Abundant but Problematic Alternative Sources of Cooling Water Exist

David Alleman

Drawing 135 billion gallons a day (BGD), thermoelectric power generation relies heavily on a constant supply of surface water and groundwater to supply consumers with a continuous source of electricity. In recent years, rising populations, regional droughts, and diminishing groundwater levels have forced coal-fired power plants to temporarily curtail or cease energy production for lack of available cooling water. The current strain on, and escalating demand for, freshwater supplies has led industry and community planners to identify alternative water sources in an effort to reduce the electric power industry's demand on the nation's freshwater resources.

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Rising populations and regional droughts create competiton between domestic, industrial, and agricultural water consumers for the nation's freshwater resources. Since 1950, the world's population has increased by 162 percent to over 6.7 billion people in 2008. It is projected that within the next 25 years, the United States' population will increase by another 70 million individuals, with most of the growth occurring in the already water-strained areas of the Southwest. As national and regional populations multiply, the growing need for energy and agricultural production—the two largest water-withdrawing industries in the nation—will continue exerting pressure on strained freshwater resources.

Growing recognition of the tight interrelationship between energy and water has sparked national discussions of the "energy-water nexus." While all forms of energy have some water needs, thermoelectric power generation is especially dependent on the availability of water, either for steam generation or cooling water.

Lack of adequate water supplies can seriously impact electricity production. In some instances, power plants have been forced to reduce energy production due to a lack of available water resources. In 2007, the southeastern United States experienced drought conditions that caused the Tennessee Valley Authority to curtail production at, or entirely shut down, both nuclear and coal-fired power plants in the region.

During prolonged and intense droughts, a power plant faces a threefold problem in the energy-water nexus. First, reduced river volumes require power plant operators to curtail energy production to decrease the volume of withdrawals from the river. Second, as most droughts occur during the warmer months of the year, the reduced river volume and increased ambient temperatures could cause warming of the river until it is no longer a viable source of cooling water. Third, the increased air temperatures that are frequently associated with the drought can

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also drive an increase in energy demand due in part to residential and commercial air-conditioning usage.

ALTERNATIVE WATER SOURCES

In order to ease the strain on the nation's freshwater resources and ensure reliable power generation, government and industry planners have begun to explore the possibility of using alternative sources of water. These alternative sources may be used to supplement or replace more conventional sources, and may be used on an ongoing basis or may only be used when conventional sources are insufficient.

There are several factors that must be considered when identifying nontraditional cooling water sources; the water's quality, available quantity, and location all affect the suitability of such sources. Quality factors include pH and the concentration of total dissolved solids (TDS) of the alternative water source, and these are frequently the biggest obstacles for suitability. Generally, the pH of cooling water needs to be between 6 and 9, while the TDS concentration should be approximately 2,000 parts per million (ppm) or less.

The economic viability of treating lower-quality water should increase as demands on traditional freshwater resources continue to increase.

Many of the alternative water sources will contain pH levels or TDS concentrations outside of the optimum range for power plant usage. Most such sources will require some level of treatment. While treatment costs may make some alternative water sources unattractive, the economic viability of treating lower-quality water should increase as demands on traditional freshwater resources continue to increase.

Alternative water sources should be able to provide at least 20 percent of the raw water needs to be considered a practical water source.

In addition to quality, a viable alternative water source must be able to reliably supply a minimum volume of water and must be near enough to make transportation economically feasible. The US Department of Energy (DOE) has determined that alternative water sources should be able to provide at least 20 percent of the raw water needs to be considered a practical water source for power plants. DOE studies have also shown that 15 miles tends to be the maximum distance that is economically feasible to transport the water.

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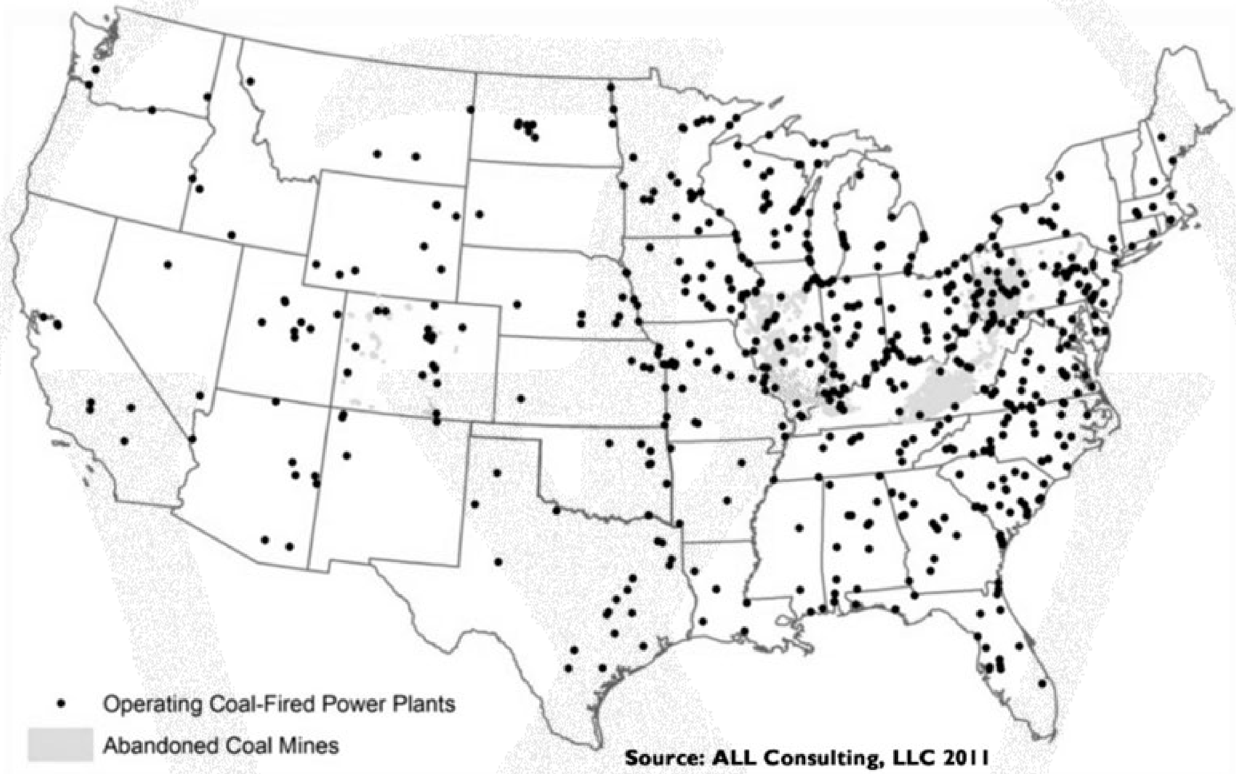
The widespread alternative water sources that meet these criteria are fairly limited. The sources that are commonly considered to meet these criteria are abandoned mine pools, oil and gas–produced water, saline aquifers, and publicly owned treatment works (POTWs). Each of these sources has unique characteristics that must be considered when evaluating their suitability. In addition, there are some general considerations that apply to all of these potential sources of water.

ABANDONED MINE POOLS

Since the mid-1800s, coal mining has been a major part of the nation's energy production. The vast networks of tunnels dug during coal production are infiltrated by water that is constantly pumped out to keep the mine dry. Once coal production ceases and the water is no longer being pumped out, the underground voids fill with groundwater and form abandoned mine pools. To use this alternative water source, the mine pool would likely be incorporated into a closed-loop cooling system as a reservoir to provide makeup water to the power plant.

Although this largely untapped resource presents a potentially viable source of water for power plants, issues such as the quality and volume of the available mine pool water, and the ability to accurately locate flooded mines must be taken into account before reaching a determination of suitability. As shown in **Exhibit 1**, most of the known mine pools are located in the eastern United States

Exhibit 1. Location of Abandoned Coal Mines vs. Power Plants



and are not necessarily located near existing plants.

In most cases, mine pool water will be of suitable quality for use at power plants with minimal treatment.

The quality of water found within abandoned mines varies greatly; thus, suitability of use is dependent on several factors, including geographic location and the length of time the mines have been flooded. Generally, the constituents found in abandoned mine pools consist of iron and heavy metals such as copper, lead, and mercury. The pH of the mine pool water typically displays a bimodal distribution at a pH of 2–4 and 6–7, and the TDS has been shown to range from 200 to 10,000 TDS. Although nearly all of the mine pool water to be used at a power plant will need to be treated for pH, metals, and TDS, in most cases, mine pool water will be of suitable quality for use at power plants with minimal treatment.

SALINE AQUIFERS

According to the US Geological Survey (USGS), thermoelectric power plants withdraw over 195 BGD of water, only 30 percent of which is saline; thus, over 135 BGD of freshwater withdrawn at power plants could go toward domestic use. Thermoelectric power plants are currently responsible for approximately 96 percent of all saline water withdrawals in the country (approximately 60 BGD), but this number could be much greater if the plants were able to access the expanse of saline groundwater that underlies large portions of the United States (**Exhibit 2**). The most complete data set was compiled by DOE as a part of the National Carbon Sequestration Database and Information System and contains available quality param-

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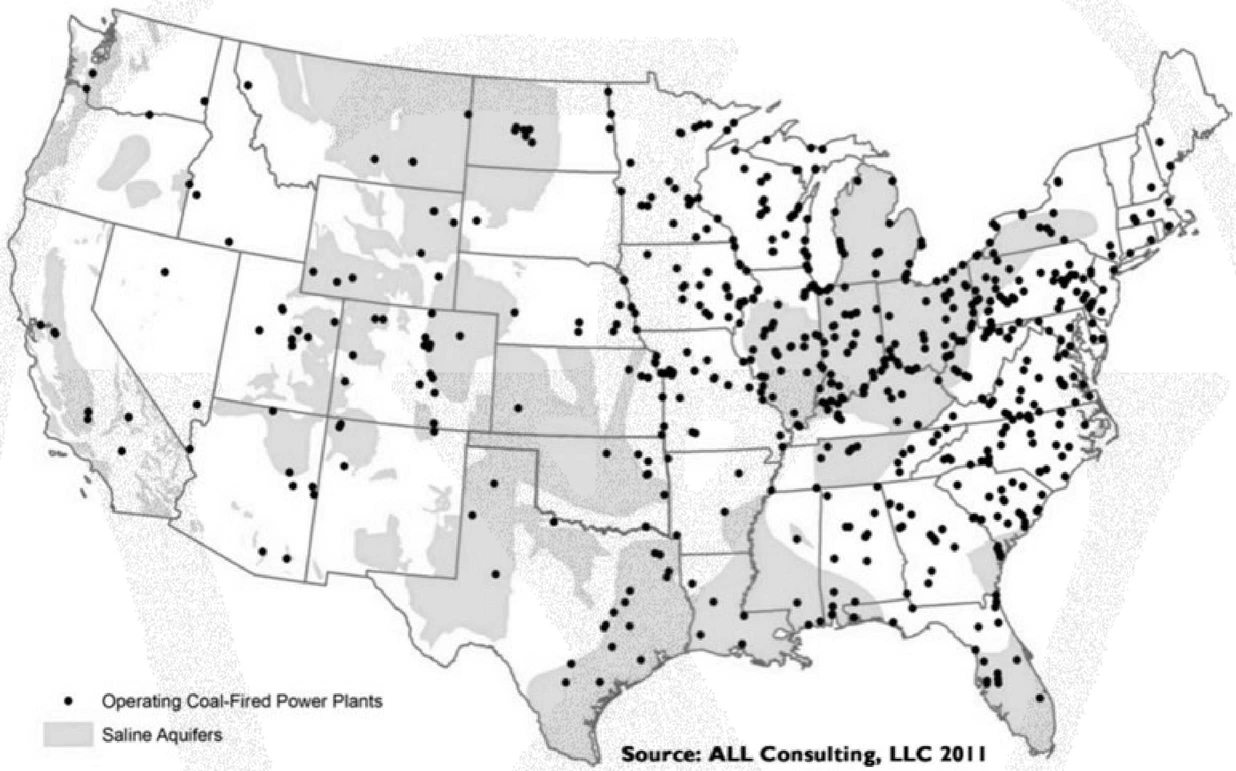
Exhibit 2. Location of Saline Aquifers vs. Power Plants



eters and the aerial extent of the saline aquifers, although the total water volume or flow rate is not documented.

As with mine pool water, the quality of the saline aquifers varies greatly even within a given region. For instance, the average TDS concentration in the Arbuckle Formation in Kansas is approximately 42,000 ppm, and the concentrations range from 1,500 to nearly 350,000 ppm. The spatial variability of TDS levels in saline aquifers will likely make it difficult for operators to predict whether the groundwater near a given power plant is of usable quality.

Although the TDS levels within the Arbuckle aquifer make some of the water impractical for use, the average pH of the groundwater is 7.11, which is within the optimum pH range for use at a power plant. The neutral pH values along with treatable levels of TDS demonstrate that a large portion of the water contained within saline aquifers may be of adequate quality for use at a thermoelectric power plant.

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PRODUCED WATER

Water trapped in underground geologic formations and brought to the surface during oil and gas production is called "produced water." Produced water is regarded as a potential nontraditional source of water for power plants because large volumes are generated throughout many regions of the United States, and much of the water has treatable TDS concentrations.

Even with 4.2 billion gallons of produced water generated every day, the inconsistency of quality from basin to basin creates uncertainty that produced water is usable in all areas of the nation for power plant water needs. The composition and quality of produced water varies based on its originating basin, formation, and depth. As shown by data from the USGS Produced Water Database (**Exhibit 3**), produced water throughout the Rocky Mountain region tends to have TDS levels below 10,000 ppm, while basins in the central and southern United States display a frequent occurrence of TDS levels at 200,000 ppm and above.

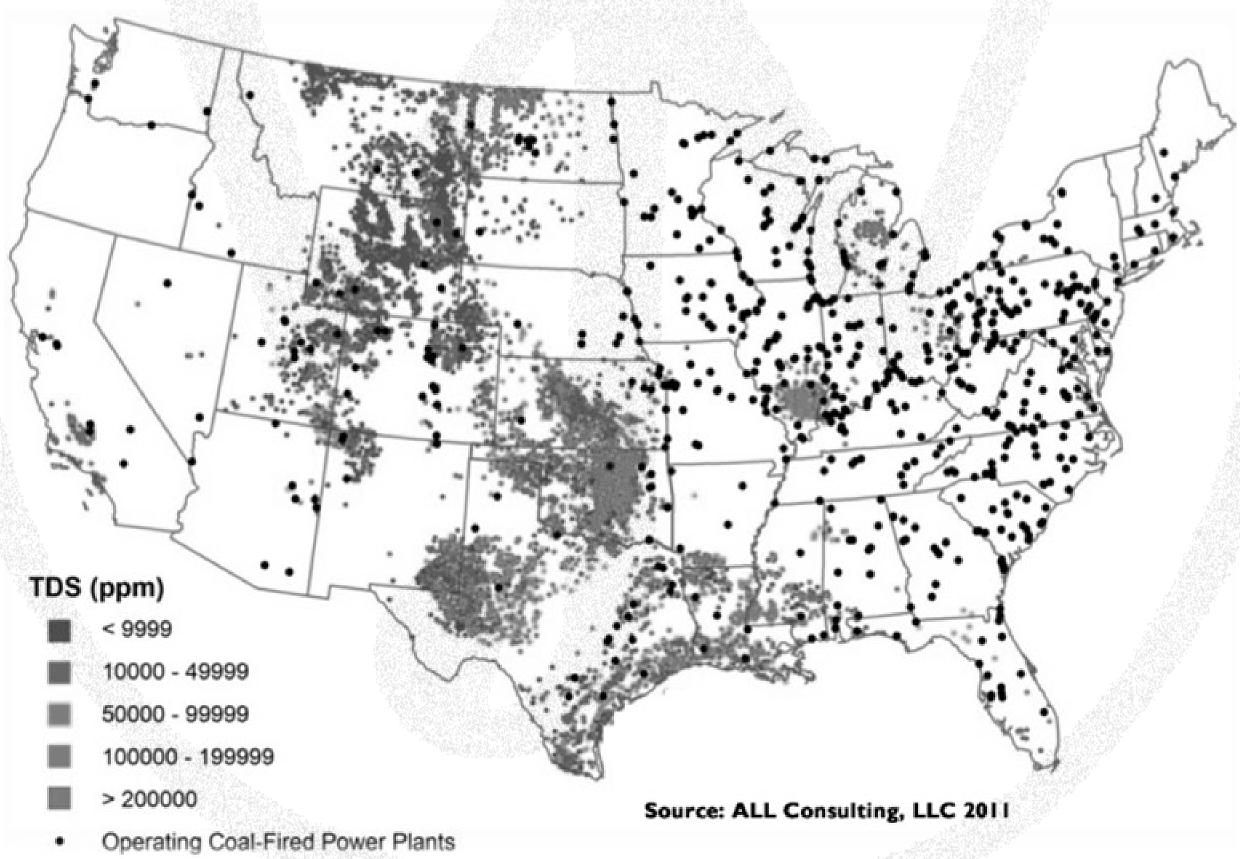
The inconsistency of quality from basin to basin creates uncertainty that produced water is usable in all areas.

Although large volumes of produced water are generated every day, the locations of the produced water and coal-fired power plants do not necessarily coincide. As shown in Exhibit 3, for many power plants located along the East Coast and elsewhere, produced water is an impractical alternative water source due to the power plants' distances from areas of oil and gas production. Conversely, for power plants in the Rocky Mountain region and the central United States, produced water could be a plentiful and economically feasible alternative water source.

PUBLICLY OWNED TREATMENT WORKS

Publicly owned treatment works, generally municipal wastewater treatment facilities, offer another potential source of water that could be used for cooling water. In general, POTWs treat municipal sewage to remove the solids and organic matter in the water. The ef-

Exhibit 3. Location and TDS of Produced Water Sources vs. Power Plants



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fluent from these plants is typically discharged into a local stream or river. While the water may have a somewhat elevated biological oxygen demand (BOD) due to the elevated organic content, the water would generally meet most of the quality criteria for power plant cooling water.

In addition to having fairly consistently good-quality characteristics, POTWs can have high-volume effluents and are fairly widespread.

In addition to having fairly consistently good-quality characteristics, POTWs can have high-volume effluents and, as shown in **Exhibit 4**, are fairly widespread. Because they are so widespread, POTWs would appear to be a likely alternative source of water for power plants. However, in many cases, municipal water has been withdrawn from the same river system into which it is being discharged. Accordingly, the POTW discharge may be needed to maintain adequate stream flow.

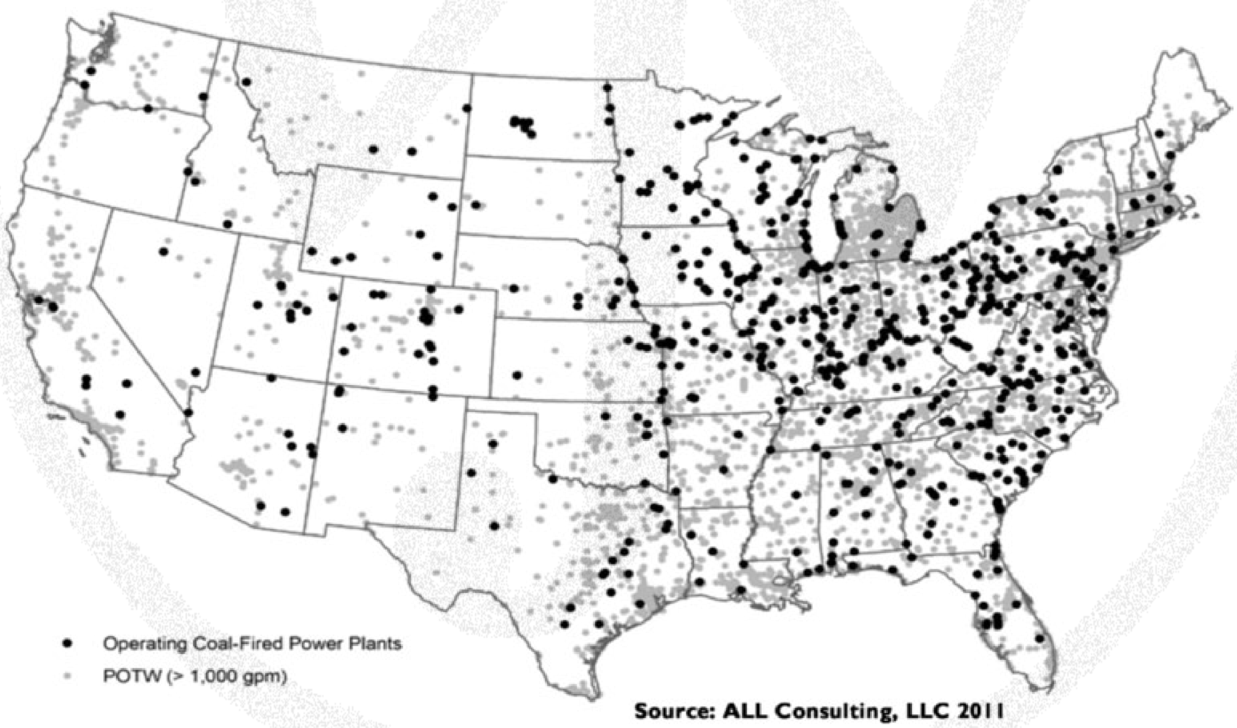
OTHER CONSIDERATIONS

In addition to the factors for each of the potential alternative water sources discussed here, there are some considerations that apply to all of these sources and that may affect whether a given source is viable. The most important of these other considerations are data limitations, access, and liability.

Quality of the data that is available varies substantially by state. In general, there are very few data-collection points.

By their very nature, these alternate water sources have not received much attention, and

Exhibit 4. Location of POTWs vs. Power Plants



information on the location, quantity, and quality of the water is very limited. The quality of the data that is available varies substantially by state. In general, there are very few data-collection points such as wells.

Legal access to the water can also be problematic. Even if an adequate alternative water source is identified, permission to use the water must be obtained. In some cases, ownership of the water may be difficult to determine or may be strictly governed by state and local water right laws. In addition to water-right determinations and any state permits that may be needed, separate landowner permission could be required.

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In addition, liability concerns can affect whether a given source is viable. Use of these alternative sources may create liability to the power plant operator if the water is discharged to surface streams, and the original owner of the water may also be concerned about liability. For example, a project in New Mexico studied the potential of using produced water at power plants. A study indicated that based on quality, quantity, and location, it would be economically feasible to use the produced water from a nearby oilfield. However, the project was not completed because the oilfield operator was concerned about the potential liability from lawsuits that might be filed alleging unforeseen impacts.

ALTERNATIVE WATER SOURCE INFORMATION SYSTEM (AWSIS)

As part of the National Energy Technology Laboratory's (NETL's) research program that focuses on reducing freshwater demands at coal-fired power plants, ALL Consulting has developed an Internet-based Geographic Information System (GIS) catalog to identify alternative water sources that could be used to supplement or replace the use of traditional water sources. Publicly available data has been collected and incorporated into a GIS-based application called the Alternative Water Source Information System (AWSIS). AWSIS allows the identification of potential alternative water sources for power plants throughout the United States.

The system is available at no charge and was specifically designed to be compatible with a wide range of operating systems and browsers. AWSIS uses a Google Earth interface and is built on a Microsoft platform (SQL Server and .NET Framework) for enhanced capability and ease of updates.

The opening screen displays a map of the United States with map symbols showing the location of each of the power plants in the Lower 48 states. By clicking on a power plant, the user sees summary power plant information and summary information on any alternative water sources that exist within 15 miles of the plant. Detailed data about each of the water sources can also be viewed or downloaded to Excel. While the system was created to address coal-fired power plants, it is generally applicable to all power plants and can be easily expanded to address any or all types of plants, regardless of fuel. The system can be accessed through http://www.all-llc.com/projects/coal_water_alternatives/.

As energy demands increase and stresses on our freshwater supplies rise, finding and using alternative sources of power plant cooling water will become more and more important. While each of the potential alternative sources has challenges, the ever-increasing need to conserve freshwater will make it more feasible to overcome these challenges.

A first step in overcoming these challenges is to identify the location, quality, and quantity of known alternative water sources relative to the location of existing or planned power plants.

A first step in overcoming these challenges is to identify the location, quality, and quantity of known alternative water sources relative to the location of existing or planned power plants. AWSIS provides this resource assessment and allows planners at all levels to identify and evaluate those sources as a way to facilitate use of alternative water sources.

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