson Ranch and Little Camas Reservoir are all shown as possible sites for pumped storage-nuclear power plant combinations. The possibility of using irrigation canals as cooling canals is also explored. The use of various combinations of the diversion of the Twin Falls South and North Side Canals and the Milner Gooding Canal are shown to have good promise as power plant cooling canals. The Boise Canal system and canals in the Heise area are also shown to have some possibilities for being used as cooling canals.

Final portions of this investigation present the authors views on the directions of energy development in the state and the adequacy of the state's governmental institutions to regulate this development. The author shows that thermal energy development in the state is not far in the future but a problem of today. He notes the lack in the state organizational planning structure of a program to plan and oversee the development of thermal power in the state and urges that such a program be implemented as soon as possible.

INTRODUCTION

In the past Idaho has been highly dependent on hydroelectric power to meet its energy demands. Since most of the favorable hydroelectric sites have already been developed and most undeveloped projects will meet environmental opposition, Idaho will have to rely more and more on nuclear, geothermal and other types of thermal power production to meet its future power demands. At present the United States does not have uranium enrichment capacity to meet the projected needs of nuclear energy power production. New enrichment facilities will have to be constructed.

Nuclear and geothermal power facilities and uranium enrichment plants all require cooling water. It is the basic purpose of this study to determine the availability of this cooling water in the state of Idaho. This investigation will not pinpoint exact locations for development; rather, it will point out general areas where water is available for cooling purposes. Both the physical and legal availability will be investigated for both surface and underground sources of water.

The first part of the study investigates the physical requirements for cooling water in nuclear and geothermal power production and uranium enrichment facilities. Water quality standards and water rights laws are investigated to determine their effect on availability of cooling water. A survey of existing sources of surface and subsurface supplies of water is made to determine what quantities of water would be available for cooling purposes. Several unconventional cooling possibilities such as combined pumped storage nuclear plant operation and use of existing canals for power plant cooling will also be presented and evaluated. Maps and diagrams will be presented to show possible general location and layout of both conventional and unconventional cooling systems for nuclear and geothermal power production and enrichment facilities.

DESCRIPTION OF THERMAL POWER PLANT SYSTEMS

Both nuclear power plants and geothermal power plants use steam as the working medium to produce electric power. In a nuclear power plant nuclear fission within the reactor is the source of heat to create the steam. In a geothermal power plant heat within the earth produces the steam.

There are four basic reactor types in use or potentially considered for power production purposes at nuclear power plants. These are pressurized water reactors, boiling water reactors, liquid metal fast breeder reactors and high temperature gas cooled reactors. In a pressurized water reactor power plant, the heat from the reactor is transferred by pressurized water through a reactor cooling loop. The heat in the reactor cooling loop is transferred to a separate steam loop that carries the steam that is used to drive the turbines. In the boiling water reactor power plant the steam that is used to drive the turbine is generated directly in the reactor. There are no separate steam loops for the turbine and reactor as in the pressurized water reactor power plant. The steam generation system of the liquid metal fast breeder reactor is much the same as the pressurized water reactor, but the primary reactor cooling loop and secondary cooling loop contain liquid sodium instead of pressurized water. In the high temperature gas cooled reactor, helium gas is circulated through the reactor core and the heated gas is used to generate the steam that is used to drive the turbines. Illustrations of these four types of reactor systems are shown on Figures 1, 2, 3, and 4.

After the exhausted steam leaves the turbine it is passed through a condenser where it is returned to the liquid state. The water which is used to cool the condenser can be cooled in several ways. These methods include cooling towers, cooling ponds and canals, dry cooling and direct release to natural streams (once-through cooling). These systems will be described in greater detail in a later paragraph.

A conventional boiling water or pressurized water nuclear reactor power plant of today's design has an operating efficiency of approximately 31 to 33 percent (National Water Commission 1973). At this efficiency, a 1000 MWe nuclear plant would be required to reject 2000 megawatts of heat. This amounts to 6.8×10^9 BTU/HR. In a nuclear power plant, almost all of this heat is rejected to the condenser cooling water. High temperature gas cooled reactors and breeder reactors have efficiencies around 40% so the cooling requirements are slightly lower, but there is still a large cooling load.

Geothermal power production faces the same type of cooling water problems as other thermal power production, but the requirements are much more unpredictable because of

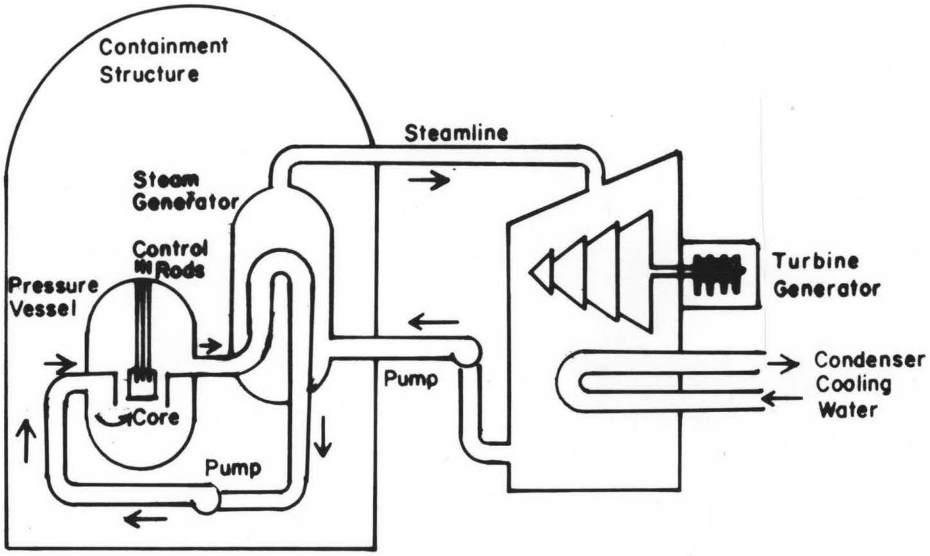

Figure 1

Pressurized Water Reactor (PWR)

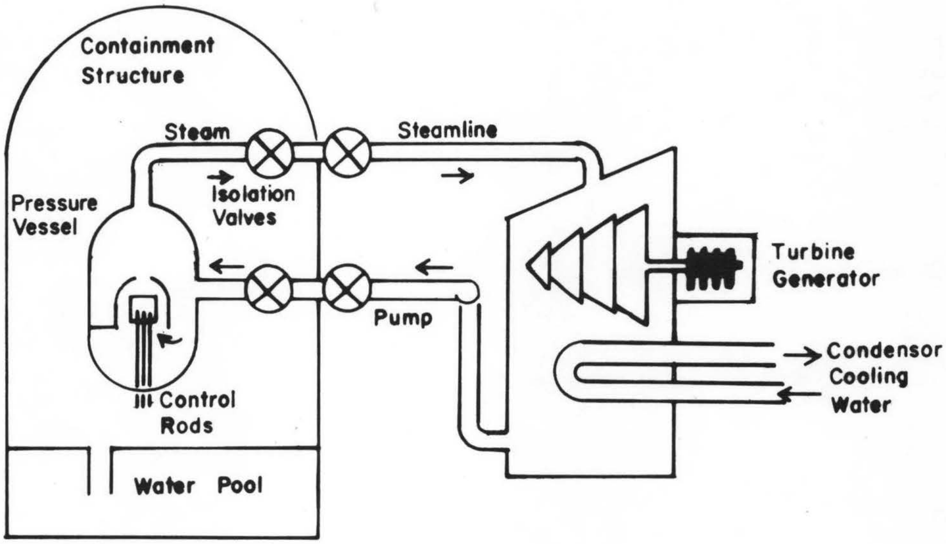

Figure 2

Boiling Water Reactor (BWR)

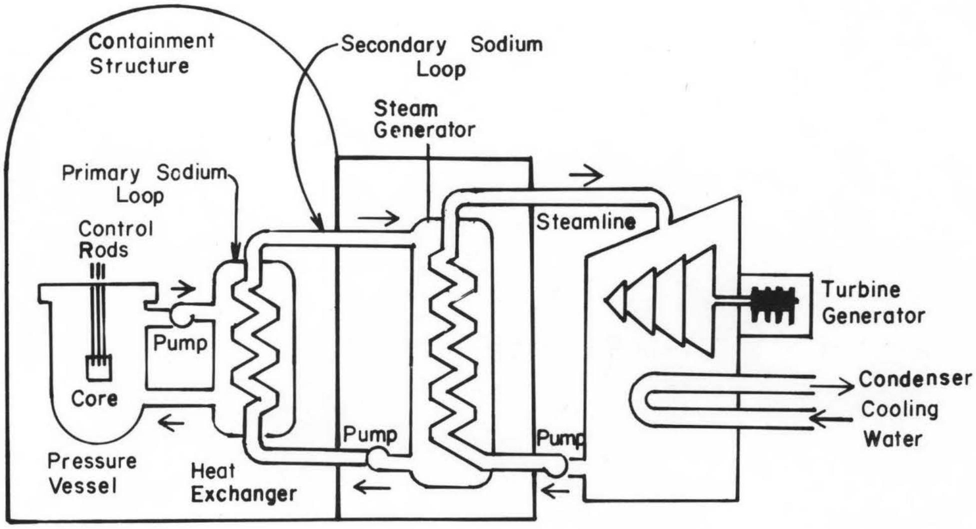

Figure 3

Liquid Metal Fast Breeder Reactor (LMFBR)

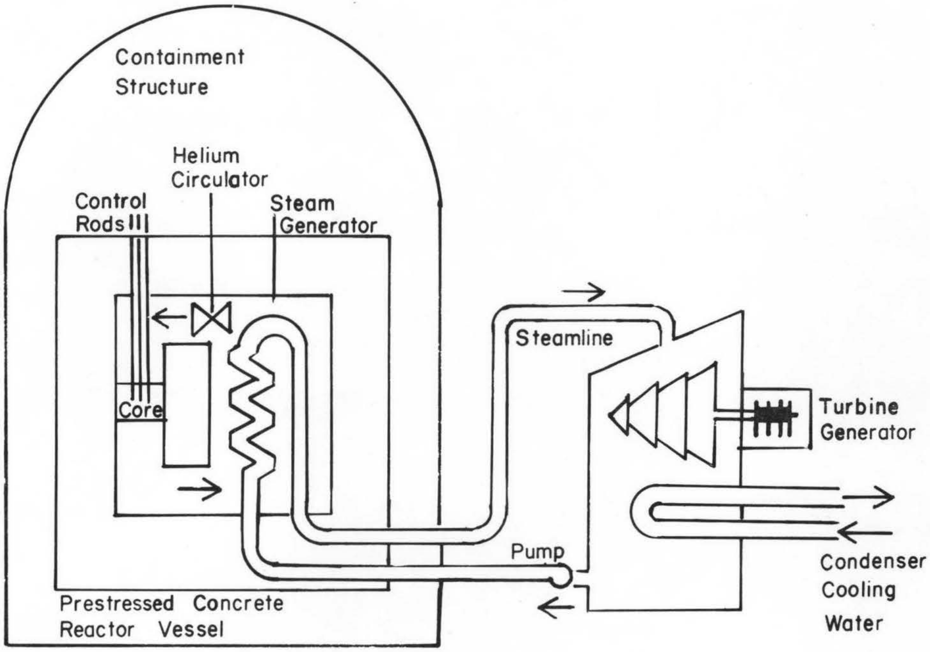

Figure 4

High Temperature Gas-Cooled Reactor (HTGR) uncertainties in steam temperature, pressure and volumes involved. Efficiencies for a geothermal power plant can be expected to be in the range of 10-15% (Seattle City Light, 1972). This means that the cooling water requirements for any of the cooling systems will range from 2 to 3 times greater than that for a nuclear power plant of the same power output. In order to predict the cooling water requirement with more accuracy extensive exploration of the geothermal fields is required. This exploration is still in its early stages in Idaho, so predicting actual cooling water requirements for geothermal power development will not be possible.

Uranium enrichment facilities are the portion of the nuclear fuel cycle that increases the content of fissionable U235 from its natural state of 0.071% to 2-5% which is required in the nuclear reactors used for power production in the U.S. (Western Interstate Nuclear Board, 1973). The gaseous diffusion process has been used almost exclusively in the U.S. and elsewhere in large scale enrichment processes. The enrichment process, in a gaseous diffusion plant, is accomplished by introducing UF_6 gas containing both the U235 and U238 isotopes into a compartment with one wall made of a special porous material. Since all the UF_6 molecules have the same kinetic energy, the molecules of the lighter $U235F_6$ must travel faster to maintain the same kinetic energy as the heavier molecules of $U238F_6$. The higher velocity molecules have a greater probability of passing through the small holes in the porous material than the heavier lower velocity molecules; therefore, there is a small concentration effect (Murphy, 1961). The concentration effect is 1.00429 for one stage of separation; therefore, approximately 1200 stages are set up in a cascading arrangement in order to reach the required level of separation (Western Interstate Nuclear Board, 1973). A schematic diagram of the gaseous diffusion process of enrichment is shown in Figure 5.

The porous barrier between the stages causes a pressure drop in the gas between the stages. The pressure is brought up to the original level by compressors between the stages. These compressors use large amounts of power. In a 8750 metric ton SWU plant a continuous power supply of 2,500 MWe would be required (Western Interstate Nuclear Board, 1973). The SWU (Separative Work Unit) is a measure of the ability of a plant to perform a desired separation at a specified rate. After each compression cycle the gas is passed through a cooler. The heat that is rejected to the cooler is eventually rejected to the atmosphere through evaporative cooling towers. Evaporative losses in these towers would amount to approximately 22,000,000 gpd or 34 cfs (Western Interstate Nuclear Board, 1973). If a nuclear power plant were constructed to supply the power used in a gaseous diffusion plant, the combined water consumption for both plants would amount to approximately 120 cfs assuming that the power plant were cooled with an evaporative

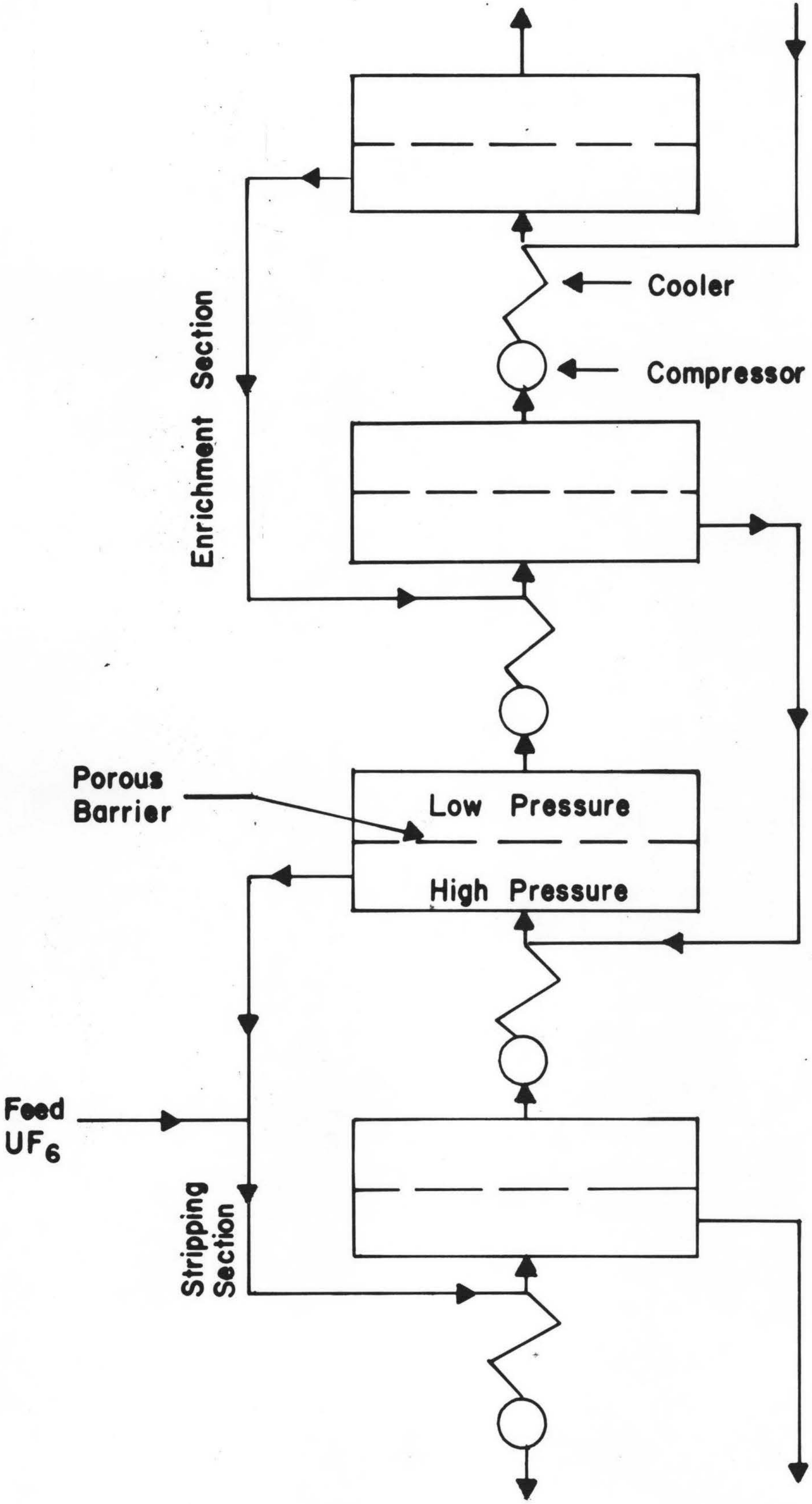

Figure 5

Gaseous Diffusion Cascade
Isotope Seperator

cooling tower.

An alternative method to the gaseous diffusion process for enriching uranium is the gas centrifuge process. In this method unenriched UF_6 gas is introduced into a centrifuge spinning at a high angular velocity. The higher mass $U238F_6$ molecules congregate toward the outside of the rotating cylinder and the lower mass $U235F_6$ molecules become more concentrated near the axis of rotation of the centrifuge (Benedict and Pigford, 1957). Centrifugal separation takes far less power than does gaseous diffusion separation. Power requirements for centrifugal separation would be approximately 250-300 MWe for 8750 metric ton SWU capacity plant (Western Interstate Nuclear Board, 1973). This is almost one tenth the power required for a gaseous diffusion plant.

Consumptive water requirements would also be in the order of 1/10th that of a gaseous diffusion plant (Van Winkle, 1975). The centrifuge process is now undergoing development and could reach a commercially feasible status in the next few years (Western Interstate Nuclear Board, 1973). Centrifugal enrichment plants because of their lower electrical power requirements would be more likely to be located close to the nuclear reactor market.

CONVENTIONAL COOLING SYSTEMS

The condenser cooling water which has been heated 12 to 30 degrees F. is either returned to the source of supply (once-through cooling) or it is passed on to some sort of final heat rejection system such as a cooling tower or pond. Here the heat from the condenser water is rejected to the atmosphere.

Once-through cooling is the largest total water user of the different cooling systems. The total condenser flow is withdrawn from the source and later returned in its heated state. The water temperature increases for once-through cooling of various sized plants for different condenser cooling water flow rates are shown in Figure 6. Values of temperature increase less than 12 degrees are not likely in the water passing through the condensers because of the condenser size required to handle the required flow rates. Total receiving stream temperature rise could be less than 12 degrees F. if there is water available for mixing with the heated condenser cooling water. Because this method uses a large portion of sensible heat transfer to achieve its heat rejection to the atmosphere, its consumptive use is the smallest of any of the wet cooling systems. Evaporative losses have been estimated at from 8 cfs (Senate Select Committee on National Water Resources, 1961) to 19 cfs (National Water Commission, 1973). This value could

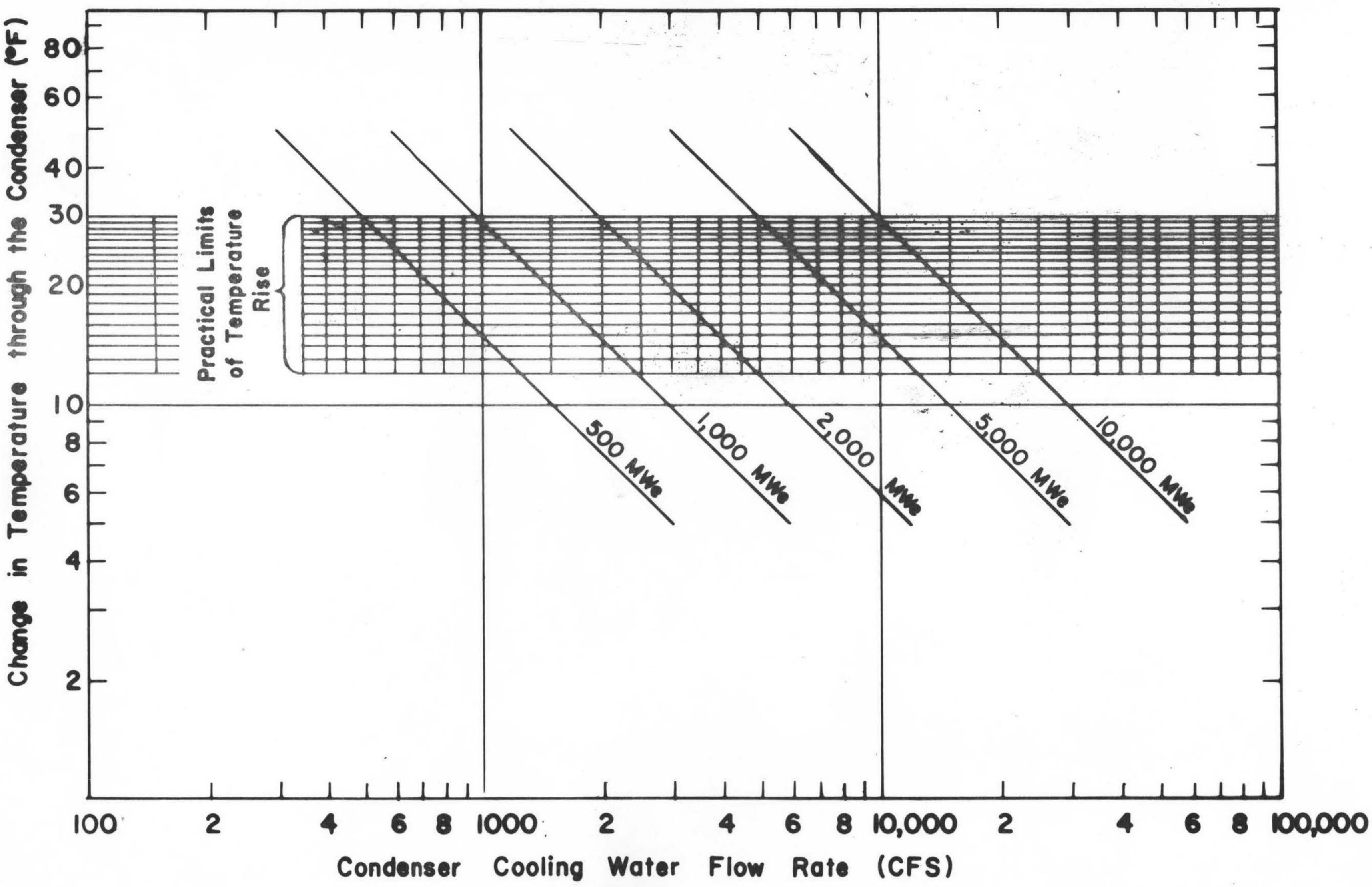

Figure 6

Condenser Cooling Water Flow Rates for Different Water Temperature Increases vary markedly depending on local conditions. A sketch of a once-through cooling system is shown on Figure 7.

Because of water recycling, closed cycle systems such as cooling towers and cooling ponds have very small total water requirements compared to once-through cooling, but the consumptive losses for these systems are much higher because a large portion of the heat rejection is carried out by evaporation. Cooling towers and cooling ponds are the main closed cycle power plant cooling systems.

Mechanical and natural induced draft cooling towers are the two types of evaporative closed cycle tower cooling systems used in the U.S. today. A schematic diagram of a tower cooling system is shown in Figure 8. A natural draft cooling tower is a tall chimney like shell usually constructed of reinforced concrete. Air flow is induced up through the shell by the buoyancy effect of the heated air. In a mechanical draft tower, fans force the air through the structure. In both natural and mechanical draft towers the condenser cooling water is dropped through a lattice work of packing material in the lower section of the tower. This packing material breaks the flow of cooling water into shallow sheets and greatly increases the water surface area exposed to the air flow through the tower. The increased surface area greatly enhances evaporative and sensible heat transfer to the atmosphere. Mechanical draft evaporative cooling towers are smaller in physical size than natural draft

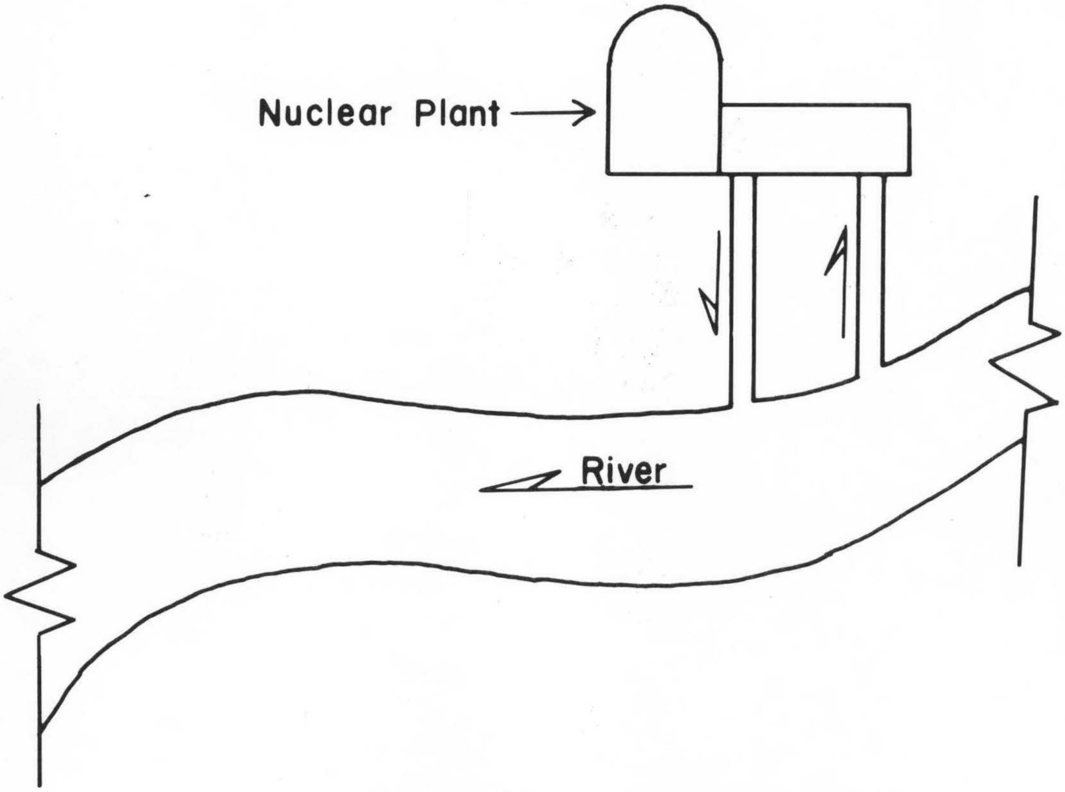

Figure 7

Nuclear Plant with Once-Through Cooling

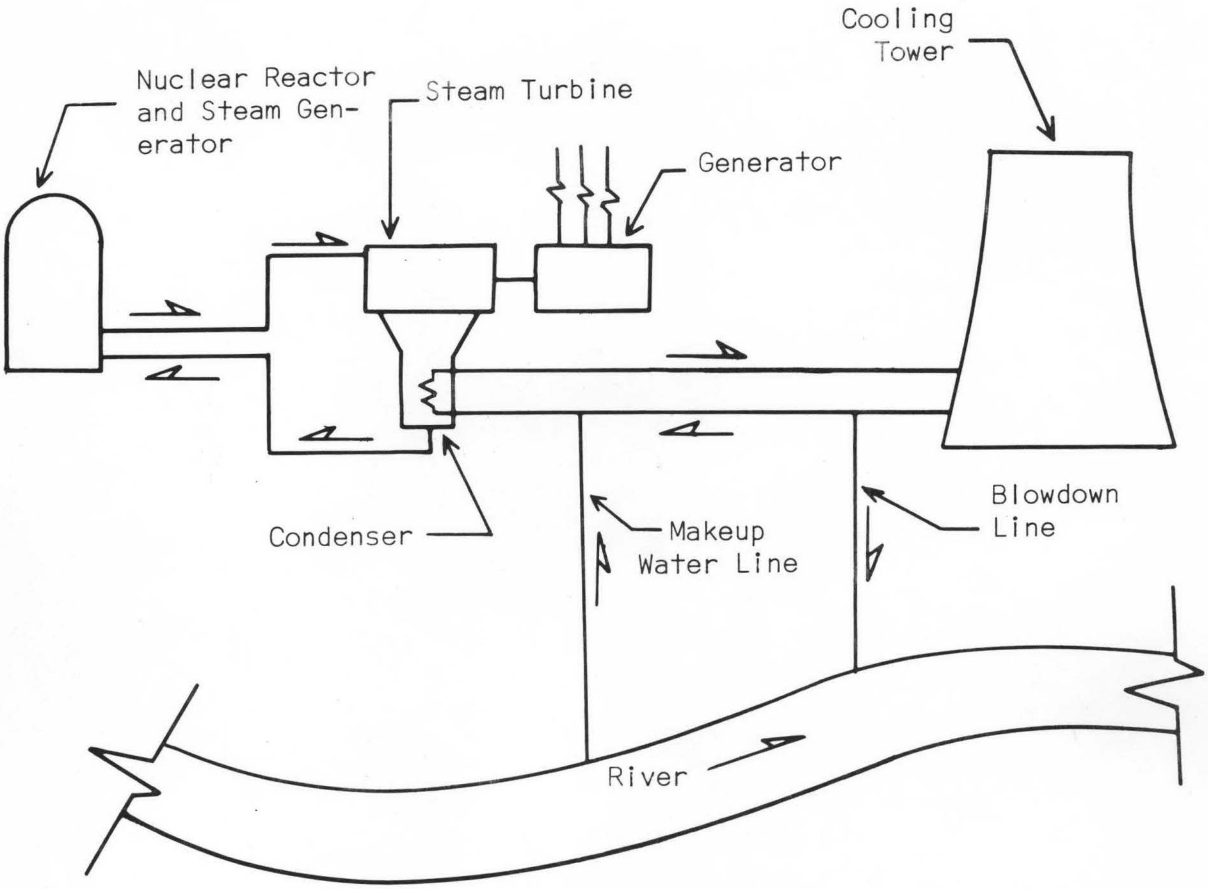

Figure 8

Components of Nuclear Generating Station Using a Cooling Tower towers, and usually much less expensive to build, but the annual operating costs are much higher than those for natural draft towers because of the operating cost of the fans. Mechanical draft towers are more likely to be used in the more arid regions of the State because of the lack of buoyancy drive required for the natural draft towers (Dallair, 1974). Mechanical draft and natural draft towers have the same consumptive water requirements. Figure 9 gives the consumptive water use versus power plant size for power plants using evaporative cooling towers.

Cooling ponds are another method used for cooling condenser water. This method uses a large lake as the heat rejection medium. Heated condenser cooling water is passed into the lake and after sufficient time for cooling the water is returned to the condenser. Consumptive losses due to evaporation for this type of system would be approximately 18 cfs for a 1000 MWe plant. Cooling lake surface area for a 1000 MWe plant would be approximately 1500 acres (Battelle Northwest, 1967). The consumptive losses and surface areas involved are highly dependent on local climatic conditions. Curves showing approximate consumptive use and lake surface areas versus power plant size are shown on Figure 10. Spray cooling ponds and canals are a modification of the cooling pond system in which pumps and spray nozzles are used to spray jets of the cooling water into the air. Spraying the water into the air increases the surface area exposed

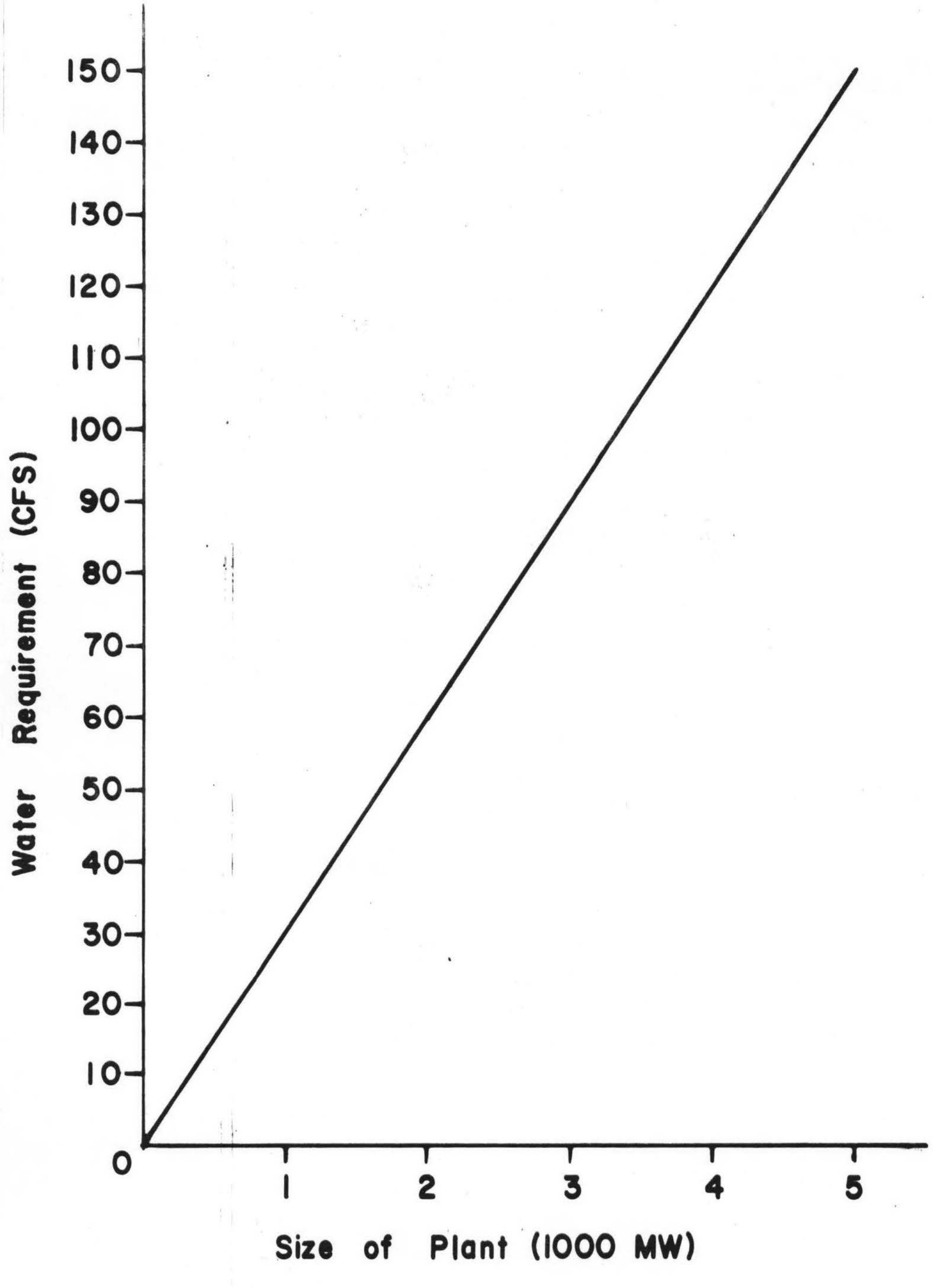

Figure 9

Consumptive Water Requirements for Tower-Cooling Nuclear Power Plant

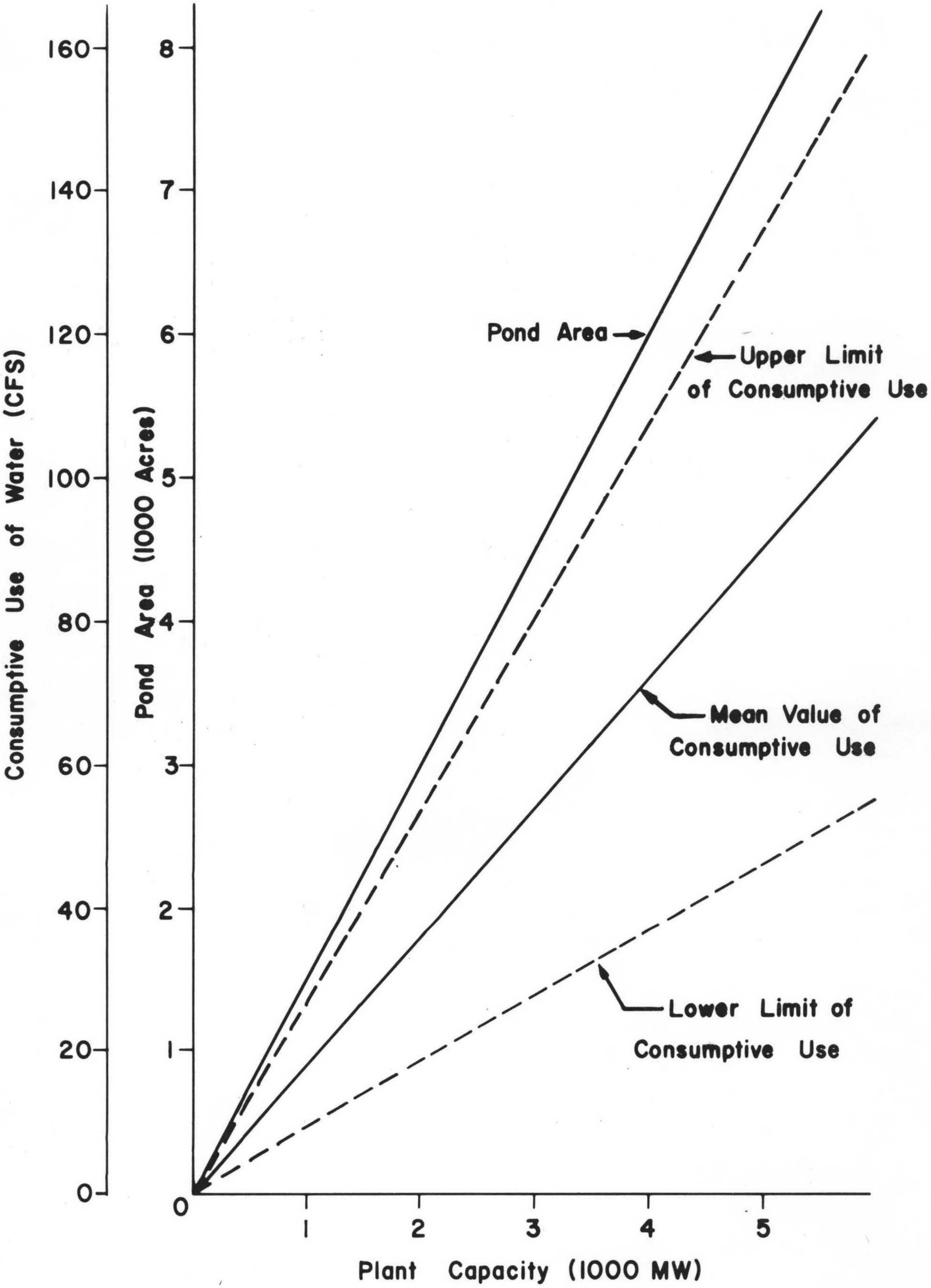

Figure 10

Consumptive Use and Pond Area Versus Power Plant Size for Power Plants Cooled with Cooling Ponds to the atmosphere and therefore increases evaporative and sensible heat loss. Pond area requirements are much smaller for the spray systems but operating expenses are higher because of power requirements for the spray system. Consumptive losses for spray ponds are almost the same as those for evaporative tower cooling methods (National Water Commission, 1973). This type of system is economically competitive with mechanical or natural draft cooling systems (Goodjohn, Fortescue, 1971).

Another possibility for power plant cooling is the dry type cooling system. This system is a completely closed system in which the final heat rejection is accomplished by inducing a flow of air through a set of coils which contain the cooling water. This system has been used successfully on smaller power plants but application to large scale power production has not been accomplished as of yet. Dry cooling systems have the advantage of removing water availability as a siting requirement, but due to lower heat rejection capabilities, turbine back pressures are increased and operating efficiencies are reduced. Large size turbines capable of operating at higher back pressures for extended periods of time have not been manufactured as of yet (Tennessee Valley Authority, 1973).

UNCONVENTIONAL COOLING SYSTEMS

Unconventional cooling systems are systems that are not ordinarily used in today's power plant system. Two basic requirements of an unconventional cooling system is that it be able to reject waste heat at all times that the power plant is expected to be in operation and that the economics of the unconventional system be competitive with conventional cooling systems.

Agricultural use of waste heat from a thermal power plant shows much promise. Studies by Oregon State University have shown marked increase in crop production using soil warming techniques which could be adapted to using heated effluent from thermal power plants (Sepaskha, Boersma, Davis, Siegel, 1974). A thermal water demonstration project sponsored by the Eugene Water and Electric Board also showed favorable results in using heated water in agricultural applications (Vitro Engineering, 1971). The cost of the heated water distribution system is fairly high so the economics of using this type of system is very much dependent on the type of crops that can be grown in the area and the market conditions for those types of crops.

Although agricultural waste heat use systems do show much promise, there are still some important drawbacks that must be overcome. The seasonal nature of the agricultural use would require that alternate cooling sources be used during the non-growing seasons. Also the high cost of the distribution systems may make competition with conventional cooling methods unattractive.

The use of waste heat from power plants and enrichments facilities in aquaculture also shows promise. Studies have shown that some fish species especially those in the catfish family show a marked increase in growth rate at temperatures around 85 degrees (Yees, 1970). Temperatures in this range could be obtained relatively easily at or near the discharge point of condenser water from a nuclear power plant. An aquaculture operation raising catfish could be easily set up in a cooling pond or cooling canal system. It is estimated that a 2000 acre cooling pond could conceivably raise 500,000,000 pounds of fish per year using a system that uses sewage effluent to raise algae which in turn feeds zooplankton and larger crustaceans that in turn act as food for the fish (Keller and Sowards, 1970).

Peterson and Jaske (1970) have shown that irrigation canals can be used very effectively in dissipating waste heat from thermal power plants. This concept seems very promising and has been given consideration in the water availability studies described later. A cooling scheme using a canal system would generally consist of diverting all or part of the discharge in the canal through the condensers of the power plant. The heated water would be discharged back into the canal where heat rejection to the atmosphere would occur. A diagram of this system is shown in Figure 11. The distance from the power plant to the first farm lateral would have to be great enough so that the temperature of the canal water would be low enough not to harm the field crops.

Presently most canals in Idaho are operated on a seasonal basis. This would present some obstacles to their use as cooling canals but it might be possible through operation agreements to arrange to have the canals flow on a year around basis. Introduction of an additional heat load to a canal would increase the evaporation rate. The water rights problem caused by this increased evaporation will be discussed in a later section.

Another problem that might be encountered is increased vegetal growth in the canal system. Growth of moss and other water borne plants would probably be accelerated because of the increased water temperature in the canals. The accelerated growth rates could result in increased maintenance costs for the irrigation companies. The utility sponsoring the power plant would probably be expected to assume the cost of this increased maintenance.

The possibility of using either or both the upper and lower reservoirs of a pumped storage project as cooling reservoirs shows much promise. A combination nuclear power and pumped storage facility has many economic and environmental advantages over separate facilities. The nuclear facility with its high capital cost but low fuel costs is designed to

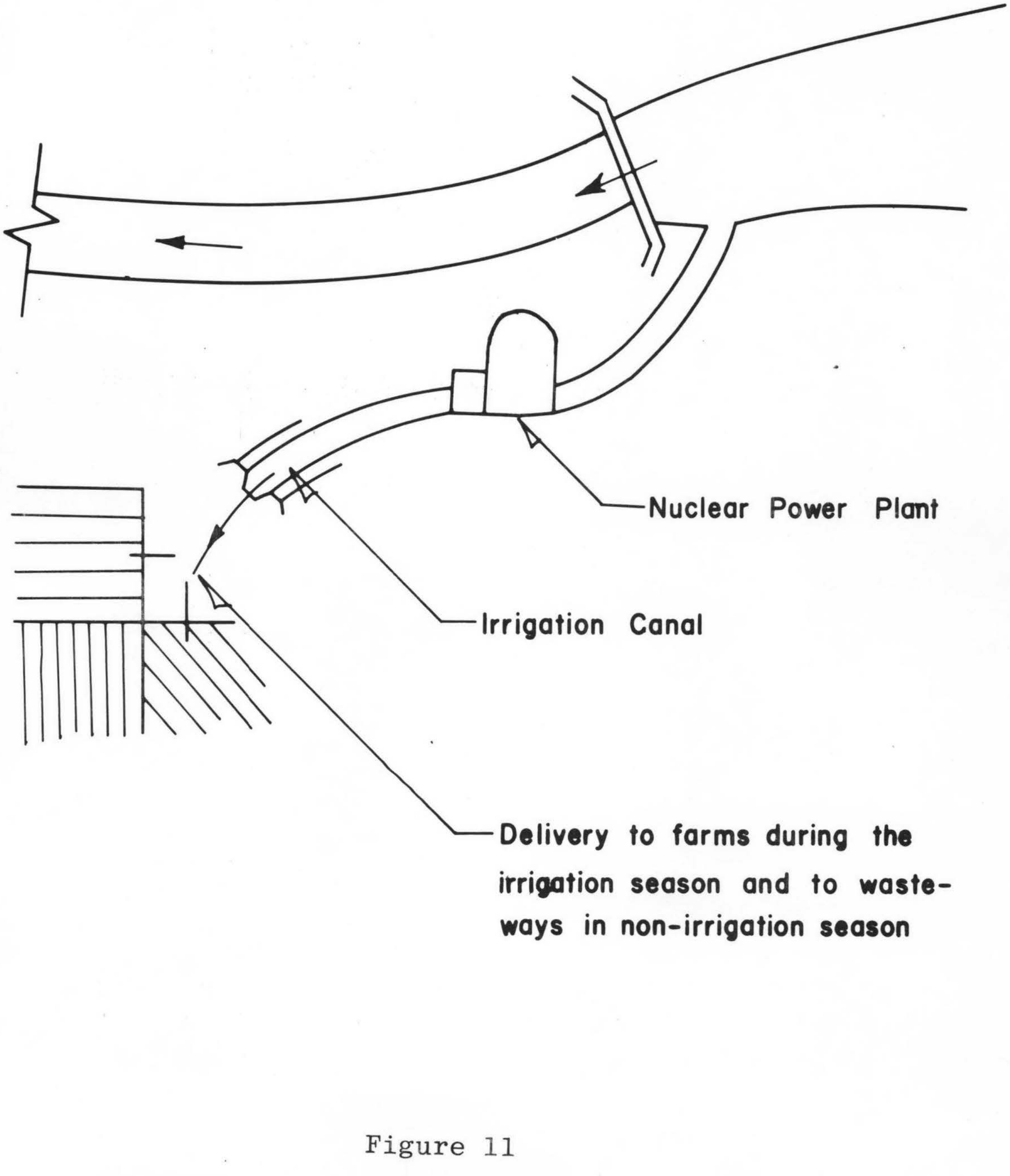

Figure 11

Once-Through Cooling Using a Canal System be operated at a high load factor, whereas, the pumped storage plant with its low maintenance and operating costs is designed to run at a low load factor. The two systems complement each other in supplying power to a fluctuating load pattern (Stubbart, Zambotti, 1966).

Some advantages of combining both facilities at one site include common facilities for both plants and lower transmission losses because the pumping load could be supplied directly from the nuclear plant. Idaho has many promising pumped storage sites and the possibility of combining these sites with nuclear power plant looks promising. Schematic diagrams showing possible layouts for combined nuclear power plants and pumped storage plants are shown on Figures 12, 13 and 14.

The use of waste heat from nuclear power generation for space heating, air conditioning and industrial purposes has been suggested by many. In Europe hot water from nuclear power plants has already been used for district residential heating (Diamant, 1970). A typical three-bedroom house requires 75,000 BTU/HR. for winter heating and 72,000 BTU/HR. to provide the 36,000 BTU/HR. required for summer cooling assuming a coefficient of performance of 0.5 for the air conditioning system (J.A. Nutant, 1970). If the steam extraction system at the turbine is modified somewhat so that 220 degree steam can be used, a 1000 MWe nuclear power plant could supply enough heat to heat and cool housing for

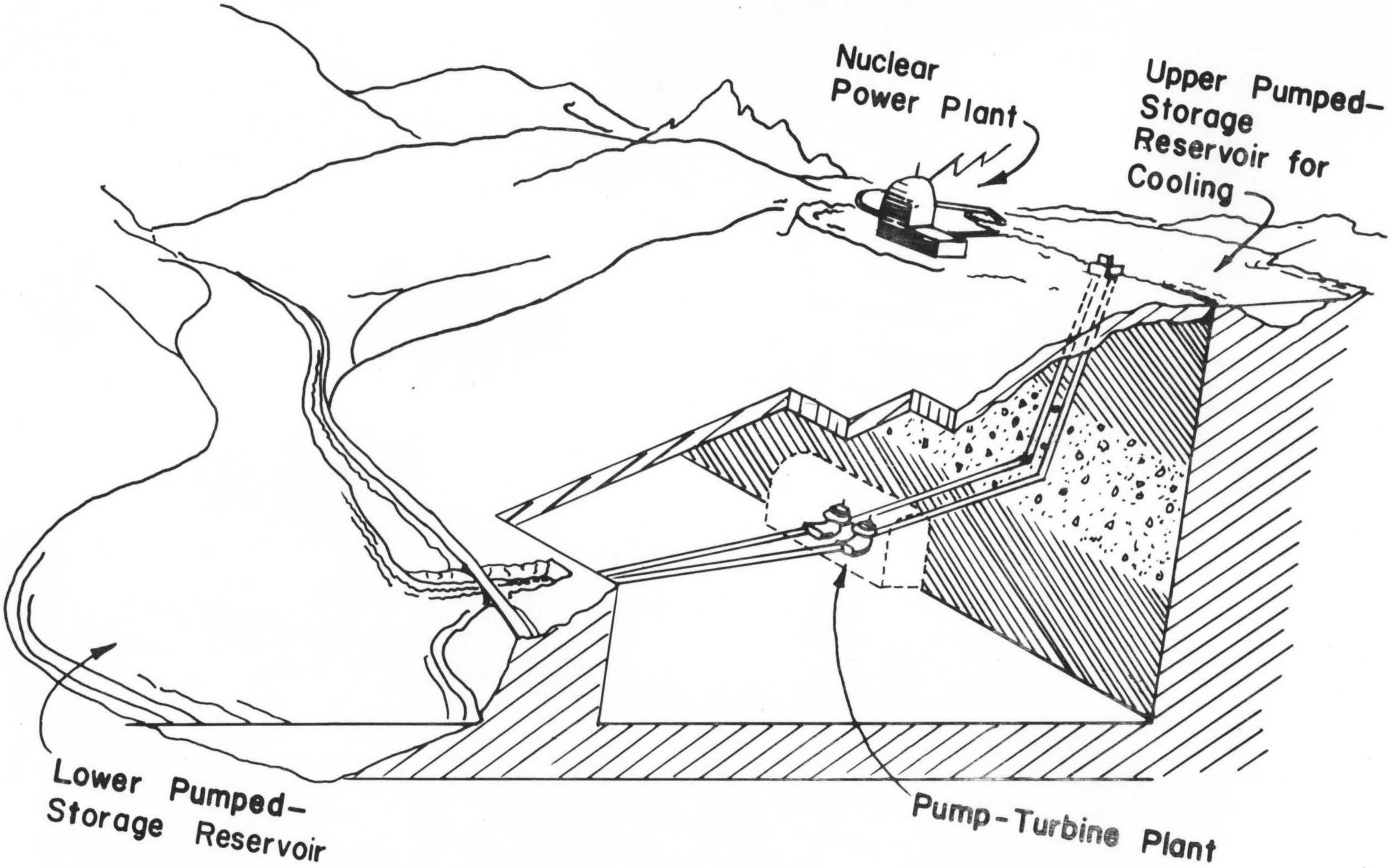

Figure 12
Nuclear Power Plant Combined with a Pump Storage Project

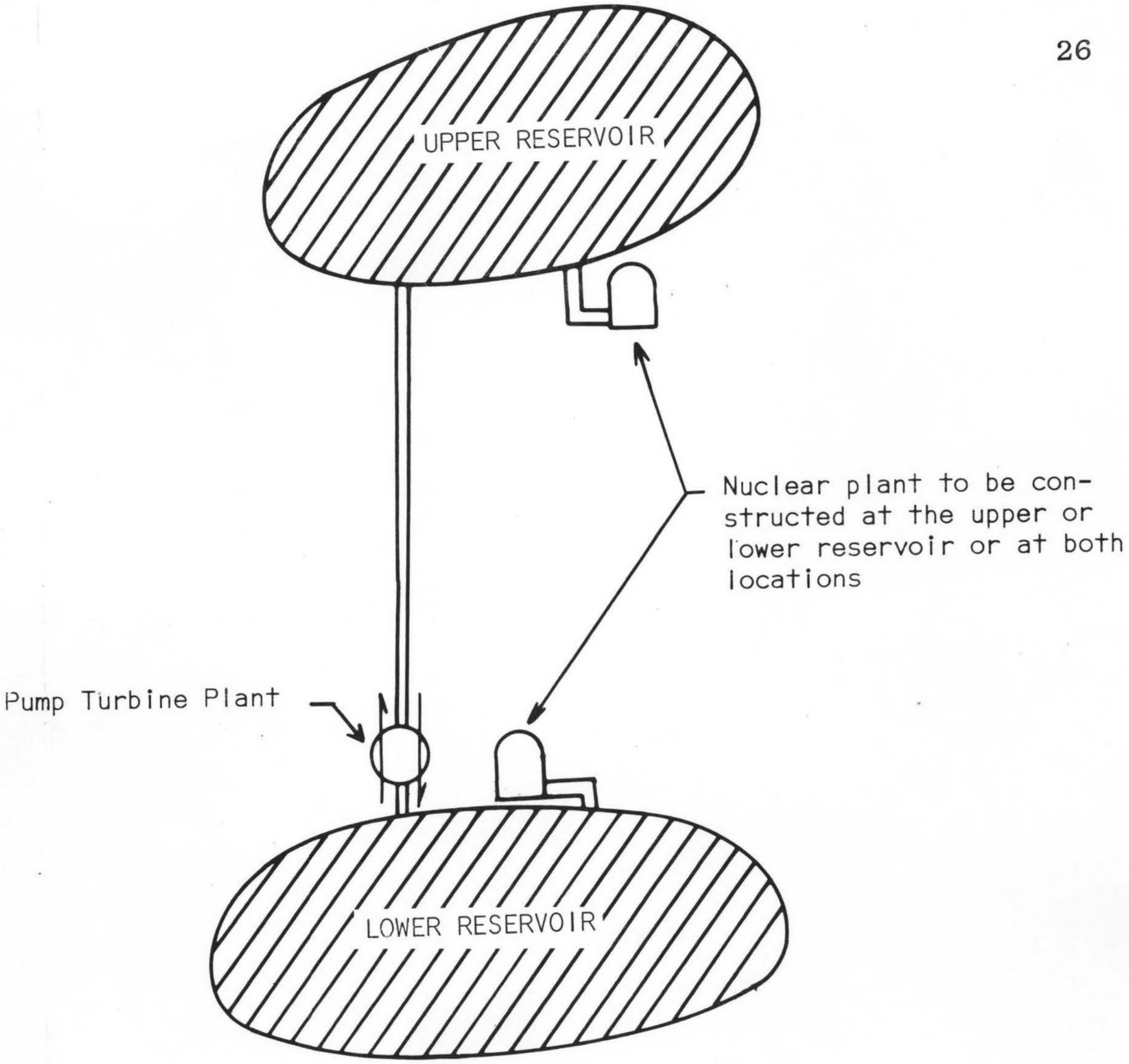

Figure 13

Nuclear Power Plant Combined with Pump Storage Reservoirs
Both Upper and Lower Reservoirs Would Be New Construction

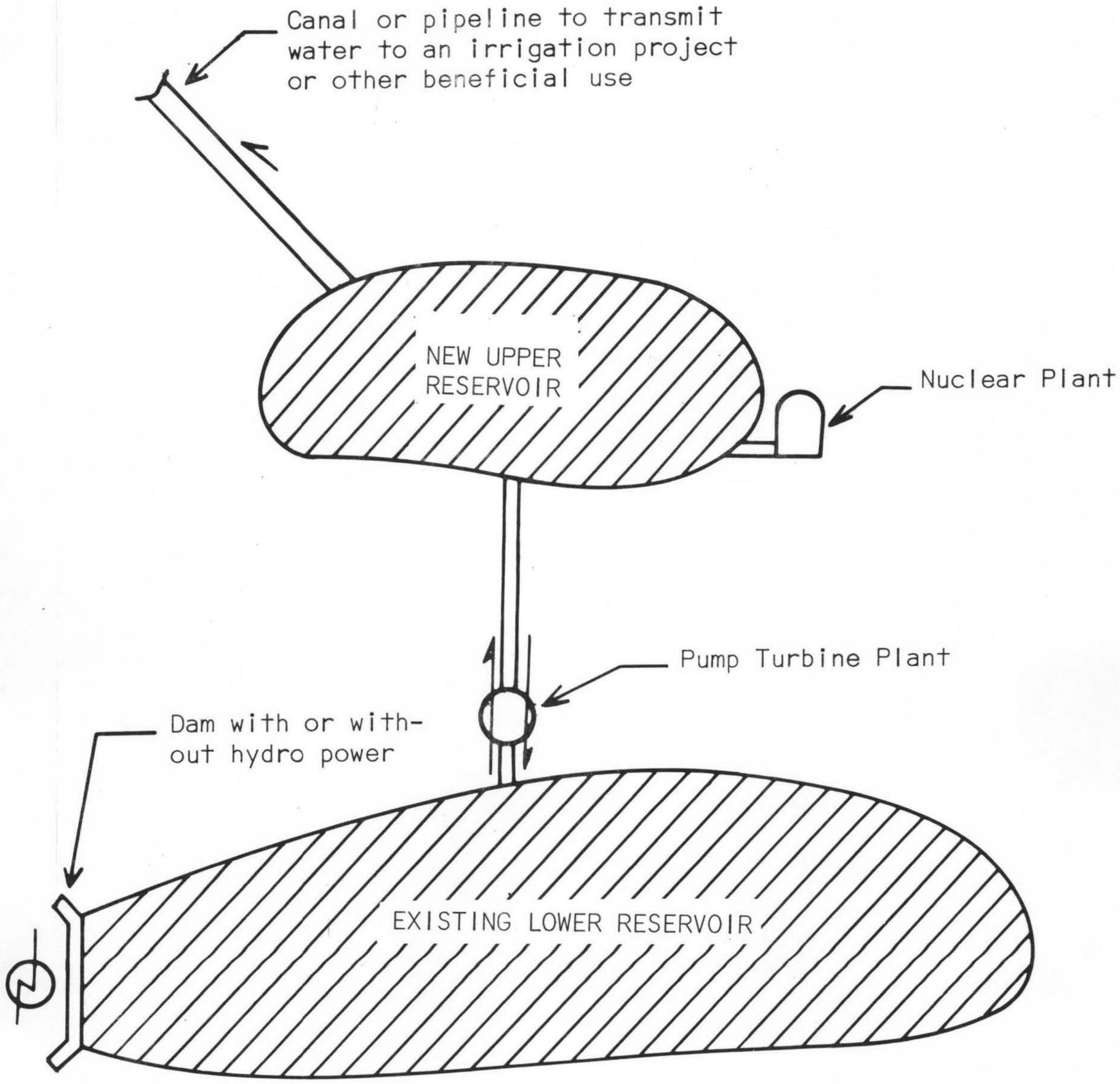

Figure 14

Nuclear Power Plant Combined with Pump Storage, Upper Reservoir is Used as a Cooling Reservoir and as a Supply to Other Uses a population of approximately 450,000 people (J.A. Nutant, 1970). Using this system would reduce the power output from the power plant, but the total energy utilization would be much greater. The use of waste heat from a power plant for space heating purposes would require an extensive system of piping and heat exchangers. This type of system could be adapted to an existing town, but the economics for using such a system would be much more favorable in a new town situation where the town and the heating and cooling systems could be designed into an integrated unit.

Industrial use of power plant waste heat is also an attractive alternative, but most industrial processes require temperatures much higher than the temperature of normal condenser cooling water. Consequently special steam extraction systems would be required in order to make industrial use of waste heat from nuclear power plants very favorable. There are a multitude of different uses that can be made of waste heat. Some of these uses and the temperature requirements are listed in Figure 15. Combining industrial, space heating, agricultural and other uses of waste has also been proposed. These combinations could be accomplished in a nuclear power park new town complex. Figure 16 shows a schematic of this sort of combination.

It is possible that the above mentioned unconventional use schemes would not be able to reject the total heat load of the power plant at all times. In this case

	Degrees F	Degrees C		
	356	180	evaporation of highly concentrated solutions refrigeration by ammonia absorption digestion in paper pulp, draft process	
	320	160	drying fish meat drying timber	conventional power production
			alumnia via Bayers process	
Saturated steam	284	140	drying farm products at high rates canning of food	
			evaporation in sugar refining extraction of salts by evaporation and crystallization	
	248	120	fresh water by distillation most multiple effect evaporation concentration of saline solutions	
			drying and curing of light aggregrate slabs	
	212	100	drying of organic materials, sea weeds, grass, vegetables, etc. washing and drying wool	
			drying of stock fish intensive de-icing	
Water	176	80	space heating greenhouse operation using space heating	
			refrigeration (lower temperature limit)	
	140	60	animal husbandry greenhouse by combined space heating and hot-bed heating	
			mushroom growing balneological baths	
	104	40	soil warming	
			swimming pools, biodegradation, fermentation warm water for year around mining in cold climates	
	68	20	de-icing hatching fish - fish farming	

Figure 15

Uses and temperature requirement for waste heat (Values taken from a paper titled, "Industrial and Other Applications of Geothermal Energy", by B. Lindal)

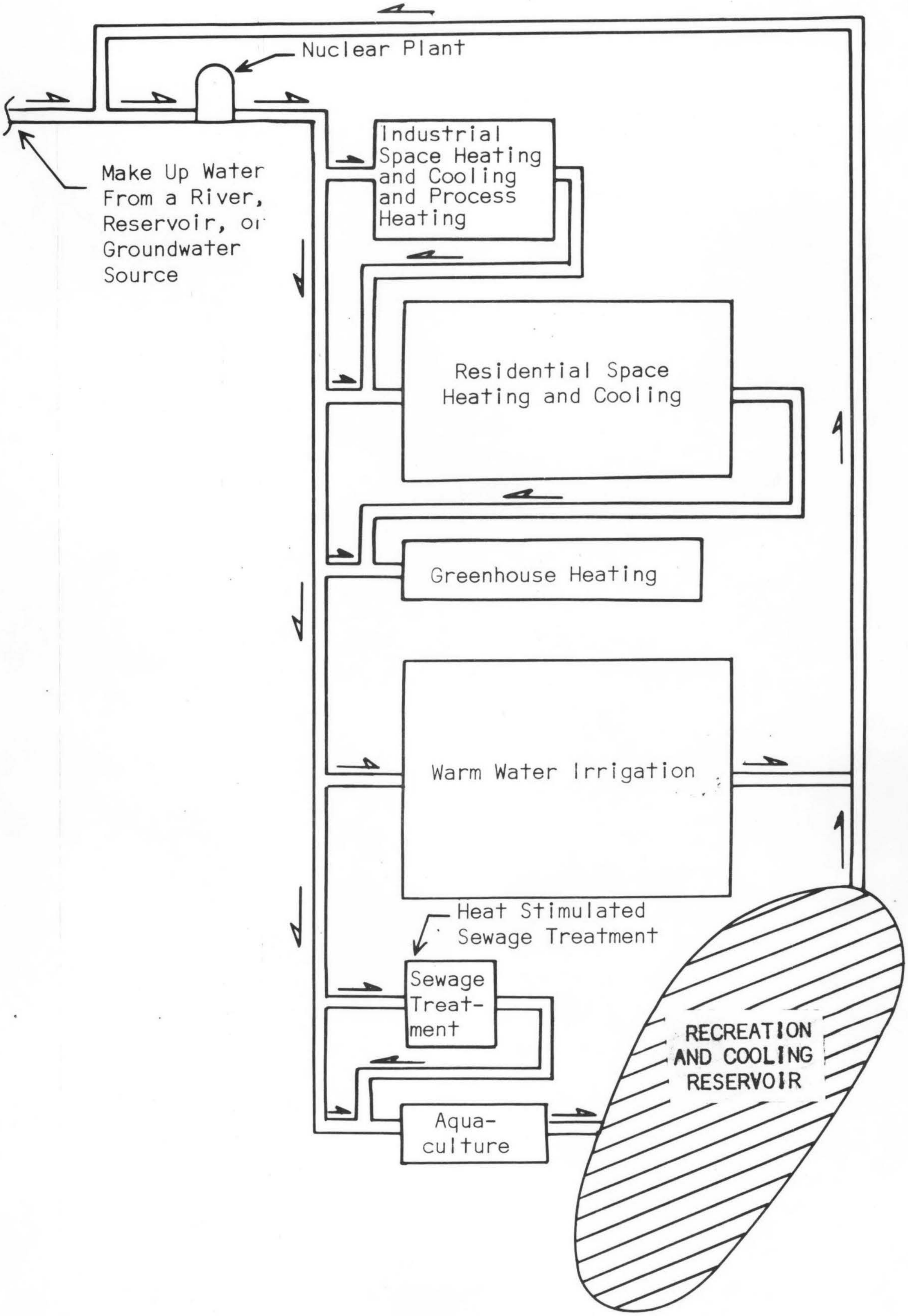

Figure 16

Multiple Use of Cooling Water In a Recycling Cooling System combinations of unconventional uses with conventional cooling methods such as cooling towers might be required. In all cases extensive economic and energy conservation analyses would have to be made to determine which combinations would present the most attractive alternative.

IDAHO'S WATER QUALITY LAWS AND THEIR AFFECT ON PLANT COOLING SYSTEMS

In order for a nuclear or geothermal power plant or a uranium enrichment facility to discharge any effluent into the streams of Idaho, the effluent must conform to the water quality standards of the State. The primary standard that will effect the above plant facilities are the thermal effluent standards. These standards are published by the Idaho Department of Health and Welfare in the publication dated June 1973 and entitled, "Water Quality Standards and Waste Treatment Requirements". The temperature standards are listed on page 11 and 12 of these Water Quality Standards. Following is a list of temperature variations to which waters of the State will be limited. These are copied directly from the standards.

1. Any measurable increase when water temperatures are 66° F or above, or more than 2° F increase other than from natural causes when water temperatures are 64° F or less (unless otherwise specified).

2. Any increase exceeding 0.5° F due to any single source, or 2° F due to all sources combined.

   For purposes of determining compliance, a "measurable increase" means no more than 0.5° rise in temperature of the receiving water as measured immediately outside of an established mixing zone. Where mixing zone boundaries have not been defined, cognizance will be given to the opportunity for admixture of wastewater with the receiving water.

3. Any measurable increase when water temperatures are 68° F or above, or more than 2° F increase other than from natural causes when

the water temperatures are 66° F or less in the following waters:

a. The main stem of the Snake River from the Oregon-Idaho border (R.M. 407) to the interstate line at Lewiston, Idaho (R.M. 139).

b. The Spokane River from Coeur d'Alene Lake outlet to the Idaho-Washington border.

c. The Palouse River from Princeton to the Idaho-Washington border.

d. The Pend Oreille River from the Pend Oreille Lake outled to the Idaho-Washington border.

The temperature standards would have the most effect on once-through type cooling. In fact, the limits prescribed would probably eliminate once-through cooling as a possible type of cooling method for thermal power plants. Since a thermal power plant would be considered as a point source, the temperature increase limit of 0.5 degrees would be imposed on all streams in the state with the exception of the four streams listed in section VIII, D, 3 of the Water Quality Standards. In order to maintain this 0.5 degree temperature rise, a 100 MWe plant would require continuous flows of approximately 6000 cfs, and a 1000 MWe plant would require continuous flows of approximately 60,000 cfs. There are very few places in the state where even the 6000 cfs requirement for the 100 MWe could be met at all let alone year around. The 60,000 cfs requirement for the 1000 MWe plant would be virtually impossible to meet. The two degree temperature increase limitation listed in section VIII, D, 3 of the Water Quality Standards could be met for a 100 MWe plant with a stream flow of approximately 1500 cfs. A 1000 MWe plant would require flows of about 15,000 cfs. Here again, the possibilities of plant sites for the 100 MWe plant with once-through cooling are not too numerous and the sites for the 1000 MWe plant would almost be nonexistent. It can be seen, from looking at these temperature standards, that the future for once-through cooling in the State of Idaho looks rather dim.

Another important question that must be reconciled is how the state's thermal effluent standards will effect a privately owned cooling pond, or an irrigation canal that is being used for cooling purposes. Under the very strictest interpretation, the Water Quality Standards include all the waters of the state. Waters is defined on page 4 of the Water Quality Standards as "all the accumulations of water, surface and underground, natural and artificial, public and private, or part thereof which are wholly or partially within, which flow through or border upon the state". By this definition, irrigation canals and cooling ponds would come under the jurisdiction of the State Water Quality Standards, but these standards probably would not be enforced on an artificial cooling pond or an irrigation canal used for cooling as long as either of the uses did not interfere with other uses made of the water and they did not cause the Water Quality Standards to be violated in a natural stream. This is a personal interpretation from conversations with Mr. Henry Moran, Environmental Engineer with the Idaho Department of Health and Welfare.

The Environmental Protection Agency is required by the Federal Water Pollution Control Act Amendments of 1972 to set forth the greatest degree of effluent reduction achievable for specific categories of sources. One of these categories is steam-electric power plants. In the October 8, 1974, Federal Register, the EPA published its effluent limitation guidelines for steam-electric power plants. Under these limits, the best available technology and standards of performance call for no discharge of heat except that discharge of blowdown from the cool side of a closed cycle cooling water system is allowed. Plants constructed after July 1, 1977, would be required to meet this no-discharge limitation. These guidelines have the effect of completely eliminating once-through cooling as a possible method of cooling steam-electric plants. The only recourse available to power plant planners is contained in section 316 of the Federal Water Pollution Control Act Amendments which states:

> Whenever the owner or operator of any such source, after opportunity for public hearing, can demonstrate to the satisfaction of the Administrator (or if appropriate the state) that any effluent limitation proposed for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of

> shellfish, fish and wildlife in and on the body of water into which the discharge is to be made, the Administrator, (or, if appropriate the state) may impose a different effluent limitation for the thermal component of the discharge than would ordinarily be required under section 301 and 306 of the Act. Effluent limitations imposed under section 316(a) must assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is to be made.

It is important to note that the burden of proof as to the absence of damage is on the owner or operator of the facility. This proof would probably require extensive environmental study of the stream system, but this is the only way that once-through cooling could ever be used as a cooling method under these rules.

IDAHO'S WATER RIGHTS LAWS AND APPROPRIATING WATER FOR POWER PLANT COOLING PURPOSES

The right to appropriate the water of the state to a beneficial use was established in Article XV, Section 3 of the Idaho State Constitution. It states, "The right to divert and appropriate the unappropriated waters of the state shall never be denied". The right of the first appropriator was established in Article XV, Section 5. It stated, "Priority in time shall give superiority of right to the use of such water in the numerical order of such settlements or improvements". With these inclusions in its Constitution, Idaho followed the basic water law pattern of many of the other arid western states. This basic doctrine became known as the Doctrine of Prior Appropriations or the Colorado Doctrine. In Idaho this doctrine has prevailed to the exclusion of the Riparian Doctrine (Hutchins, 1968).

There are two methods of appropriating water in the state. The first being the Constitutional method. In this method, the appropriator simply diverts the water from the stream and applies it to some beneficial use. The date of appropriation is the same date as the water was applied to the beneficial use. The second method is the statutory method. In this method the appropriator, before starting work on the diversion, files an application with the State Department of Water Resources. A permit for construction of the diversion works is issued and when the water is applied to beneficial use, the water use permit is issued with the date of appropriation being the date that the application for construction of the diversion works was filed.

There is no strict definition of beneficial use given in the State Constitution, although there is a list of priorities among some various kinds of beneficial uses. These are domestic use, agricultural use, manufacturing and mining and milling in conjunction with mining. The priorities are as listed except in an organized mining district where mining uses have priority over agricultural or manufacturing uses. This list does not cover all the beneficial uses that are possible. Cromwell in his book "Research in Idaho Water Law", defines a beneficial use as any use that promotes economic betterment within the community. Hutchins, Ellis and DeBraal in their book "Water Rights in the Nineteen Western States", define beneficial use as, "The use of such quantity of water when reasonable intelligence and reasonable diligence are exercised in its application for a lawful purpose, as is economically necessary for that purpose". These definitions are probably a good representation of the criteria used by the Department of Water Resources to judge the validity of a beneficial use.

Many states are broadening their definition of beneficial use in order to protect such in-stream uses as recreational use, scenic beauty and water quality (Dewsnup, Jensen, Swenson, 1973). By broadening the beneficial use definition to include the above non-diversion values, these values are afforded the same protection as any other legally appropriated beneficial use. Idaho has followed in this trend in that the Legislature has passed appropriate legislation authorizing the State Parks Department to file on water in certain streams for public use by the people of Idaho. A recent Idaho Supreme Court decision (Supreme Court Decision, 31 December 1974, Idaho Department of Parks and Recreation vs. Idaho Department of Water Administration) has upheld the right of the state to appropriate water for public use. This decision also held that no physical diversion is required for the use to be a legal one under the state's laws and constitution.

If this newly established legislative authority were used in other streams of the state, especially in establishing minimum streamflow standards, there could be reductions in the amounts of water available for power plant cooling.

LEGAL MEANS OF OBTAINING WATER FOR POWER PLANT OR ENRICHMENT FACILITY USE

There has been no appropriation made in Idaho for water to be used as cooling water for a thermal power plant. Idaho Power Company has applied for a water right for 30 cfs of water from the Snake River to be used for cooling purposes in their proposed Pioneer Plant at Orchard, but a water right has not been granted (Fleenor, 1975). Since the basic requirement for appropriation is that the water be applied to beneficial use, and power production is definitely of benefit to the people of the state, it would be hard to imagine a case where, if the water were available, a license to appropriate water for power plant use would be denied. Mr. Bobby Fleenor, of the Water Rights Bureau of the Idaho Department of Water Resources, agreed on this point and added that this water use would be classified as an industrial use and an appropriation be made as long as the use for power does not interfere with other existing uses.

The purchase of existing irrigation rights is another possible method of obtaining rights to water to be used for cooling purposes. This could be accomplished in Idaho and the use classification could be changed from agricultural to industrial as long as no harm was done to any existing water rights (Hutchins, 1968). It is important to emphasize the word existing because this means all appropriators are protected even though their date of appropriation may be junior to the right that is being changed. The date of appropriation for the new use will be the same as the date of appropriation of the original use (Hutchins, 1968).

Another possible method of cooling power plants would be to use existing irrigation canals. This would involve an agreement between the irrigation company and the power producer in which all or part of the flow in a canal would be diverted from the canal and returned immediately after running through the condensers. This possibility presents a problem in that the return water from the power plant would be warmer than the existing canal water and this increased water temperature would increase evaporation rates in the canal. The increased evaporation rates would cause higher losses than would be encountered under normal operation. Since the original appropriation for the water in the canal would be for irrigation and not for losses due to an artificial cooling load, the irrigation company would be using the water for a use other than what it was originally appropriated and would be in danger of losing right to this water. For this reason, the irrigation company would probably require the power producer to purchase the right to the water that would be lost due to excess evaporation. This type of transfer of right was discussed in the preceeding paragraph.

If existing reservoirs were used as large cooling ponds, many of the same problems would arise that were discussed in the preceeding paragraph. If the water were appropriated to another use, it would have to be changed to industrial cooling use. Even if the water was appropriated only for power production, some compensation would have to be made for the hydro-power losses due to the increased lake evaporation caused by the thermal cooling load.

GEOTHERMAL RESOURCES ACT

Geothermal power production may be a possibility in Idaho. This type of power production probably would require cooling systems similar to other thermal power production plants. These cooling systems have been covered in previous sections of this paper, but the geothermal fluid itself requires some special consideration. Sections 42-4001 through 42-4015 of the Idaho Code is the Idaho Geothermal Resources Act. This act contains the laws applicable to the exploration and development of Idaho's geothermal resources. In Section 42-4002, C, of this act the definition of a geothermal resource is given as:

> The natural heat energy of the earth, the energy in whatever form, which may be found in any position and at any depth below the surface of the earth present in, resulting from, or created by, or which may be extracted from such natural heat, and all minerals in solution or other products obtained from the material medium of any geothermal resource. Geothermal resources are found and hereby declared to be closely related to and possibly affecting and affected by water and mineral resources in many instances.

Any person who proposes to construct a geothermal well in the state must first file an application with the State Department of Water Resources. This application must contain information pertaining to who is making the application, the location of the well, a detailed description of the proposed well, character and description of the material expected to be derived from the well, how the geothermal fluid will be managed, whether the well is for production or exploration purposes, and any other information that the Director of the Department of Water Resources feels is necessary. After receiving the application, the Department of Water Resources will study the proposal to see if the proposed project will be in the public interest. Some items that might be considered in this study for the geothermal permit would include financial resources of the applicant and his ability to bear the costs of construction and maintenance of the wells, adequacy of measures to safeguard subsurface, surface and atmospheric resources from degradation due to the proposed project, the possibility that construction of the proposed project will cause waste or damage to another geothermal resource and the possibility of interdependence between the proposed source and waters from aquifers that are already being applied to beneficial use. If after making the study, the Department of Water Resources feels that the proposed project is in the public interest, according to the guidelines set out by the act, a geothermal well permit will be issued.

It appears that Idaho is on its way to a well planned development of the geothermal resources of the state. If the Department of Water Resources follows the guidelines presented in the Geothermal Act, and this agency works closely with the geothermal developers and researchers, the geothermal resources of the state should become a valuable asset to the citizens of Idaho. The questions that must be answered now are where are the best geothermal fields for power production located, and what are the economics of developing these areas into power producing geothermal fields. These questions can be answered only by the exploration and research studies that are currently under way.

DETERMINATION OF WHERE WATER IS AVAILABLE FOR CONVENTIONALLY COOLED NUCLEAR POWER PLANTS

This section will describe the methodology, sources of data, and final results of the investigations that were made to determine what quantities of water are available in the State of Idaho for use in conventionally cooled nuclear power plants. The first cooling system that will be covered will be once-through cooling.

The present thermal effluent standards of the state and the present effluent limitation guidelines for steam-electric power plants published by the Environmental Protection Agency would restrict the temperature rise to at least 2 degrees or less. In some cases these regulations might be too restrictive and possibly in the future there might be a relaxation of these standards. In order to present a more complete picture of the cooling water supply for once-through cooling, the total stream flow required so that a 2, 5, 10 and 15 degree temperature rise would occur, assuming complete mixing of the condenser cooling effluent with the remaining stream flow, will be investigated.

Since the quantity of water available for any type of cooling purpose is dependent on the degree of development of other uses that would consume water, a reference time frame must be established so that the water availability can be placed in some time perspective. All cooling water supply investigations in this study were based on stream flows at the 1970 level of development. Future development of agricultural, industrial and other uses of water would have the effect of reducing the amount of water available for cooling purposes, but predicting the development that will occur in the future is beyond the scope of this study.

For a 1000 MWe nuclear plant, assuming 33% heat energy conversion efficiency, the total flow requirements for 2, 5, 10 and 15 degree temperature rise would be 15,000, 6000, 3000 and 2000 cfs respectively. These requirements would be on the high conservative side if the higher efficiency gas cooled or fast breeder reactors were being considered.

In order to determine the once-through cooling capacity of a given stream, it is necessary to choose some specific frequency low flow of that stream and assume that this flow is the governing flow as far as the thermal cooling capacity of the stream. For this study the annual 7-day average low flow with a recurrence interval of 10 years was used. This flow will be referred to as the 7-day 10-yr. low flow condition. This flow condition has been used by many state agencies as a basis for their stream water quality standards (Singh, Stall, 1974). Although Idaho does not presently use the 7-day 10-yr. flow in their thermal effluent standards, it is considered that this criteria would be a reasonable one to use as a basis for this study.

In order to determine the 7-day 10-yr. average flow, a statistical analysis was made on the flow records at key study locations on various streams of the state. Five basic criteria were used to determine approximately where these key study locations should be located. These criteria were Indian reservations, national parks, existence of wild rivers, population and availability of flow records. All Indian reservations, national parks and reaches of wild rivers were eliminated as possible reaches of study. A 25 mile radius was drawn around all cities expected to have a population greater than 25,000 by the year 2000. In most cases the areas within the circles were excluded from consideration. This population criterion is similar to that used by Dames and Moore in their study titled, "Pacific Northwest Regional Nuclear Power Plant Siting Study". The remaining areas were evaluated as far as the availability of flow records and the key study locations were then selected. These same key locations were used for the water availability studies for all of the cooling methods.

The stream flow data used for analysis on the unregulated streams investigated in the study were taken from the U.S. Geological Survey water supply records. These records were analyzed and the 7-day average low flow for each year of record for the stream of interest was recorded. A statistical analysis on these 7-day average flows was made and a frequency curve was computed using standard methods described in "Statistical Methods in Hydrology," by Leo Beard. The 10-yr. recurrence low flow was taken from this frequency curve. The 7-day 10-yr. average flows for the various streams that were studied and the power plant cooling capacity of the streams for the four different temperature increases that were studied are shown in Table 1.

The method of determining the 7-day 10-yr. average low flow for streams where the flow has been modified due to diversion or regulation was approached in a slightly different manner. No records of daily flows modified to the 1970 level of development were available so it was necessary to use monthly average modified flows. These monthly average modified flows were taken from studies made by the Idaho Department of Water Resources and studies made by the Columbia River Water Management Group. The study by the Water Management Group is titled, "Provisional Report on Modified Flows at Selected Sites 1928 to 1968 for the 1970 Level of Development Columbia River and Coastal Basins". These modified flows are analyzed and the low monthly average flow was recorded for each year of record. A statistical analysis was made of these annual low monthly average flows and a frequency curve was made using the same method described above for the unmodified stream flows. The 10-yr. recurrence low monthly average flow was taken from the frequency curve.

TABLE 1

AVAILABILITY OF COOLING WATER FOR ONCE-THROUGH COOLING

STREAM	LOCATION	10-YR. RECURRENCE MONTHLY AVERAGE FLOW cfs	7-DAY 10-YR. AVERAGE LOW FLOW cfs	SIZE OF POWER PLANT IN MWe WITH TEMP. RISE IN STREAM OF			
				2°F	5°F	10°F	15°F
Snake	King Hill	6550	5880	392	980	1960	2940
Snake	Weiser	8100	7300	487	1217	2433	3650
Salmon	Salmon	NA	600	40	100	200	300
Salmon	White Bird	NA	2400	160	400	800	1200
Clearwater	Orofino	NA	680	45	113	227	340
Coeur d'Alene	Cataldo	NA	230	15	38	77	115
Pend Orielle	Albeni Falls	4350	1000	67	166	333	500
Kootenai	Bonners Ferry	NA	2159	144	360	720	1079

The next step was to find the relationship between the annual low monthly average flow and the annual low 7-day average flow. This was done by correlating the annual low 7-day average flow found in the U.S. Geological Survey Water supply records with the annual low monthly average flows of the modified flow studies. This correlation was made for the last 10 years of record available. It was considered that 10 years of historical data would be sufficient to make an approximate correlation between the annual 7-day average low flow and the annual low monthly average modified flow. It was also considered that the development in the last 10 years would not have changed enough in that period to materially affect the correlation so that it could be assumed to be valid for the 1970 level of development. Using the 10-yr. recurrence annual low monthly average flow found in the frequency study and the correlation between this flow and the annual 7-day average low flow, the 7-day 10-yr. low flow could be found. All the low flow information for the key study locations on the Snake River and Pend-Oreville River were found in this manner. The actual flows and the power plant cooling capacities for the four different temperature increase values are shown in Table 1.

The method of getting the 7-day 10-yr. average low flow for the Kootenai River at Bonners Ferry was approached in a slightly different manner since it is a modified stream but there were no modified flow records available for the reach near Bonners Ferry. The 7-day 10-yr. flow at Bonners Ferry was determined by adding the expected minimum flow from Libby Re-regulation Dam with the 7-day 10-yr. flows from the Moyie and Yakk Rivers. The estimated minimum flow from the proposed Libby Re-regulation Dam was found through telephone conversations with Mr. Larry Merkel of the Seattle District, U.S. Army Corps of Engineers. This flow was found to be 2000 cfs. The 7-day 10-yr. average flows for the Yakk and Moyie Rivers were determined in the same way as that used for the unregulated streams which is described above. This approach gives flows that are probably on the low conservative side because the local contributions from the drainage area between the proposed Libby Re-regulation Dam and the Yakk River and between the Yakk and Moyie River are not considered. Results of this study are shown in Table 1. Figures 17 and 18 show the approximate location of the key study reach locations and also the once-through cooling capacity of each reach of the stream.

The most probable legal problems that will be encountered in once-through cooling will be the problems of thermal effluent standards. As the laws are now written it would be very unlikely that a nuclear power plant with generating capacity of more than 500 MWe employing once-through cooling could ever be brough on line if natural streamflows are used for cooling. The only real chance

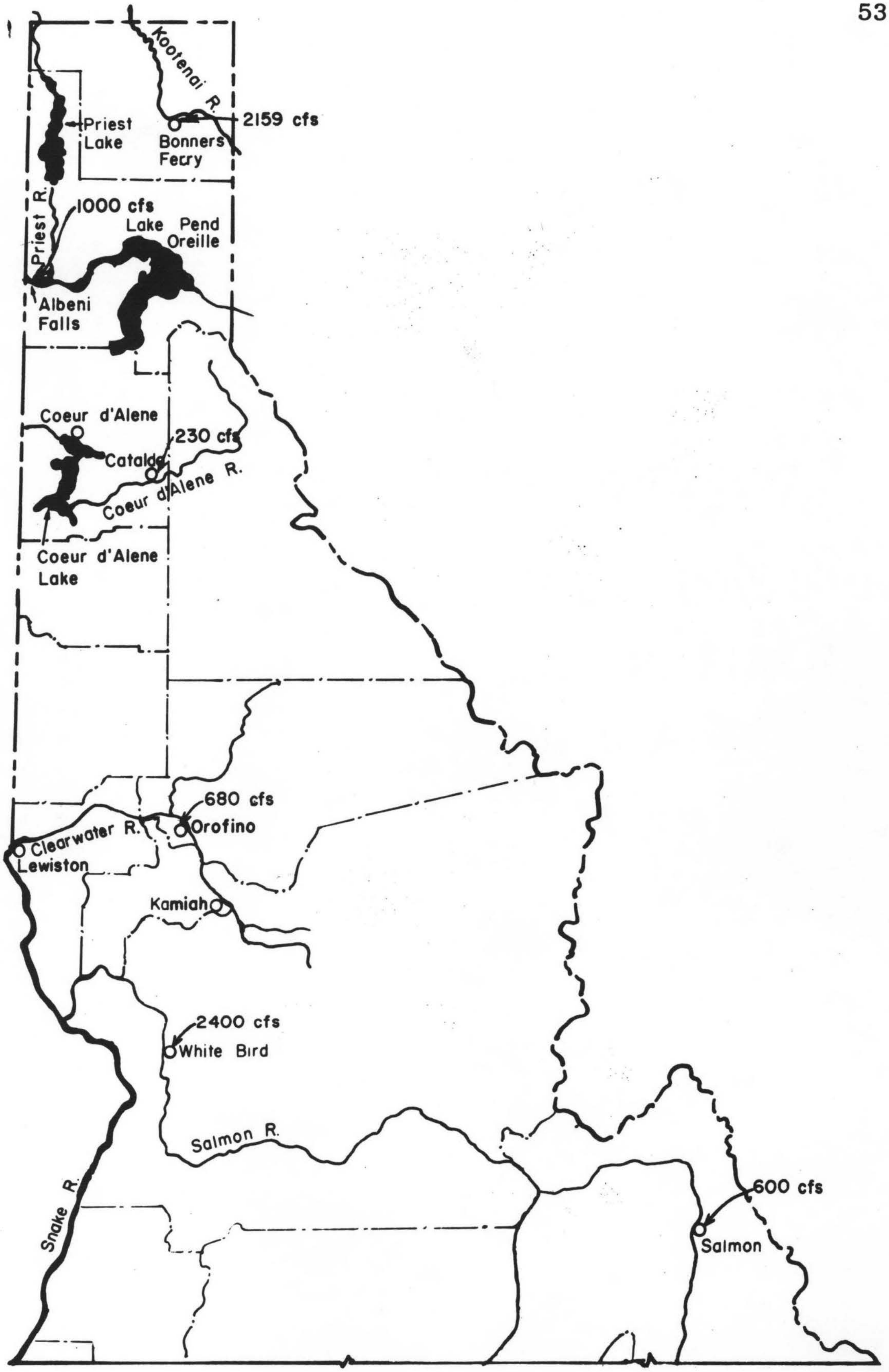

Figure 17

Location of Key Study Locations and Availability of Once-Through Cooling Water

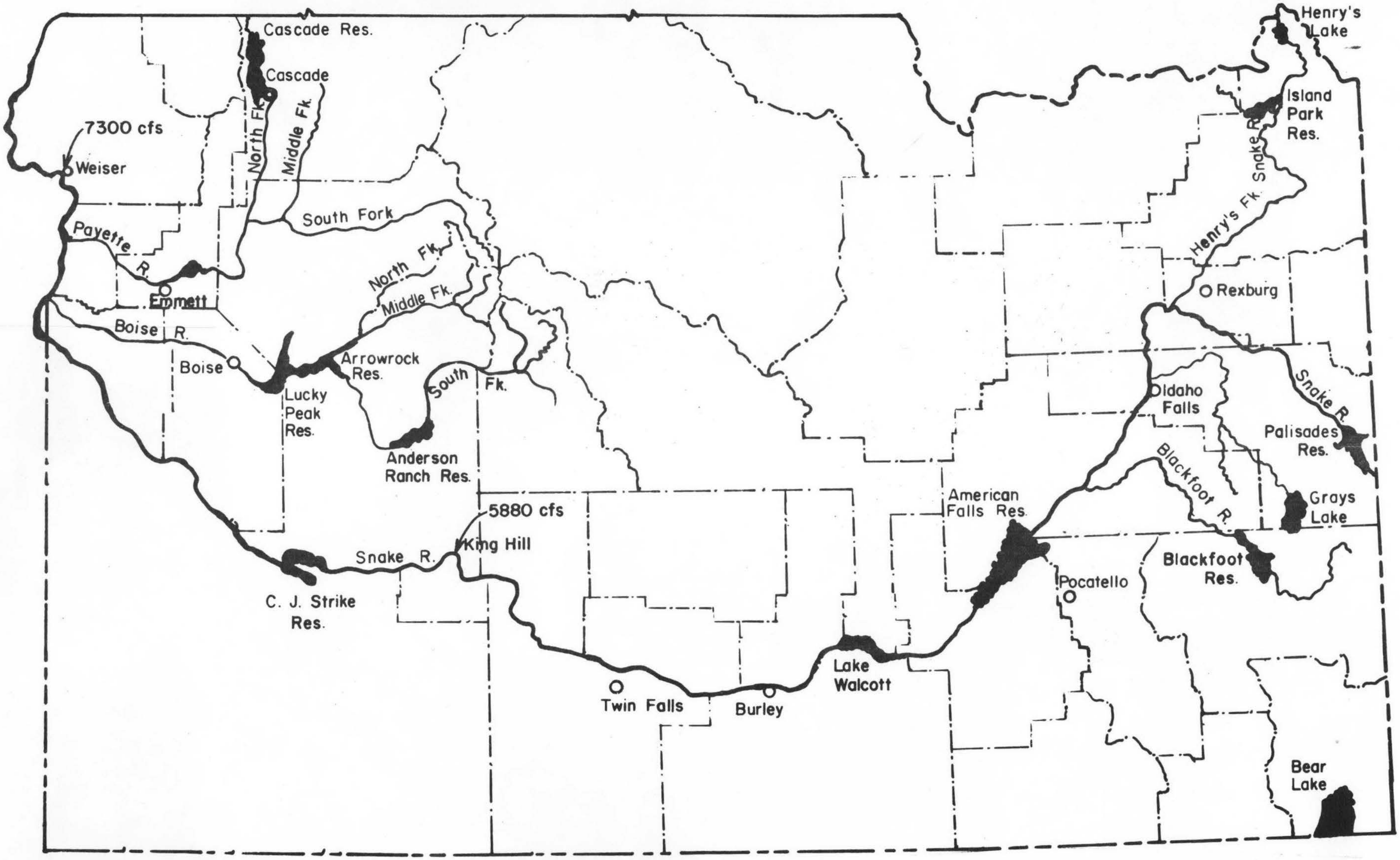

Figure 18

Location of Key Study Locations and Availability of Once-Through Cooling Water for once-through cooling in the state would come with relaxation of the state's thermal effluent standards and the E.P.A. guidelines on steam-power plant operation.

The next conventional cooling system that will be covered in this investigation will be the closed cycle cooling systems. These systems include evaporative cooling towers, spray cooling ponds and ordinary cooling ponds. The quantity of water available from a natural stream for consumptive use in a closed cycle cooling system was assumed to be 1/10 of the 7-day 10-yr. average low flow. This criteria is the same as that used in other siting studies (Dames and Moore, 1973). In talking with Mr. West of Dames and Moore he stated that the use of the 1/10 of the 7-day 10-yr. average low flow as a rule of thumb for use in power plant siting has evolved through their many years of experience in making power plant siting studies. Because of the limited resources and time of the study it is felt that using this rule of thumb criteria, that has been used by others, is valid for a general water availability study. When more detailed analysis is made of specific sites, it will be possible to further refine this criteria with biological and other studies.

Values of quantities of water available for closed cycle cooling for the key study locations in streams of the state are shown in Table 2. These values were obtained simply by taking 1/10 of the values found in the once-through

TABLE 2

AVAILABILITY OF COOLING WATER FOR EVAPORATIVE COOLING SYSTEMS

STREAM	LOCATION	7-DAY 10-YR. AVERAGE LOW FLOW cfs	1/10 7-DAY 10-YR. AVERAGE LOW FLOW cfs	SIZE OF POWER PLANT IN MWe ASSUMING EVAPORATIVE TOWERS*	COOLING PONDS**
Snake	King Hill	5880	588	20,000	33,000
Snake	Weiser	7300	730	24,000	40,500
Salmon	Salmon	600	60	2,000	3,000
Salmon	White Bird	2400	240	8,000	13,000
Clearwater	Orofino	680	68	2,000	4,000
Coeur d'Alene	Cataldo	230	23	800	1,000
Pend Orielle	Albeni Falls	1000	100	3,300	5,500
Kootenai	Bonners Ferry	2159	216	7,000	12,000

* Power plant size taken from Figure

**Power plant size taken from Figure

cooling studies. The values of power plant capacity that each stream could support was obtained by dividing the amount of water available for consumptive use by the quantity of water required for the different closed cycle systems per MWe of power plant output. The consumptive requirements for the different types of closed systems are shown in Figure 9 and Figure 10. Figures 19 and 20 show the location and approximate closed cycle cooling capacity of the various key study reaches that were investigated.

A special case of the cooling pond would be the use of a natural lake or an already existing reservoir as a cooling source. This is not too likely in view of Idaho's thermal effluent standards and the E.P.A. guidelines on steam power plant generation, but if these critierion were relaxed there are several large reservoirs where this type of cooling could be employed. Pend Oreille Lake, Coeur d'Alene Lake, Cascade Reservoir and Dworshak Reservoir are all likely candidates for this type of cooling system. There is water available in all of these reservoirs to offset the losses due to increased evaporation caused by the power plant heat load. These increased consumptive losses would reduce the hydroelectric power output of the downstream dams. Coeur d'Alene Lake would also present some special problems because of the issue of Indian claims to rights to the waters of the Lake.

Figure 19

Location of Key Study Locations and Availability of Water for Closed Cycle Cooling Systems

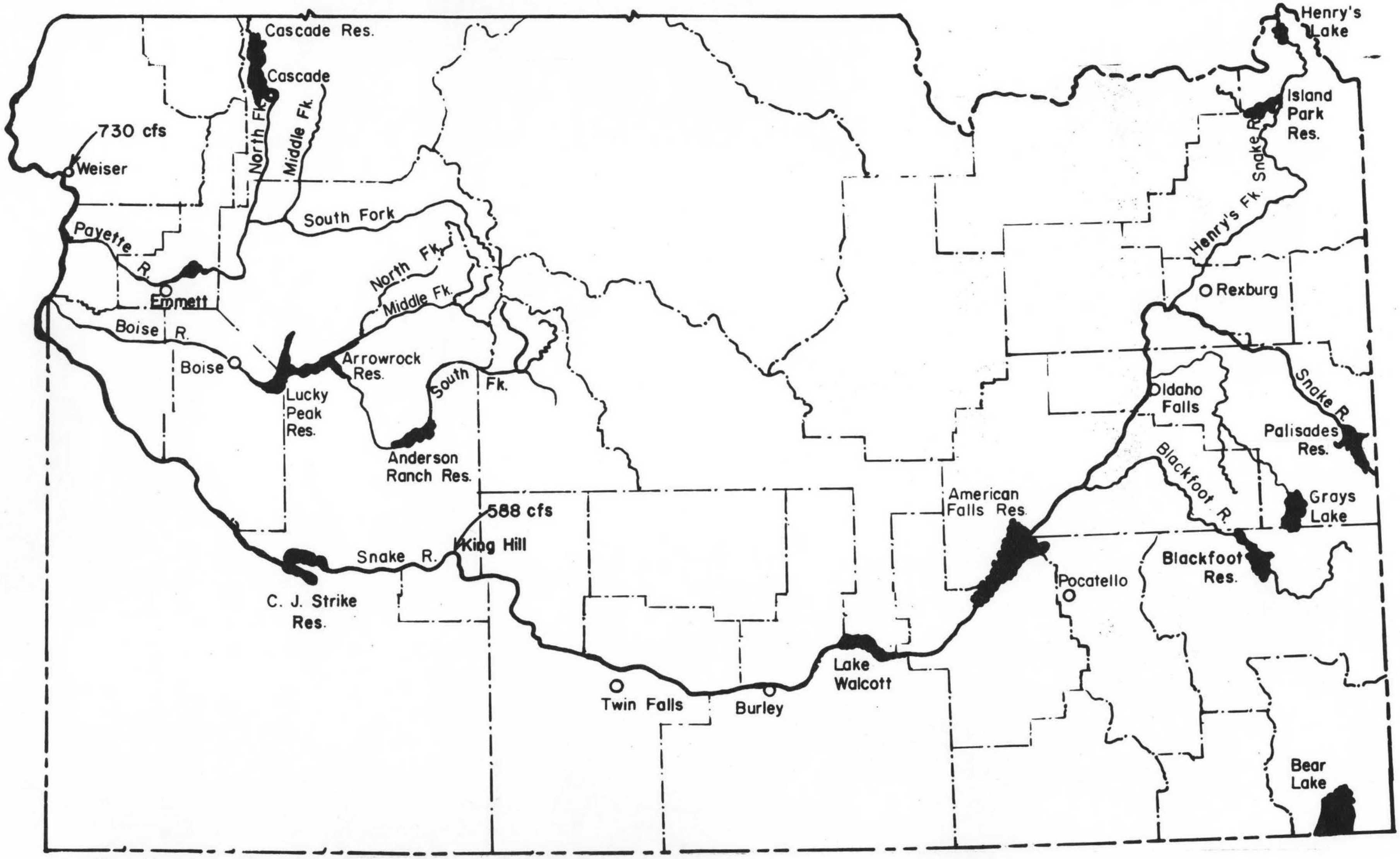

Figure 20

Location of Key Study Locations and Availability of Water for Closed Cycle Cooling Systems

Another possible source of water for evaporative cooling systems is water that would be saved if existing irrigation practices were made more efficient. Studies done by the U.S. Soil Conservation Service show that annual savings of 116,600 acre feet of water could be made in the area irrigated from the Henrys Fork River upstream of its confluence with the Snake River (McArthur, 1974). If this water were managed appropriately by upstream storage it would mean that a continuous supply of 159 cfs would be available for some other use. This would be enough water to supply a 5300 MWe plant which was cooled by evaporative cooling towers. McArthur's study further shows that 1,282,800 acre feet of water is available through increased efficiencies in application and conveyance in irrigation of those lands irrigated from diversions from the reach of the Snake River from American Falls Reservoir to Milner Reservoir. Again if proper upstream management facilities were available and properly operated this volume of water would amount to approximately 1757 cfs. This is enough water to supply evaporative cooling water for plants totalling 59,000 MWe in capacity and once-through cooling water for a 1200 MWe plant.

One problem with consumptively using this saved water is that water used in this manner would not have the chance of entering the Snake River aquifer or returning to the Snake River as it normally would if it were being used in the present irrigation system. This reduced recharge could ultimately have the effect of reducing the flows of Thousand Springs and possibly reducing groundwater levels in the Snake River aquifer. Even if irrigation water savings could be accomplished there is still no guarantee that all or even part of the saved water could be used for cooling purposes. There will be a keen competition for this water. Land developers and industrial water users will be interested in any new water sources that are made available. Under the present water law system there is no incentive for irrigation districts to conserve water. It appears that if conservation measures are to be implemented, those desiring to use the saved water will have to bear the burden of the cost of the water saving measures. It will then become a question of economics as to which prospective user will be able to justify his purchase of saved water.

SUPPLIES OF COOLING WATER FOR URANIUM ENRICHMENT FACILITIES

In evaluating the availability of water for an enrichment facility it was assumed that any water available for evaporative tower cooling of power plants would also be available for cooling of a uranium enrichment facility. All the sites listed in Table 2 except the Coeur d'Alene River at Cataldo site have adequate cooling water for a 8750 metric ton SWU plant. If a gaseous diffusion plant were constructed in the state it would probably be necessary to construct a power plant to supply all or part of the huge power requirements of the enrichment plant. The possibility of an enrichment plant and power plant built at the same site is an alternative that might be considered. If both plants were cooled using evaporative cooling the total consumptive use requirements would be approximately 120 cfs. This assumes a 8750 metric ton SWU gaseous diffusion plant and a 2500 MWe nuclear power plant. Cooling for such a combined plant would be available at the King Hill and Weiser key study reaches on the Snake River, Salmon River at White Bird, the Pend Orielle River at Albeni Falls and the Kootenai at Bonners Ferry. Data on water availability for cooling at these points are shown on Table 2.

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SUPPLIES OF COOLING WATER FOR GEOTHERMAL POWER PRODUCTION

Any water supply that was found to be available for cooling of nuclear plants would also be available for use in geothermal power production. The quantities of water required for geothermal power production will be 2 to 3 times greater than that required for a nuclear power plant with the same power output, but the geothermal power plant output at each site would generally be less than that at a single nuclear power station. Determination of actual cooling capacity of the available water supply will depend on complete exploration of each geothermal field. One problem that must be faced in geothermal power production is the fact that many of the promising geothermal areas are at fairly great distances from adequate supplies of cooling water. This consideration may adversely affect the economics of geothermal power production. Environmental problems such as air pollution, groundwater contamination and land subsidence must also be solved before geothermal power production can become a practical energy source in Idaho.

WATER AVAILABILITY FOR UNCONVENTIONAL COOLING SYSTEMS

The first unconventional use scheme that will be discussed is the use of existing or planned irrigation canals as cooling canals. This system would involve diversion of all or part of the canal flow through the condensers of the power plant. After the flow has passed through the condensers it would be returned directly to the canal. The canal discharge requirement that was used in the study was a minimum of 1.5 cfs per MWe output of the power plant. At this flow rate the temperature rise of the water going through the condenser would be 20°F. It was felt that the 1.5 cfs per MWe of power plant output would be adequate for a preliminary water supply study for this type of cooling system.

The first group of canals that were considered were the North Side Twin Falls Canal, Milner Gooding Canal and South Side Twin Falls Canal. The historical deliveries of each of the three canals were evaluated separately as to availability of water to accomodate a power plant employing once-through cooling using the criteria discussed above. Next the combination of the North Side Twin Falls and Milner Gooding Canals and the combination of all three canal systems were evaluated.

Data compiled by the S.C.S. was used in determining the quantities of water available in the various canal systems (McArthur, 1974). This study contained data on present use of water in the systems and projected use if increases in application efficiencies were made and more efficient conveyance systems were used. Operation studies were performed on each of the canals and the canal combinations discussed above. Each canal system was evaluated as to its capability to support various size power plants. If water presently used in the system was in excess to that which McArthur had determined was necessary and in excess to that required for the particular size power plant under study, it was assumed that this water could be switched to another time period. This other time period would be when the presently used amount was less than that required for power plant cooling. In each case it was determined whether there would be an excess or deficit of total water needed for cooling for each particular sized power plant. A sample of these computations is shown in Table 3. Units of flow volumes involved were all measured in thousands of acre feet. A 1000 MWe nuclear power plant operating with a 20°F temperature rise through the condenser would be expected to use 89 thousand acre feet per month. Water requirements for other size plants were assumed to be directly proportional to the plant power output.

Another source of cooling water for the three canal systems is the flow of water that passes Milner Dam in the winter season. The minimum flows of record passing Milner

TABLE 3

COMPUTATION OF WATER AVAILABILITY FOR CANAL COOLING USING COMBINED FLOWS OF MILNER, GOODING AND NORTH SIDE TWIN FALLS CANALS

(Units are in thousands of acre feet)

MONTH	PRESENT*	FUTURE*	POWER PLANT REQUIREMENT	DEFICIT	AVAILABLE TO BE SWITCHED
OCT.	89.4	77.9	89	00	.4
NOV.	27.2	00	89	61.8	00
DEC.	00	00	89	89	00
JAN.	00	00	89	89	00
FEB.	00	00	89	89	00
MAR.	00	00	89	89	00
APR.	100.4	86.5	89	00	11.4
MAY	277.4	237.3	89	00	40.1
JUNE	285.7	244.6	89	00	41.1
JULY	336.6	287.8	89	00	48.8
AUG.	314.8	269.1	89	00	45.7
SEP.	236.9	202.9	89	00	34.0
			TOTAL	417.8	221.5

TOTAL REQUIRED FROM OTHER SOURCES

417.8 - 221.5 = 196.3 thousand acre feet

*Data from study by R. McArthur, 1974.

Dam adjusted to the 1970 level of development were taken from studies by the Idaho Department of Water Resources. These flows were summed and it was found that they amounted to a total of 131.7 thousand acre feet for the period from October to March. It was assumed that these flows could be used to supplement the flows in the canals in the winter period when the total flows were not enough to support a given size power plant. The final results of the once-through cooling studies are shown on Table 4.

Even when the Milner flows were used to supplement the canal flows there was a deficit of water in some of the studies. This water could be supplied from savings in water from various upstream irrigation projects. It is recognized that a portion of the water that could be saved is already reentering the Snake River before the diversion for the three canals under study. But because of the huge volume of water that could be saved it is felt that if there is enough upstream storage available and if this storage is managed properly enough water could be saved for use in power plant cooling using all or parts of these canal systems.

Another problem that will have to be overcome is the wintertime capacity of the canal systems. Since there will be little agricultural consumptive use of the flows in the winter months, the quantity of water delivered to the waste ways and downstream canals will be greatly

TABLE 4

WATER AVAILABILITY FOR CANAL COOLING ON TWIN FALLS SOUTH SIDE, MILNER GOODING AND NORTH SIDE TWIN FALLS CANALS

(Units are thousands of acre feet)

TWIN FALLS SOUTH SIDE CANAL

a.	1000 MWe Plant	293.5 deficit
	using flows passing Milner	161,9 deficit
b.	500 MWe Plant	48 deficit
	using flows passing Milner	83.7 excess

MILNER GOODING CANAL

a.	1000 MWe Plant	597.4 deficit
	using flows passing Milner	465.7 deficit
b.	500 MWe Plant	196.5 deficit
	using flows passing Milner	64.8 deficit

NORTH SIDE TWIN FALLS CANAL

a.	1000 MWe Plant	311.3 deficit
	using flows passing Milner	179.6 deficit
b.	500 MWe Plant	42.1 deficit
	using flows passing Milner	89.6 excess

COMBINED MILNER GOODING AND NORTH SIDE TWIN CANAL

a.	1000 MWe Plant	196.3 deficit
	using flows passing Milner	64.6 deficit
b.	500 MWe Plant	39.3 excess

COMBINED MILNER GOODING, NORTH SIDE TWIN FALLS AND SOUTH SIDE TWIN FALLS CANALS

a.	1500 MWe Plant	230.2 deficit
	using flows passing Milner	98.5 deficit
b.	1000 MWe Plant	7.7 deficit
	using flows passing Milner	124.0 excess

increased. The availability of adequately sized waste ways and downstream canals to handle the larger winter time flows will have to be investigated. If required capacities are not available then enlargement of the existing system and possible new construction may be required. Another possibility is to use a reservoir to store flows that can't be adequately handled by the existing waste way system. Water stored there could be put to other use on new or existing irrigation projects or wasted to the Snake River at a slower uniform rate for the entire year. In years past there was a certain amount of flow passing through the canal systems in the winter for stock watering purposes. This practice has ceased since the construction of the Palisades project because the winter flows that were passed down the canal system are now used in filling Palisades Reservoir (U.S. Bureau of Reclamation, 1968). In order to reestablish winter time flows in canals for power plant cooling purposes, operating procedures and agreements might have to be re-negotiated. In order to do this, operation studies of the whole system would have to be made to determine the feasibility of this type of operation and that is beyond the scope of this study. Figure 21 shows the location of the proposed power plant and cooling canals for this cooling scheme.

Another unconventional use scheme that was considered was the replacement of some of the canals in the irrigated

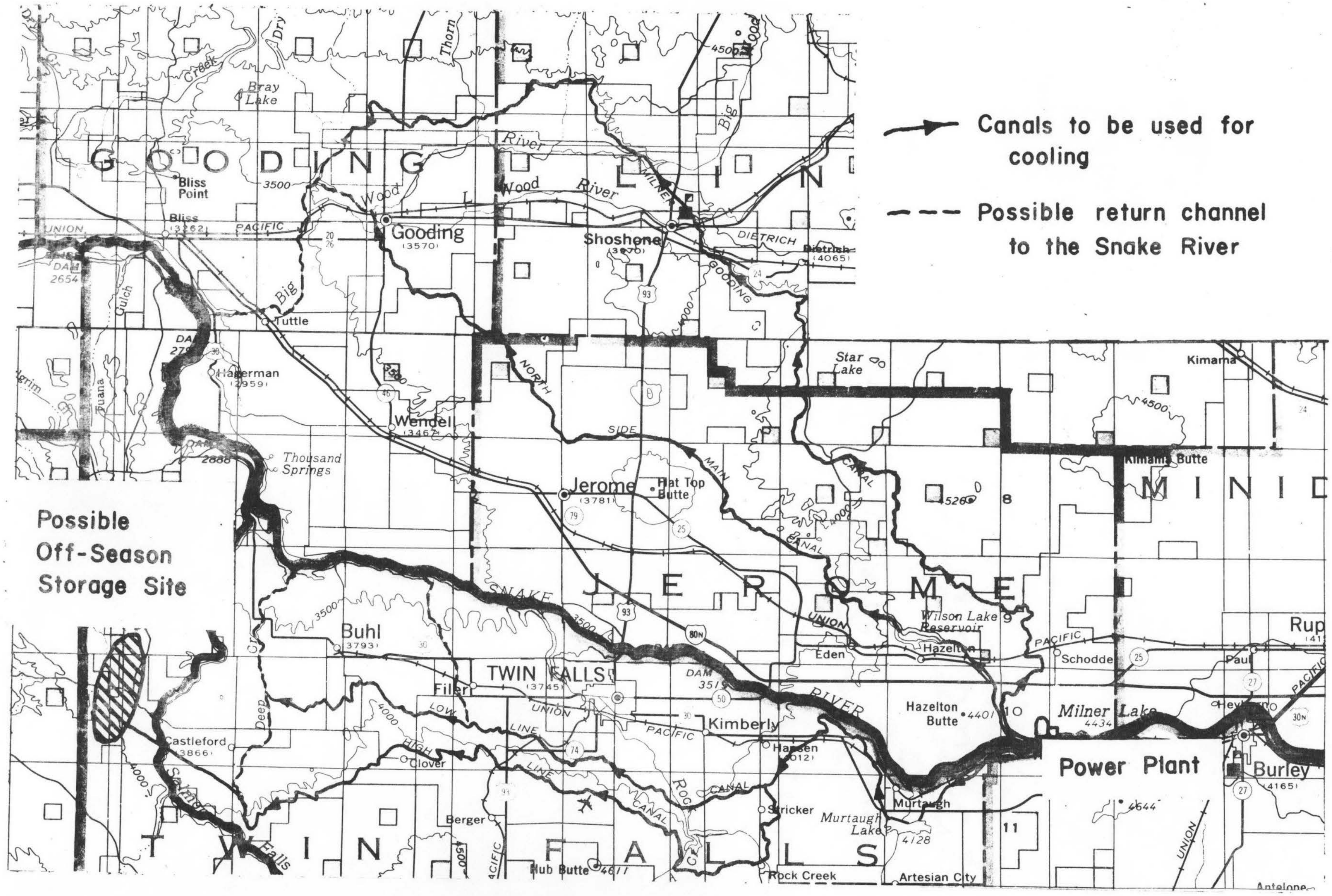

Figure 21

Canal Cooling Scheme in Twin Falls Area

area below Heise. In this plan one large diversion would be made from the Snake River above Heise. After the diversion the water would be passed through a power plant and then into closed conduits which would conduct the heated water to the irrigation projects. Figure 22 shows the approximate location of the proposed project. Because of the high elevation of the point of diversion and the fact that closed conduits are used, it would be possible to deliver the water under pressure. This pressurized water could then be used in sprinkler applications if desired. Another aspect of this project is the fact that the closed conduits would retain much of the heat that was added to the water at the power plant. There is the possibility of using this heated water in soil warming applications on farms serviced by the system. If the economics of using pressure conduits on this project proved unfavorable it would be possible to construct new canals in place of the pipelines.

Summer time flows in the canal system would be sufficient to support a 1000 MWe power plant using once-through cooling. Winter flows are lower in all of the canal systems so water would have to be made available through additional diversion of Snake River flows. There seems to be sufficient flows in the Snake River above Heise in the winter to supply the necessary cooling requirements. These winter flows would not be lost from the system, only rerouted through the new conduit or canal and later reintroduced to

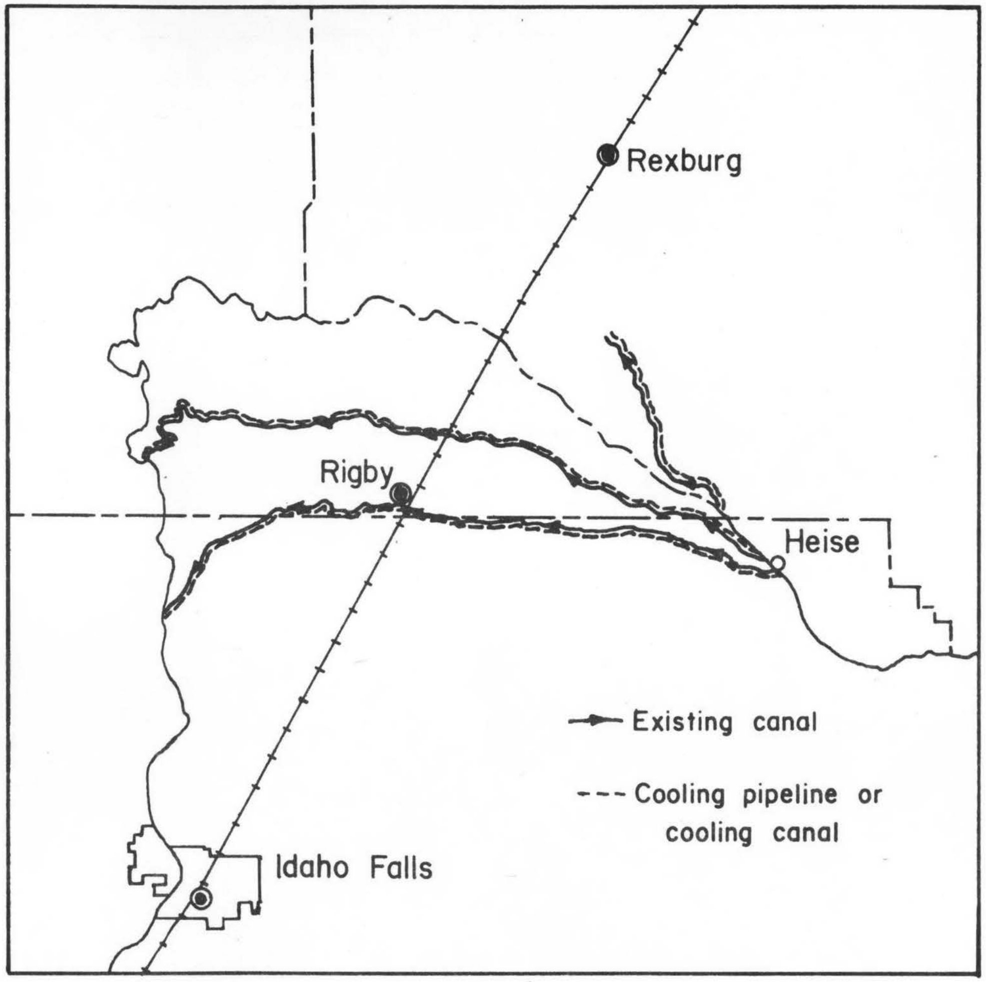

Figure 22

Heise Area Canal Replacement Cooling Scheme the river after sufficient cooling had taken place. This project would probably face the same winter time capacity problems as the previous canal use scheme. Waste ways and downstream canals might have to be enlarged in order to accomodate the larger flows that would occur in the winter months.

Another canal system that was given consideration for use as a cooling canal is the Boise canal system. In this scheme, once-through cooling water would be diverted from the New York Canal just after it leaves the Boise River. After passing through the power plant condensers, the water would be returned to the canal system for cooling and delivery to the farms. If a 1000 MWe nuclear plant were used in this plan, there would be a maximum annual shortage of cooling water of 397,000 acre feet. Part of this water shortage could be made up by purchasing uncontracted water that is available in Lucky Peak Reservoir. This uncontracted storage amounts to 110,000 acre feet (Warnick, C.C., Brockway, C.E., 1974). Other sources for the water deficiency might be new storage projects on the Boise system and also water designated as transfers from the Payette River system for the Southwest Idaho Development Project could be an alternative source for this deficiency (U.S. Bureau of Reclamation, 1966).

Winter time capacity of the Boise canal system would probably be insufficient if 1000 MWe of cooling capacity was desired. This system does have an advantage in that there is a capability of transferring water through the system to Lake Lowell, but additional wintertime capacity would have to be obtained through enlargement of downstream canals and waste ways. The most serious problem that this scheme would face is that of population proximity. Under current A.E.C. safety regulations construction of a power plant at or near the present Boise River diversion would be impossible because of the high population density of the area.

The final canal cooling project that was considered is one at Black Canyon Reservoir on the Payette River. In this scheme a new cooling canal would be constructed that would extend from the upstream end of the reservoir to the dam as shown in Figure 23. Once-through cooling water would be diverted from the Payette River through the power plant and down the new canal to the dam. The water would be returned to the river either just below or just above the dam or allowed to flow down Black Canyon Canal or any combination of the three possibilities. The course the water would take at the downstream end of the cooling canal would depend on flows in the Black Canyon Canal, the temperature of the water at the downstream end of the canal, storage in Black Canyon Reservoir and the quantity of flow passing Black Canyon Dam.

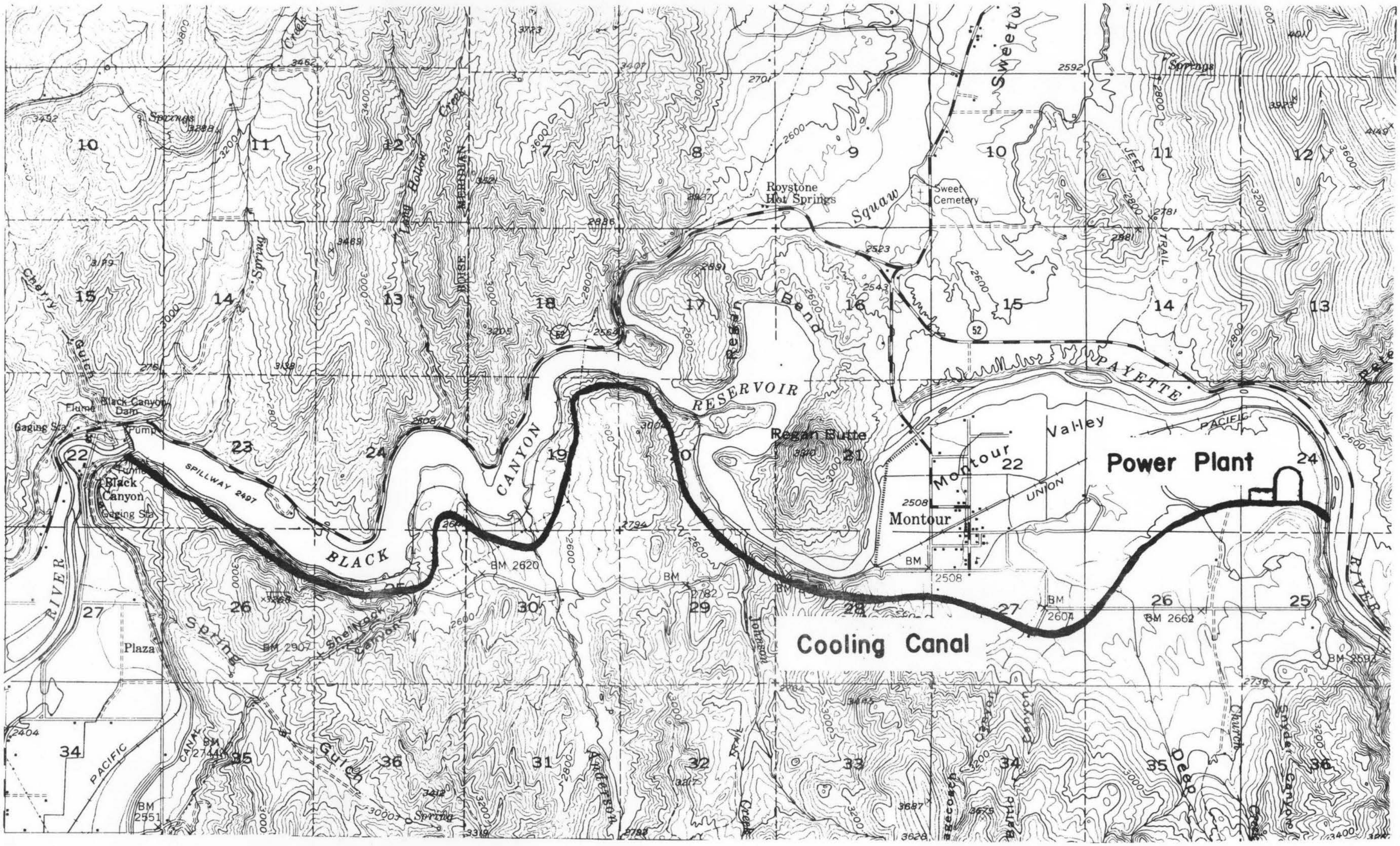

Figure 23

Black Canyon Reservoir Bypass Cooling Canal

Evaluation of the available flows in the Payette River and in the Black Canyon Canal from normal irrigation operation show a maximum annual deficiency of cooling water for a 1000 MWe plant of about 209,000 acre feet.

This deficiency would have to be made up by using space in upstream storage projects such as Deadwood Reservoir or Cascade Reservoir. At present Cascade Reservoir has 378,312 acre feet of uncontracted storage that possibly could be made available for cooling use (Alan Robertson, 1975).

The next unconventional cooling scheme that will be investigated is the use of one or both of the reservoirs involved in a pumped storage plant as cooling reservoirs. Any water that was found available for use in cooling pond systems would be available to make up for increased evaporative losses incurred if a pumped storage reservoir were used as a cooling reservoir. Table 2 lists the amounts available for pond cooling and the approximate location of that water in the system.

The Investigations Division of the Idaho Water Resources Board has made a study of the pumped storage potential in subregion 5 in Idaho as designated by the Columbia-North Pacific Region Comprehensive Study (Mellin, 1974). This study was a map reconnaisance investigation and the results were a listing of 40 potential pumped storage sites in or near subregion 5. Reservoir location, potential head and other information is listed in this study.

Several of the sites show good promise for use in this cooling scheme. Two sites near the King Hill study reach seem to have very good possibilities. These are the Sinker Creek Butte and Rabbit Creek sites. The upper reservoirs have the areas required to cool nuclear power plants in the 1000 MWe range. The cooling pond studies that were described early in this investigation show that there is adequate water in the Snake River to supply the make up water required if the upper reservoirs of these two pumped storage projects were used as cooling reservoirs.

There are several possible pumped storage sites using Cascade Reservoir as the lower reservoir. If the upper reservoirs at these sites were used for cooling reservoirs the plant size would probably be restricted to less than 1000 MWe because of the small size of the upper reservoirs. If Cascade Reservoir was used as the cooling reservoir a 1000 MWe plant could easily be accomodated. Using Cascade Reservoir for cooling purposes would require changes in both Idaho water quality standards and the EPA power plant guidelines. No matter which reservoirs were used for cooling at least part of the consumptive loss water would probably have to be obtained by purchase of existing uncontracted storage in Cascade Reservoir.

Another favorable pumped storage site is the combination of Anderson Ranch and Little Camas Reservoirs. If either the upper or lower reservoir were used for cooling, a change in the state and EPA water quality standards would again be required. The streamflows in this area were not surveyed to see if cooling make up water requirements could be met by normal streamflows. It is considered that if streamflows are not sufficient, additional make up water could be taken from the portion of the uncontracted storage in Lucky Peak Reservoir that originate upstream of Anderson Ranch Dam. This site could easily accomodate a 1000 MWe plant at either reservoir.

The North Pacific Division of the U.S. Army Corps of Engineers is in the process of making a pumped storage potential study for the entire State of Idaho (Bruton, 1974). This study will undoubtedly uncover other pumped storage sites that will have a good potential for use in pumped storage cooling reservoir schemes.

The use of heated water from a power plant in industrial application and in space heating is probably not too likely on a large scale in Idaho under present conditions. It is possible that new industries might come into the state which could use more waste heat, but probably most power plants would still have to rely on a back up conventional cooling system even if these kinds of waste heat uses were incorporated into the total cooling scheme.

Because of these required conventional cooling back up systems the siting would probably still be confined to the areas already defined as good siting areas in early parts of the study.

The energy park concept where large users of power and waste heat would be concentrated in one area is an idea that has been mentioned for Idaho. Even with this concept there would still probably be a need for some type of auxiliary cooling such as cooling towers or ponds. This requirement would indicate that some make up water will still be needed. If agricultural development is planned into the energy park system, there will be further requirements for water. It is considered that without extensive economic studies it would be hard to predict the total water requirements for an energy park system. Water which was found available for other cooling methods would be available for an energy park system. If there are fairly large water requirements for the energy park it would probably be more likely to be sited in the Snake Basin in the area downstream from where Thousand Springs flows into the Snake River.

The use of groundwater as a source for the consumptively used water in energy facilities has also been investigated. The Snake Plain Aquifer is probably the most likely source of this groundwater supply in the state. This aquifer is capable of providing ample amounts of cooling water without adversely affecting water table elevations or spring flows. However, certain specific areas offer greater potential and would cause smaller disruptions in the normal flow pattern.

Figure 24 shows the general boundaries of the aquifer and the irrigated areas on the plain. A majority of the recharge is derived from irrigation.

Two major factors need to be evaluated when considering groundwater as a cooling source. First is the aquifer potential water transfer capability and second is the potential effect on aquifer discharge and water table. The water transfer capability is measured by the transmissivity property which is the product of the Hydraulic conductivity (KH) times the aquifer thickness. For the basalts of the Snake Plain Aquifer, these values vary from 0.2 to 20 million square feet per day. High transmissivity occurs in an area from Rupert north to the Craters of the Moon, north and east of American Falls Reservoir and in the area between Idaho Falls and Mud Lake. Transmissivities in the west end of the aquifer near Jerome and Shoshone are generally lower than in the eastern part.

Locations of large pumping facilities adjacent to major spring areas could be detrimental to existing developments on the springs such as commercial fish facilities and recreation sites. Therefore, potential locations of major pumping in the part of the aquifer west of Burley are probably not feasible. Also major development at short

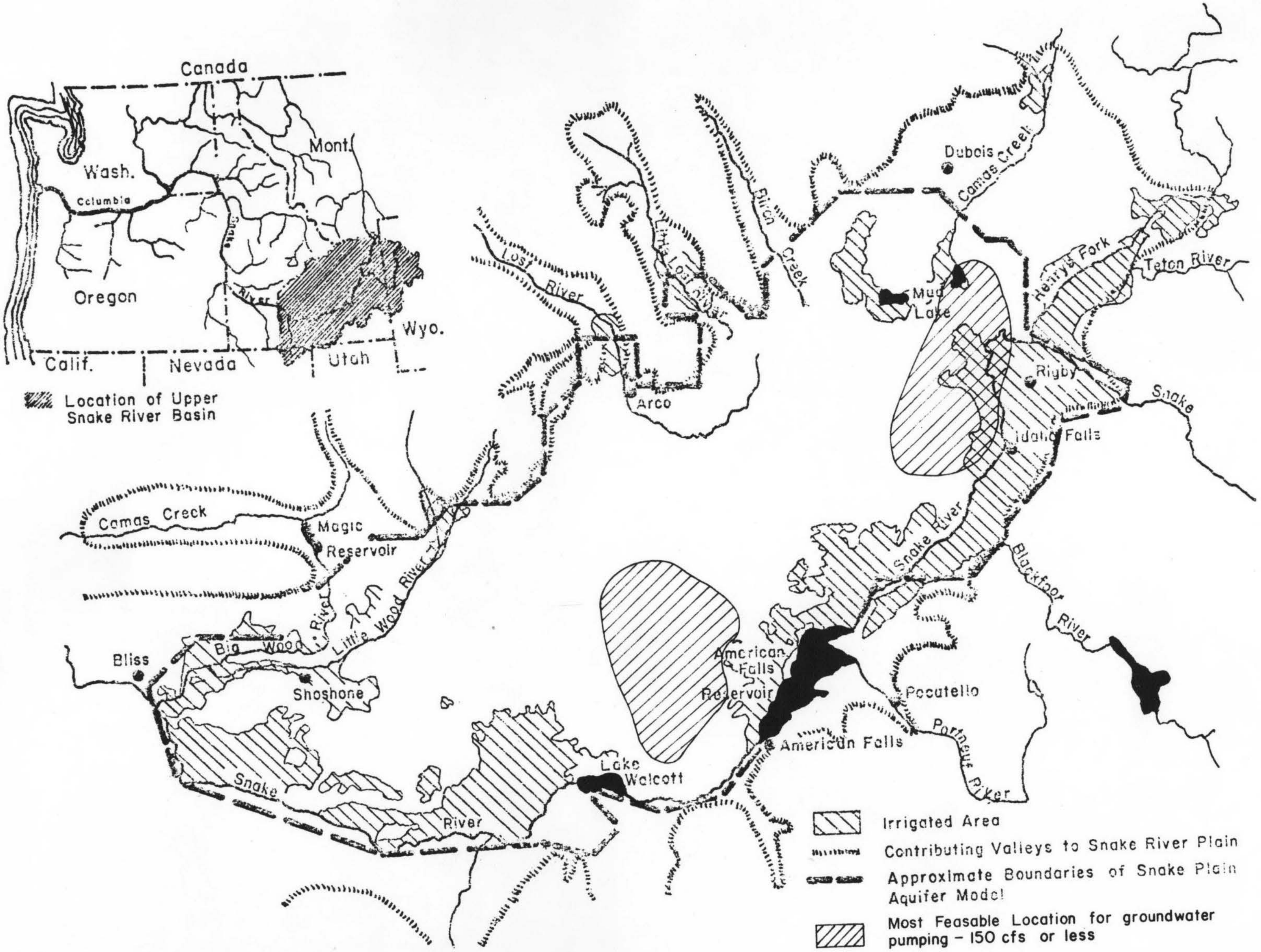

Figure 24

Most Feasible Location for Pumping Cooling Water distances north and northeast of American Falls Reservoir offer less potential.

In evaluating the expected net effect of major groundwater pumping for cooling purposes, the total quantities of water involved should be examined. For instance, the total flow of the western springs (Milner to King Hill) is 4.9 million acre feet annually and the total annual outflow from the aquifer in the American Falls reach (Blackfoot to Neeley) is 1.1 million acre feet. A major pumping facility to serve a 6000 megawatt nuclear generating plant may require 150 cfs or 108,400 acre feet per year for cooling purposes. This quantity represents only about 2 percent of the total spring outflow from the basin so that unless the pumping is performed at short distances from the spring outlets detection of the diminished flow may not be possible.

The Idaho Department of Water Resources has performed some preliminary tests using an aquifer model to determine the effect on spring flows due to pumping or decreased recharge in specific areas of the plains. Removal of 200,000 acre feet per year (277 cfs) in the Rigby-St. Anthony area caused a decrease in annual flow of the springs in the American Falls area of 7 percent and a decrease in the western springs of .01 percent.

A removal of 300 cfs distributed over irrigated lands from Minidoka to King Hill plus 400 cfs removal in the St. Anthony area caused a 4.7 percent reduction in Thousand

Spring flows and a 5.8 percent reduction in American Falls springs.

It is likely therefore that pumping of 150 cfs or less from several areas in the aquifer would be possible without adversely affecting spring flows. The area in the north central part of the plain near the Idaho National Engineering Laboratory has generally lower transmissivity than many other areas in the aquifer. The areas in which aquifer conditions are most favorable and where pumping of 150 cfs or less would have the least impact on the spring flows are shown on Figure 24.

Any potential locations will require in depth geologic and hydrologic studies to determine optimum well spacing and pumping rates to avoid interference. Some wells in the eastern part of the plain have been tested at 6-10 cfs with negligible drawdown. The above information on water availability in the Snake Plain Aquifer was obtained through conversations and correspondence with Professor Charles Brockway of the University of Idaho. Professor Brockway has been involved with many studies concerning this aquifer and is very familiar with the physical parameters that determine the flow characteristics of the aquifer.

SUMMARY AND CONCLUSION

The general outlook for supplies of cooling water for all types of cooling systems for nuclear power plants, geothermal power plants and uranium enrichment facilities appears very favorable. As can be seen on Table 2 and Figures 19 and 20, there is a large supply of cooling water for evaporative cooling towers and cooling ponds. There is also a supply of water that could be available for once-through cooling if the laws or regulations prohibiting stream temperature increases on that type of cooling were relaxed. These supplies are shown on Table 1 and Figures 17 and 18. The possibility of using groundwater as make up water in closed cycle cooling systems has very good possibilities. The Snake River aquifer has excellent supply potential for water used for this purpose. The more promising aquifer supply sites are shown on Figure 24.

There are also many possibilities of using unconventional cooling schemes for cooling power plants. These schemes include such possibilities as use of irrigation canals as cooling canals, combining nuclear power plants and pumped storage facilities and the use of waste heat from a thermal power plant to stimulate agricultural production. Table 4 and Figures 21, 22 and 23 show water availability for and location of several canal cooling schemes. Several combined pumped storage-nuclear power plant sites are listed in the section on unconventional cooling schemes.

The possibility of a combined nuclear power plant and uranium enrichment facility appears promising from a water supply standpoint. There are 5 sites in the state where presently there is enough water to supply the needs for a 8750 metric ton SWU gaseous diffussion enrichment plant and a nuclear power plant to supply its required power load. These sites are indicated in the section on uranium enrichment facilities.

The outlook for cooling water for geothermal plants is favorable also because any water that is available for cooling of power plants would be available for cooling of geothermal power plants. The biggest problem that will be encountered is getting the available cooling water supplies to the geothermal areas. It will be hard to get a clear picture of the water supply problems for geothermal power production until adequate exploration has been accomplished to delineate the most promising geothermal power areas and to determine the quantity and quality of heated effluent that will be encountered in these areas.

The water required for the various cooling methods will come under the jurisdiction of the water rights laws and water quality standards of the state. Under the present water rights laws, there seems to be little problem in making an appropriation of water to the use of power plant cooling. The beneficial use classification of the water would probably be considered as industrial and the appropriations would have all the same rights as any other industrial use in the state. Changing of an established appropriation such as one made to irrigation to power plant cooling also seems entirely possible. Although there are not many legal precedents in Idaho on this type of case, experts in the field agree that this type of water rights transaction could take place.

The state thermal effluent standards could have a very limiting effect on the possibility of once-through cooling of power plants in Idaho. These standards allow such a small increase in water temperature of the receiving body that flow rates of the quantities required for once-through cooling would almost be impossible to find in the natural streams of the state. Under the letter of the law, private cooling ponds and the use of irrigation canals as cooling systems would come under the jurisdiction of the thermal effluent standards, but indications are that these types of systems will not be forced to comply with the regulations if these cooling systems do not present any problems to existing water users or to the water quality of the natural streams of the state.

The Environmental Protection Agency has issued a new set of standards for steam-electric power plants. These standards call for an end to the use of once-through cooling as a possible source of cooling for new steam-electric power plants. If once-through cooling is to be used by a steam-electric power plant extensive pre-construction studies would have to be made to prove to the satisfaction of the Administrator of the Environmental Protection Agency that the use of once-through cooling would not endanger the ecosystems of the receiving body. Geothermal power production, although not very far along in its development, seems to be on a strong and protective legal base in the state. The Idaho Geothermal Act is a start in the right direction in the proper development of the geothermal resources of the state. In order to maintain this direction of development, a close liason will be required between the geothermal developers and researchers and the Department of Water Resources.

Although not tied directly to thermal power production, irrigation use of water has an effect on almost every type of water use in the state. It has been shown that there are places in the state where irrigation use of water is greater than need be for good crop production. The writer contends that there is wisdom in changing the State Constitution and state laws to provide legal incentives for farmers to use more efficient irrigation practices. These changes would be slow to come and very hard fought because of the State Constitution and statuatory law obstructions and because of the resistance of the farmers to changes in their irrigation practices. If these changes were made large amounts of water would be made available for other uses including thermal power production.

Another possible affect on cooling water supplies will be the expansion of existing water using industries and the possible introduction of new industries that consume water. Both of these would have the effect of reducing the supplies of water that were predicted as being available for cooling purposes.

Another possible affect on cooling water supply is the possibility of the state applying for water rights for minimum flows in the stream; or for other public uses. This would in effect reduce the water available for any other uses.

Under the present thermal effluent laws there are virtually no sites available for thermal plants using once-through cooling. This in itself has an effect on the cooling water supply system. Once-through cooling does not consume as much water as closed evaporative systems so applying existing standards has the effect of reducing total cooling water supplies. Possibly these standards could be changed. The standards are relatively new and perhaps after studying the thermal effluent problem in greater detail, these standards will be relaxed, This would in effect reduce total consumptive use and make available water for other uses. Changing these standards would not only require state action but would also require changes by the Environmental Protection Agency. These changes would probably be hard fought and slow in coming.

Idaho is quickly running out of new power sources. Trends show that Idaho has become more and more reliant on its neighboring states for electric power (Verl G. King, 1974). The Idaho Water Resources Board lists in The Objectives, Part I of the State Water Plan, dated June 1974, an objective concerning electric energy. This objective is written on page 17 as follows:

> The Idaho Water Resource Board adopts as a planning objective, a reduction in the reliance upon imported electric power. To achieve this objective, the state water resource policy is to promote and encourage those projects and programs which provide for the development of new electrical energy and more efficient use of existing energy sources.

If this objective is to be carried out, Idaho must start producing more electric power. Most of the more favorable hydroelectric power sites in the state have been developed and many of those potential sites that aren't producing electricity are in scenic or wilderness areas where public opposition to construction of hydro power developments is great. This leaves the state one alternative to change the power supply trends of the past. This alternative is thermal power.

In the course of this investigation, it has become apparent that presently there appears to be a lack in the planning of state agencies of a program to plan and oversee the development of thermal power in the state. Idaho Power Company is already planning to construct a thermal power plant in the state, so this type of power development is not far in the future. The State of Washington, which already has operating thermal power plants, has established a Thermal Power Plant Site Evaluation Council. This council accepts applications from power developers and makes recommendations to the Governor of that state on the acceptability of the development which is seeking certification for construction. The writer suggests that Idaho should have a similar council with similar duties.

There is also a need for further planning in the area of thermal power plant siting. It is the writers understanding, through conversations with Mr. Steve Allred of the Department of Water Resources, that a planning program is being organized whose function will be thermal power plant siting. In order for this organization to provide adequate planning, a multidisciplinary look at power plant planning will have to be made. Water supply, legal aspects, electric loads, environmental concerns, transmission costs and social aspects are just a few of the problem variables that must be input into this type of planning effort. The sooner this type of planning effort could be initiated the better Idaho would be able to plan for the required new thermal power plants in the state.

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