WATER FOR ENERGY PRODUCTION

EXECUTIVE SUMMARY

February, 1978

Foreword

The information presented in this summary document has been based on the comprehensive, "Task Force Report on Water for Energy Production", prepared by and filed with the Iowa Natural Resources Council. The reader should refer to the task force document for more detailed information.

INTRODUCTION

Energy production is one of the many competing uses for the water resource. Withdrawals of water for condenser cooling in thermal-electric plants are by far the largest use of water in the energy industry. Water is used in mining and reclamation of mined lands, processing and refining of fuels, conversion of a solid fuel into gaseous or liquid disposal of waste products and in other aspects of energy production. Water is also the prime mover in hydroelectric plants.

Iowa is not in a region where water supplies are expected to be critically short. However, there will still be water resource problems and conflicts involved with meeting the total water needs of the expanding energy industry and other beneficial users. This is particularly true for the interior portions of the state.

THE RESOURCE

Energy Resources

Almost all of Iowa's energy comes from fuels imported from out of state. Imports account for 98 percent of the fuel resources consumed. All the petroleum and natural gas used in Iowa comes from out-of-state, and only 7 percent of the coal used in Iowa is mined locally.

Petroleum

Iowa has little petroleum potential. Only one well has ever produced oil in the history of the state, and furthermore, there are no petroleum refineries in the state, either. Thus, it is unlikely that Iowa's water resources will ever be burdened by the demands of petroleum extraction or refining.

Coal

Although the coal industry in Iowa is small, the state has 21 billion tons of potential coal resources, 3.5 billion tons of which are measured and indicated reserves. However, Iowa coal has a high sulfur content and current air quality standards restrict its use.

It would be to Iowa's economic advantage to increase the mining of native coal, since the state's electric utilities expect to double their use of coal for power generation by 1985.

To import the necessary coal would require an annual cash outflow of $300 to $500 million.

Hydroelectricity

Hydroelectric power accounts for less than six percent of Iowa sales of electricity. The largest portion of hydroelectric power used in Iowa is supplied from plants on the Missouri River and its tributaries in North and South Dakota. This electricity is sold primarily to rural electric cooperatives and municipalities in northwest Iowa. The potential for developing additional hydroelectric facilities in Iowa is very small. Full development of all potential hydroelectric plant sites in Iowa would provide only 2,500 million kilowatt hours per year, less than one percent of Iowa's current energy consumption. The largest run of the river plant in Iowa is on the Mississippi River at Keokuk.

Alternative Energy Sources

Alternative energy sources such as the sun and the wind are not expected to make a significant contribution in this century. It is expected that only 3.5 percent of total U.S. energy demands in the year 2000 will be met by these sources. Increased attention is being given to these potential sources in the National Energy Program.

Energy Use

Currently, Iowans are dependent on natural gas as the primary fuel for home, business, and industrial uses. Industries supplement natural gas with fuel oils and coal. Coal and nuclear fuels supplemented by hydropower are the primary fuels used to generate electrical energy. (See Figures 6-1 and 6-2).

Natural gas supplies to Iowa have diminished every year since 1974, but are expected to hold steady at current levels of consumption, with household use being of highest priority. For business and industrial expansion, oil, coal, or electricity must be used. Most industries currently use oil as a substitute for gas during winter months and will continue to do so unless federal restrictions limit petroleum availability. Conversion to coal or electricity would entail major equipment retrofit, and would necessitate the installation of emission-control equipment.

It is expected that electricity will be substituted for gas and oil when supplies of those fuels diminish since coal, nuclear fuels, gas, and oil can all be converted into electricity. To meet the expected demands, Iowa utilities plan to build an additional 4,914 megawatts (Mw) capacity in new power plants, almost doubling existing capacity. As the demand for electric power grows, more stress will be put on Iowa's water resources for use in power plant cooling.

Figure 6-1 FUEL USE BY FUEL TYPE IN IOWA, 1976

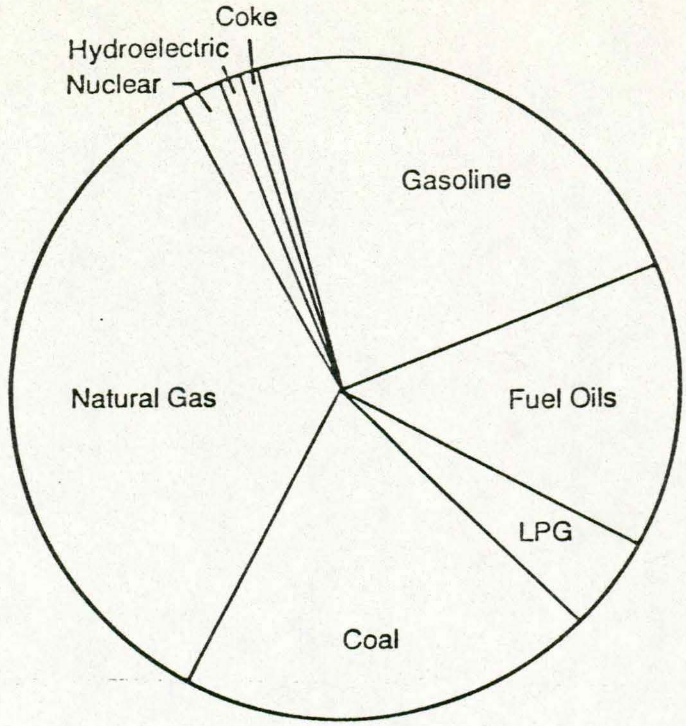
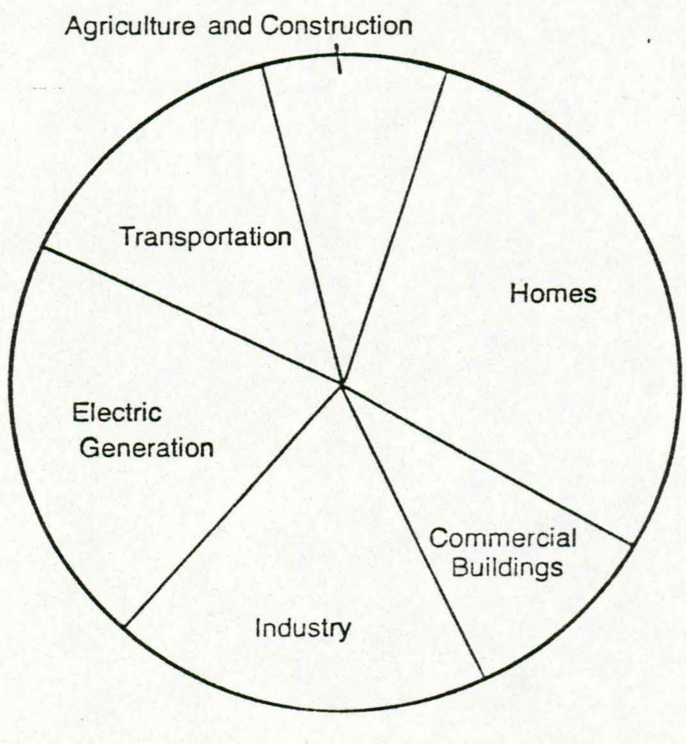


Figure 6-2 ENERGY USE BY CONSUMERS IN IOWA, 1975



Coal will continue to be the source of most of the electric power used in Iowa. To meet increasing fuel requirements, Iowa utilities plan to increase their coal use by 111 percent between 1975 and 1980. Most of this increase will be low-sulfur coal imported from the Western states.

PRESENT SITUATIONS AND FUTURE TRENDS

Coal

Development of Iowa's coal resources could have a significant impact on the state's water resources. By 1985, it is expected that coal-fired electric generators will account for 69 percent of Iowa's installed generating capacity. Another more speculative use of coal will be gasification, or converting coal into a gas; this has large water requirements.

Water is consumed in mining to wet coal surface areas and access roads in order to reduce levels of coal dust pollution. However, these requirements are small; at the most, four gallons per ton in surface mining or 15 gallons per ton in underground mining. For example, the estimated amount of water used to produce the 644,000 tons of coal mined in Iowa in 1976 was 6.1 million gallons, only a fraction of 1 percent of Iowa's total annual water withdrawal requirements.

Larger quantities of water are used to remove sulfur and other impurities from coal. The water requirements for coal beneficiation, or preparation, vary according to the amount of waste which must be removed. The pilot coal preparation plant at Iowa State University processes 70 tons per hour and requires about 600 gallons per minute (gpm) for operation, however, due to recycling, the consumptive water loss is only about 35 gpm or about 5 percent of the circulating water requirement. Coal mining, reclamation and washing are not expected to pose any serious water supply problems; however, there are some significant water quality problems associated with mining. Runoff or leachate from mined sites often is extremely acidic, thus, seriously impairing the productivity of the aquatic habitat. In addition, erosion from strip-mined lands causes sedimentation of streams and lakes and impairs the productivity of the land. Strip-mining would not be practical in many areas of southwestern Iowa where the coal deposits are deep beneath the surface. Deep shaft mining or in-situ gasification would be required in these areas.

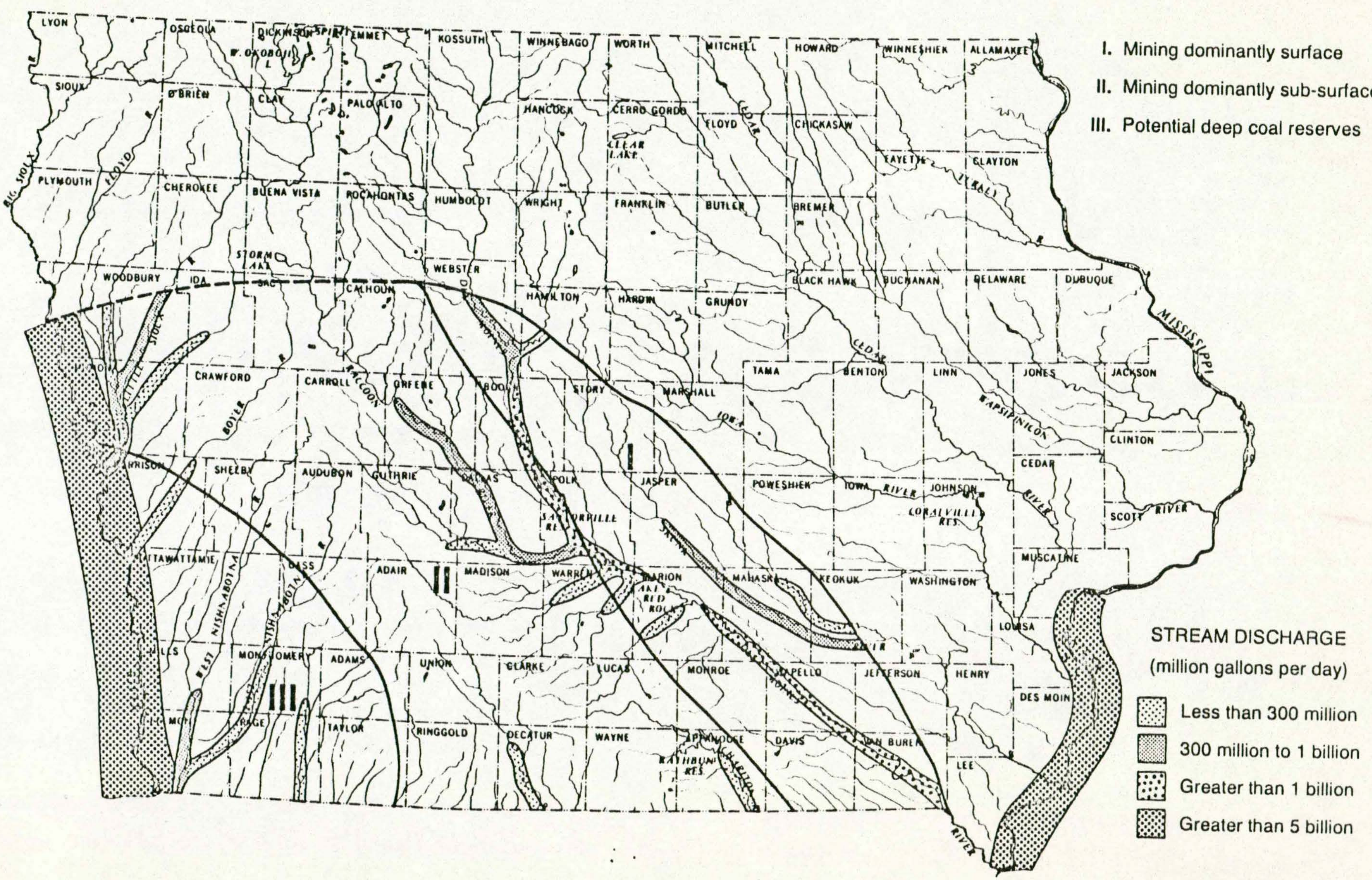
Gasification

Through physical and chemical processes, coal can be converted to a variety of other fuels. High- and low-BTU gasification processes are now close to commercial development and may affect Iowa's fuel situation. Water is used in gasification in processing and cooling. Estimates of water requirements for a high-BTU plant range from 5,100 to 22,000 gpm and for a low-BTU plant from 2,400 to 3,200 gpm. The variations in water requirements are primarily the result of the priority given to water conservation and recycling in the process.

The greatest quantities of water in the state lie outside the coal-bearing areas, which will make supplying water for a gasification facility difficult. (Figures 6-3, 6-4, 6-5, and 6-6 show water supplies in the southern part of the state.) The low flows of the Des Moines River which runs through the part of Iowa in which the surface-recoverable coal deposits lie are not sufficient to satisfy gasification demands. Moreover, many water users compete for the Des Moines River water, so it is unrealistic to consider its entire flow as available for use in coal gasification.

Streams with lower potential yields flow in areas where coal is located farther beneath the surface. The potential yield of a well in the Jordan aquifer in this same area exceeds 500 gpm.

Figure 6-3 SURFACE WATER AVAILABILITY BASED ON AVERAGE FLOW



WATER QUALITY

Stream water quality in the coal producing areas is generally equal to or less than 500 mg/1 total dissolved solids.

Figure 6-4 SURFACE WATER AVAILABILITY BASED ON LOW FLOW

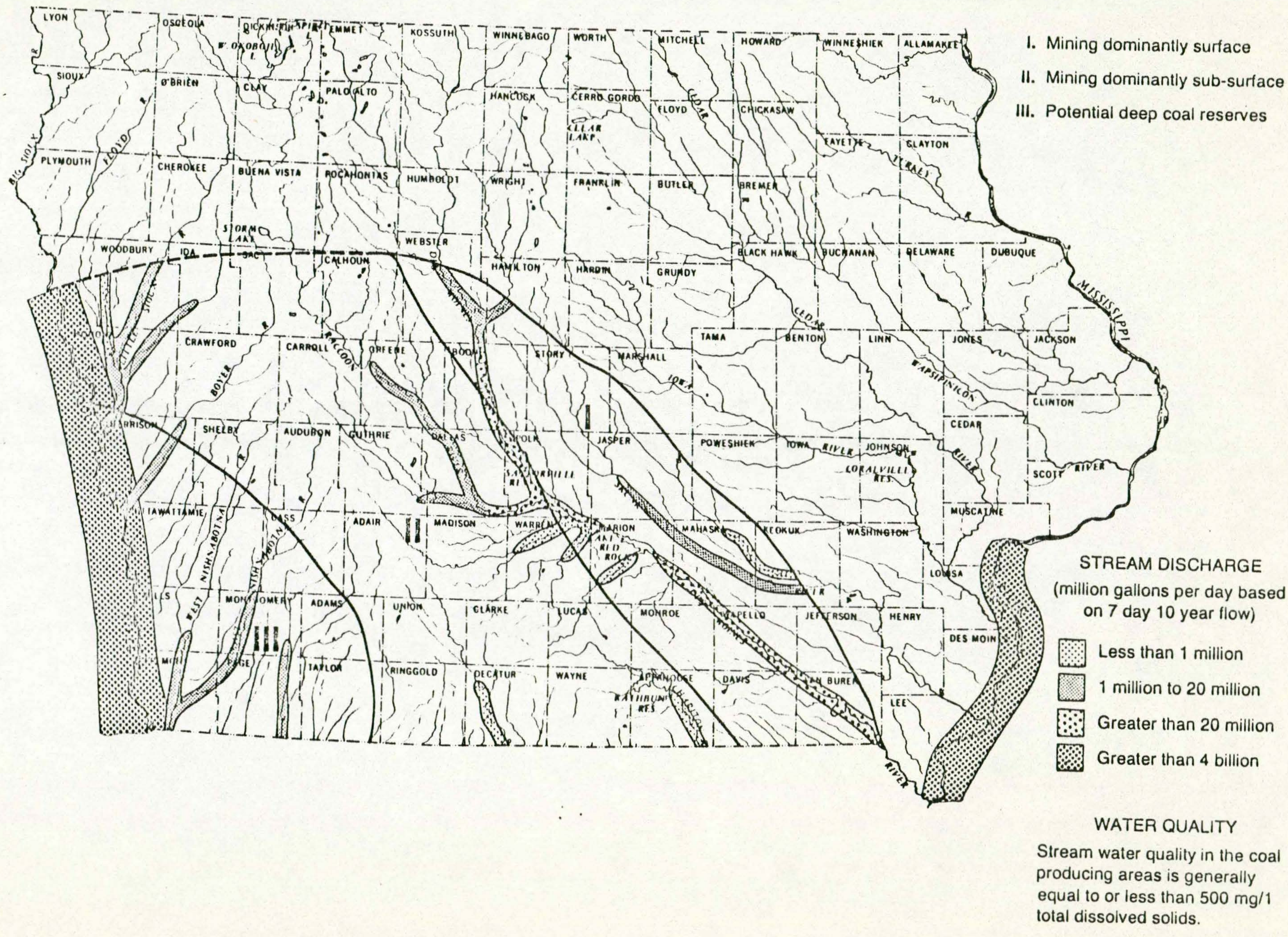


Figure 6-5 BEDROCK WATER QUALITY AND POTENTIAL YIELD

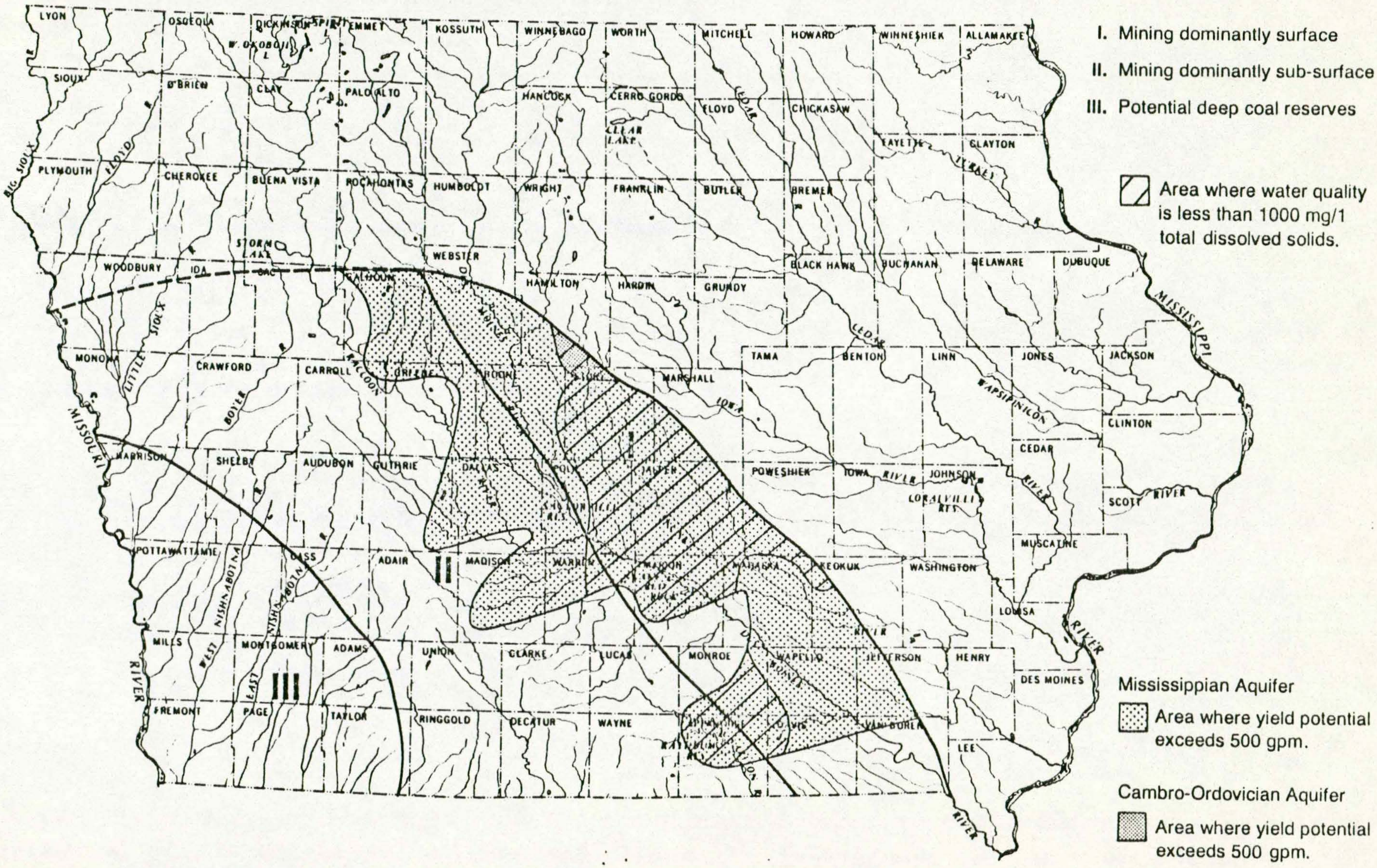
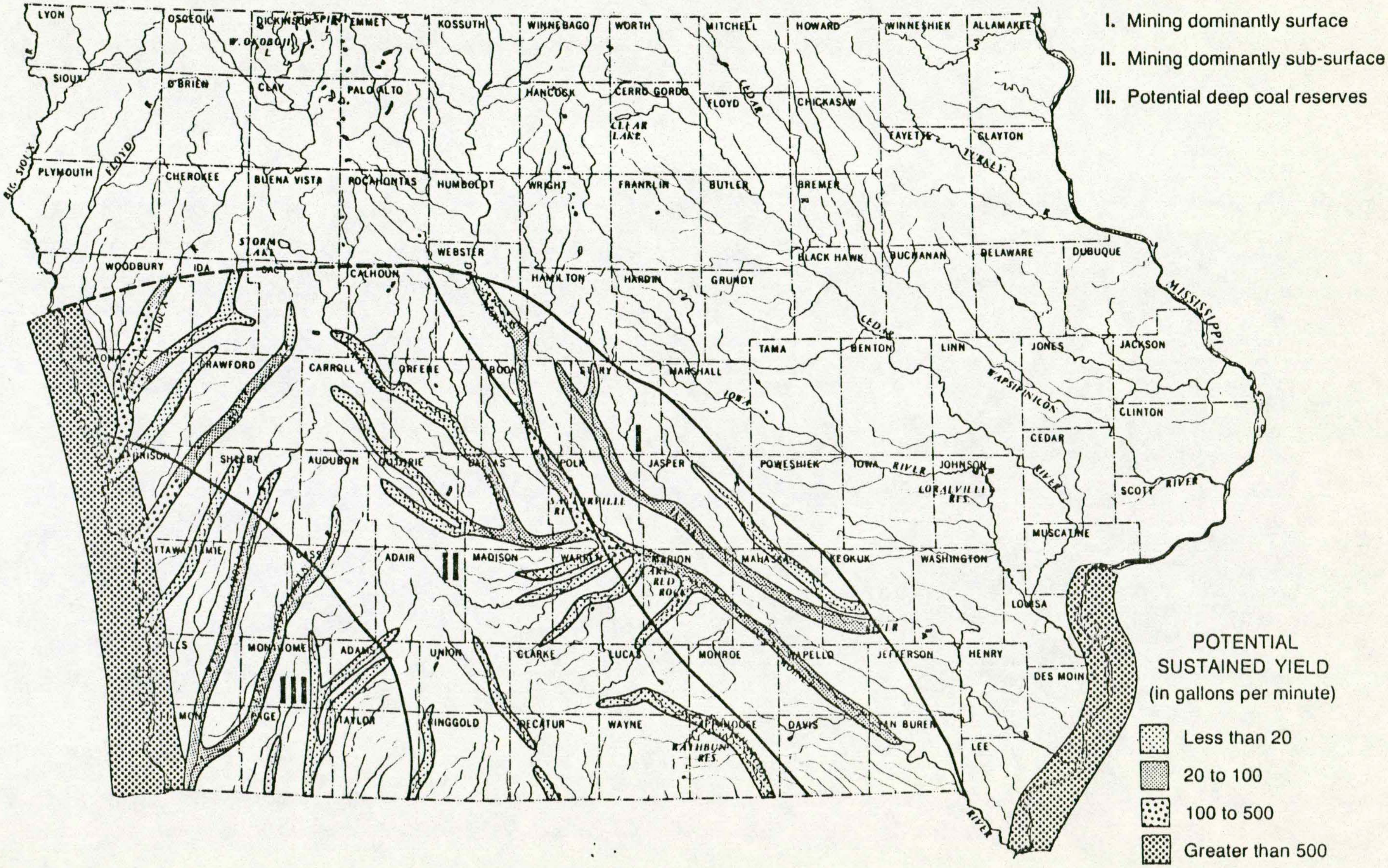


Figure 6-6 POTENTIAL SUSTAINED YIELD FROM ALLUVIAL AQUIFERS



However, much of this surface and groundwater is already allocated to other beneficial uses. Water demands for a gasification facility in this area could be met by constructing a storage impoundment, by piping water from the Mississippi or Missouri River, or by shipping the coal to a facility located on one of these border streams. In addition, a low-BTU facility must be sited where the gas is going to be used, because low-BTU gas, unlike high-BTU gas, cannot be transported by pipeline.

A gasification plant could have a significant impact on water quality. Many potential water pollutants, including tars, oils, cyanides, ammonia, and sulfur compounds are produced and like a steam electric plant, a gasification facility will have to deal with the problem of dissipating the waste heat from the cooling water.

Major expansion of Iowa's coal industry will be necessary to produce the five to eight million tons per year required by a high-BTU gasification plant (Iowa's coal industry only produced 644,000 tons in 1975. However, a low-BTU plant requires only 1.1 to 1.8 million tons per year. Coal gasification may never by profitable in Iowa due to the lack of thick coal deposits, lack of water unless storage is provided, and lack of substantial population or industrial centers in the coal regions to use the low-BTU gas.

Currently, this synthetic gas is not economically competitive with other energy sources. However, as improved processes for conversion at lower costs are developed, as natural gas and petroleum supplies tighten, and air quality standards continue to restrict the potential for burning coal, the demand for any clean, gaseous fuel may be less restricted by price factors. Since gasification offers an alternate means of using Iowa's high sulfur coal, the potential for gasification may eventually gain importance even though the economic and natural resource requirements are large. Low-BTU gasification, in particular, should be investigated because it has lower coal, land, water and money resource requirements.

Electricity

Withdrawal of water for dissipating waste heat from thermal-electric power plants is the largest category of water use in Iowa. (Figure 6-7 shows the location of existing and proposed power plants in Iowa.) About 68 percent of all ground and surface water withdrawal in Iowa is used to cool the condensers of steam-electric power plants. However, less than two percent of this gross water use is actually consumed; that is, lost by evaporation to the atmosphere.

Our use of electricity increases every year. Since 1969, Iowa has experienced more than a 7 percent annual increase in the use of electricity. It is unclear if this growth rate will continue until the year 2020, but if it does, electric power production will remain the largest non-consumptive user of Iowa's water resources.

If our use of electricity increases at this same annual rate, in 2020, we will need to withdraw 54.9 million acre-feet of water for power plant condenser cooling, as compared to the 2.9 million acre-feet withdrawn for this purpose in 1976. Tables 6-1, 6-2, and 6-3 depict the three most likely trends in electrical use in Iowa and the effects on water needs. With low growth of 4 percent per year, 20.3 million acre-feet would be required for cooling in 2020; with high growth of 7 percent per year, 54.9 million acre-feet would be needed; and with the high growth of 9 percent per year until 1985 and leveling off at 4 percent thereafter, 32.5 million acre-feet would be required.

Although new technological developments in power generation such as magnetohydrodynamics (MHD) and nuclear fusion have the potential for making a significant impact on water requirements, they are many years in the future. Estimates indicate that nearly two-thirds of the nation's generating capacity in the year 2000 will be comprised of systems presently in widespread use. This means that water requirements for power generation will not be significantly reduced.

Although the largest category of water use is for cooling purposes, emission control systems on coal-fired plants can have significant water demands. These systems control emissions of particulates and sulfur dioxide in order to meet air quality standards. Control of particulates by electrostatic precipitators requires only 0.8 percent of cooling water requirements; however, this can jump to 16 percent if water from the settling pond is not reused. Particulates can be removed by wet scrubbers; but this system consumes water by evaporation; consequently, water requirements for scrubbers are higher, accounting for about 10 percent of the cooling water requirements. Several processes have been developed for the removal of sulfur dioxide from gases emitted from a coal-fired plant. Each system has about the same water requirement due to evaporation--about 10 percent of the cooling water requirement.

Cooling Systems

Steam-electric plants use water for a variety of purposes, the most significant being for condenser cooling. Several designs of cooling systems are used either alone or in combination; the system most suited for a plant being dependent on a multitude of factors. Each system varies in cost and requires a different amount of energy, land, and water as shown in Tables 6-4 and 6-5.

Once-through

Once-through cooling systems consume the least water, with water loss at least 25 percent less than that of a closed cycle system. A once-through system is also the least costly to install and maintain and the most energy efficient to operate. However, the water is pumped directly in and out of the condenser without any form of processing, resulting in discharge of heated water to the receiving stream. This "thermal pollution" is a cause of environmental concern, and present water quality standards limit the amount the temperature of a stream can be raised; for example, 5° along the Mississippi and Missouri Rivers.

Although consumptive losses with a once-through system are small, withdrawal requirements are high--about 1 cubic foot per second per megawatt (cfs per Mw) for fossil fired plants, and 1.5

cfs per Mw for nuclear plants. Only Iowa's border streams have the heated discharge from the large power plants being built today. A recent study indicates that the Mississippi and Missouri Rivers could accommodate plants using once-through cooling if they are properly sited and use well-designed discharge structures.

Cooling Ponds

There are several alternatives to the use of once-through cooling. A man-made or natural cooling pond may be used. These ponds serve a dual purpose: they provide a dispersion mechanism for the waste heat, and they provide water storage for plant operation. Water loss is less than that for wet cooling towers and energy utilization is about as low as that of a once-through system. On the average, installation and maintenance costs of a pond are lower than those of cooling towers; however, the land requirements are higher. There is a great deal of environmental concern about the construction of a large reservoir and about the inundation of valuable farmland. Utilization of one of the state's existing four major reservoirs (Red Rock, Rathbun, Saylorville, and Coralville) as cooling ponds is unlikely because they were authorized for other purposes. To utilize these impoundments for once-through cooling for steam-electric plants might create severe conflicts of interest.

Wet Cooling Towers

A wet cooling tower is another alternative to once-through cooling. Although water withdrawal needs are lower, consumptive water loss is usually about twice the loss from a once-through system. Towers also consume more energy than a once-through system. From 2 to 6 percent of the Mw capacity is needed to run a tower in warm months compared to between 1 and 2 percent for a once-through system. Despite high costs and consumptive losses by the system, the EPA considers the tower to be the best control technology. Towers discharge only "blowdown" and recirculate all other waters. Blowdown is water which must be eliminated to get rid of dissolved solids and which contains very little heat. Water withdrawal requirements are much less because water is recirculated, and new withdrawals are needed only to replace water lost through evaporation and blowdown. However, due to the variability of stream flow, a plant located in the interior of the state would still need some type of water storage facility to guarantee a water supply in times of low flow. Existing Army Corps of Engineers' reservoirs might be used for this purpose if reallocation of storage was considered. At the present time, supplies are earmarked for uses other than water supply augmentation for energy production, but studies on storage reallocation are currently being undertaken. Privately owned reservoirs are another alternative. Central Iowa Power Corporation recently purchased Lake Panorama, a real estate lake. On the border streams, supplemental storage would not be necessary; and thus, they are the preferred sites for power plants in terms of water supply.

Spray Ponds and Canals

Spray ponds and canals combine the features of cooling ponds and towers to eliminate the inherent problem of the large land requirements for cooling ponds. Only .1 to .2 acre per megawatt (ac/Mw) are needed compared to 2 ac/Mw for ponds. However, disadvantages of this method include initial capital costs, high energy use, increased consumptive water loss, and technological unfeasibility. The Quad-Cities nuclear plant along Iowa's eastern border utilizes a spray canal.

Dry Towers

Dry towers have minimal water requirements because they remove heat by conduction and convection rather than evaporation. They operate like an automobile or truck radiator. This makes them most attractive in areas that are critically short of water. However, they are the most expensive to construct and operate of all cooling methods.

With the exception of dry towers, the alternative cooling systems have significant water requirements. Thus, the requirements of a power plant or any other large individual user can best be met by utilizing surface water, which is more easily renewable than groundwater.

Plant Sites

Conclusion

Iowa has an impressive supply of surface water; however, the actual developable supply is much smaller due to the variability of stream flow. On the average, every other year, a peak flow is reached that is 30 or more times the average flow. During 10 percent of the time, however, low flows occur amounting to only about three percent of the annual flow. Due to this, Iowa's interior streams are able to provide makeup water for a large power plant only if additional storage is provided so that water is available in times of low flow. Even with additional storage, Iowa's interior streams do not have the capacity to accommodate once-through cooling for a large power plant. Storage is a means of making water available for energy production. There are several alternatives regarding storage for water supply purposes. Physical and geological factors limit the number of potential reservoir sites throughout the state. Even when a suitable site is found, there are numerous social, environmental,and land use factors that must be taken into consideration. There is a great deal of concern over flooding scenic areas, or large areas of valuable farmland.

Recommendation

A power plant siting program should be developed and implemented.

The possibility of reallocation of storage in existing reservoirs, for the purpose of providing water for energy development, needs to be investigated.

A study should be undertaken to identify reservoir sites suitable for energy development, throughout the state. A reservoir site preservation program is needed to reserve sites for future use.

In view of the physical limitations, environmental concern, and other conflicts, priority should be given to the development of multiple-use reservoirs in power plant siting.

The potential use of existing reservoirs as cooling ponds should be investigated as the need arises. The assimilative capacities of the reservoirs, the environmental affects of discharging heated water, and legal and institutional constraints of such a use should be assessed in such investigations.

CONCLUSIONS AND RECOMMENDATIONS

Groundwater Withdrawal

Conclusion

The best yielding water wells in the state produce only between 500 and 2,000 gallons per minute (or between 1 and 4 cfs). It is easily recognized that this range of yield could not meet the 1.5 cfs/Mw (675 gpm/Mw) requirements of a once-through cooling system. The makeup water requirement for a plant with a closed cycle cooling system could potentially be met at a limited number of locations. However, the long-term effects on the aquifer and on existing and potential users would have to be determined. There is concern that the volume and rate of water withdrawal needed for cooling purposes would cause the mining of groundwater--that is, the rate of withdrawal would exceed the rate of recharge. Large withdrawals could have material adverse impacts on existing groundwater uses.

Recommendation

Energy development in the state should depend on the surface water resource, because of the high rate and large quantity of water required for a power plant cooling system. Smaller plant requirements might still be met by groundwater as well as tower makeup demands for plants with 100 Mw capacity or less.

Thermal Pollution

Conclusion

Once-through cooling is the least water consumptive, is cheapest to install and operate, has the least land requirements, and, is the most energy efficient to operate. Concern over the environmental effects of thermal pollution have prohibited its use on most streams. Iowa is fortunate in being bordered by two major rivers, the Mississippi and Missouri, which have the flow to satisfy the water requirements and the assimilative capacity to accommodate once-through cooling.

Recommendation

Because energy facility siting and development must consider optimal use of all natural resources, including land, water, and energy, as well as capital costs, once-through cooling on the border streams should carry the highest priority when it can be shown that no significant harm to the environment will occur.

There needs to be some flexibility in the implementation of temperature standards. There should be a mechanism whereby a variance from the five-degree temperature limit could be obtained, based on seasonal differences, hydrological differences, and on the diversity of the ecological system involved.

Gasification

Conclusion

The natural and economic resource requirements of a high-BTU gasification facility are large. It would require a tremendous increase in coal production which could create some serious land-use problems. The water requirements and water pollution potential for such a facility are significant. However, the land, coal, and water resource requirements for a low-BTU facility are considerably less.

Recommendations

Energy studies should include evaluation of the low-BTU gasification potential as a means of using Iowa coal in an environmentally acceptable fashion.

Before a large scale, high-BTU gasification facility is considered in Iowa, a careful study should be made in order to assess the associated water and land resource problems.

Energy Conservation

Conclusion

Electrical energy demands will continue to grow even if not at the present high rates, and new sites will be needed for electric generating facilities. Not only will there be an increasing number of power plants, but there will be an increase in the size of these plants. Although these plants will be generally more efficient than the older, smaller plants, they will create larger, more concentrated sources of waste heat.

There are both water quantity and quality problems associated with providing water for energy development. Although energy conservation cannot solve all of these problems, it can lessen the impact on the state's water resources. Also, additional benefits to be gained from energy conservation include conservation of fuel resources and reduction in air pollution.

Recommendation

Continued support of EPC's energy conservation program is recommended as an aid in controlling the amount of water which must be withdrawn and used for energy production.

Data Collection

Conclusion

Current methods of water use data collection by Iowa regulatory agencies are not adequate. Reports do not separate consumptive from non-consumptive use or individual uses such as condenser cooling, ash control, boiler feed, and blowdown. A more adequate data base will allow the planners to make better decisions regarding these competing water uses.

Recommendation

The data collection system should be updated and improved, with more emphasis placed on the quality (accuracy) of data received. The large water uses within a plant, such as condenser cooling flow rates, tower makeup, and ash control should be reported along with the gross water usage, regardless of the cooling system used. A more reasonable time base should be used, such as monthly, with the data reports submitted semi-annually or annually. Accuracy of the data submitted should be assured by requiring annual calibration of all instrumentation.

Acid Mine Drainage

Conclusion

The water requirements for mining and cleaning coal are modest, but there are some significant water quality problems associated with surface coal mining. Acid mine drainage problems occur when water contacts the mined surfaces of the earth and becomes contaminated from reactions with iron pyrite (or other sulfurous materials) and oxygen, resulting in the formation of sulfuric acid. This can result in runoff or leachate with an extremely low pH, which will seriously impair the productivity of the aquatic habitat. Erosion from strip mined lands is another serious water and land quality problem. Erosion impairs the future productivity of the land and causes sedimentation of streams and lakes.

Recommendations

In view of the serious environmental consequences of strip mining, Iowa's current mining and reclamation regulations should be strengthened and thereafter strictly enforced in order to prevent any significant degradation of land and water quality.