Identification of Incentive Options to Encourage the Use of Produced Water, Coal Bed Methane Water, and Mine Pool Water

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

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I Background

A growing population and a steady or diminishing supply of water have begun to place limitations on the production of electricity and other commodities essential to the economic growth and energy security of the United States. As a result, the current imbalance between freshwater demand and economic supply has created a growing market for desalination of seawater and brackish water. Other potential methods of enlarging the supply include:

- Promoting the development of brownfields into green spaces to recharge groundwater aquifers;
- Diverting storm water to supplement the water requirements of freshwater treatment plants rather than wastewater facilities, as is commonly done;
- Recharging groundwater supplies with treated wastewater; and
- Using other sources of treatable water such as produced water from oil and gas fields, water from coal bed methane recovery operations, and mine pool waters.

This report is focused on the last of these potential partial solutions to this increasingly important water supply problem, namely, the use of produced water from conventional gas/oil wells (referred to as produced water in this document), coal bed methane operations (CBM water), and groundwater that has accumulated in an underground mine (mine pool water). While most mine pool water has accumulated after mining operations have ceased, it is conceivable that mine pool water could be withdrawn and used even during active mining operations, as miners need to dewater the excavations in order to work. Mine pool waters withdrawn during mining operations will be considered no different from those withdrawn after mining operations, for purposes of the discussion presented in this paper. Previous analyses have suggested that the use of mine pool water in the production of electricity is feasible, and is actually being done at a number of locations in the Appalachian Coal Basin in the Eastern United States (Veil et al. 2003a and 2003b).

CBM accounted for 7–9% of the natural gas supply in the 2000–2002 time frame (Pinsker 2002), and natural gas demand is expected to reach 163 trillion cubic feet by the year 2020, with the CBM percentage expected to significantly increase above the current level (Pinsker 2002). Thus, there is an expectation that the supply of this potential water resource will increase, offering the promise of using these waters in a beneficial manner. Continued oil and gas production also offers the potential for a steady supply of produced water, as well.

The work described in this report has been supported by the U.S. Department of Energy's National Energy Technology Laboratory (DOE/NETL) as part of its Innovations for Existing Plants (IEP) program. This program is part of a comprehensive, integrated research and development program intended to develop advanced technologies and information that enhance the environmental performance of existing coal-fired electric power plants. It also provides high-quality information on environmental issues for use by regulatory and policy decision makers (Feeley and Ramezan 2003). NETL websites on coal/water issues (NETL Environmental and Water Resources – http://www.netl.doe.gov/coal/E&WR/index.html) and oil and natural gas (NETL Strategic Center for Natural Gas and Oil – http://www.netl.doe.gov/scngo/index.html) provide more information on the research sponsored by and available from NETL.

II Study Objectives

The objective of the effort described in this report is to identify a limited set of scenarios involving combinations of water resources, applications, and incentives that might define the range of near-term opportunities for developing these resources. The set of identified scenarios could then be reviewed by a group of knowledgeable people, to certify that they are reasonable representations of potential situations. This group of experts could also suggest additional or alternative scenarios, if appropriate. A subset of the scenarios would be selected and subjected to quantitative analyses to estimate the benefits attributable to the assumed incentives and to determine which of them might be most effective in promoting the development and use of these resources. It is expected that these more detailed analyses will provide greater insight into the types and magnitudes of the incentives that may be most beneficial in promoting the use of these waters.

This report meshes with the NETL's research objectives in several ways. NETL has a program to examine various technologies intended to enhance the environmental performance of coal-fired electric power plants, including those that lead to the use of unconventional water sources such as those of interest in this report. Another NETL program supports research into beneficial reuse of produced water, while this report describes incentives for encouraging the use of produced water as a water supply. Offering incentives to developers and/or users of a resource can provide a means whereby various government entities stimulate the development of the resource. Incentives can be, and have been, used to reduce some of the risks associated with the development of a new resource, thereby making the opportunity more financially attractive than it might otherwise appear.

III Water Resources

Section IV of this report describes examples of the use of mine pool water, coal bed methane water, and other unconventional water sources in the electric power sector. However, these applications represent only a very small fraction of such water sources and only a limited number of potential applications. The potential for using these waters remains great and largely untapped. There is considerable uncertainty as to the volume of water potentially available for use from the three sources considered in this report. There is even greater uncertainty as to the ability of these sources to provide water of consistent quantity and quality over periods of time of interest to developers of the resources, i.e., their sustainability. Veil et al. (2003a) provides information on initial efforts to determine the volume of mine pool water in western Pennsylvania and northern West Virginia. The National Mineland Reclamation Center has estimated the total available volume for mine pool water in these areas at 250 billion gallons (768,000 acre-feet). This estimate represents the water accumulated in only 130 of the tens of thousands of abandoned underground mines in these two states. For the sake of comparison, the volume of Lake Erie is about 127,000 billion gallons, and the average flow of the Potomac River near Washington, D.C., is about 7 billion gallons per day. By contrast, the estimated discharge from these 130 abandoned underground mines in Pennsylvania and West Virginia is 19.1 billion gallons per year (Veil et al. 2003a). This value relates to the quantity of mine pool water that is flowing into surface water sources such as rivers, streams, and lakes. Other estimates presented in Veil et al. (2003a) put the volume of mine pool water in the anthracite fields in eastern Pennsylvania and northern New Jersey in excess of 47 billion gallons.

According to the Pennsylvania Department of Environmental Protection (DEP), examples of large mine pool sources in Pennsylvania include a 80-billion-gallon mine pool in Westmoreland County that is 50 miles long and 10 miles wide and the Jetto Discharge in Luzerne County that produces 3 million gallons per hour (DEP 2002).

Still another assessment of mine pool water in Pennsylvania and West Virginia puts the total quantity at 1.36 trillion gallons (Herald-Standard 2003). It is also noted that about 27.2 billion gallons of this water are being discharged annually into surface water sources, and only 37% of this water is being treated. The above-mentioned article quoted researchers as saying that the law is unclear concerning the rights to underground water and who owns this resource.

The amount of produced water from gas and oil extraction can be quite large. As seen in Table 1, a total of about 2.16 billion barrels (90.9 billion gallons) was produced during oil and gas extraction operations in the State of California during 2001 (data adapted from State of California 2002).

TABLE 1 Produced Water in California in 2001				
County	Number of Wells	Oil Production (bbl)	Net Gas Production (mcf)	Water Production (bbl)
Alameda	5	11,179	0	17,489
Butte	9	0	289,948	2,068
Colusa	142	0	8,530,640	111,384
Contra Costa	26	0	1,167,609	24,913
Fresno	2,028	7,572,977	3,536,782	89,542,792
Glenn	168	0	10,406,098	138,289
Humboldt	31	0	1,157,152	13,049
Kern	37,101	200,813,016	221,731,873	1,165,468,011
Kings	167	158,584	565,449	740,808
Lassen	0	0	0	0
Los Angeles	3,255	28,104,571	12,728,732	557,099,611
Madera	13	0	1,294,213	831
Merced	1	0	9,574	1,164
Monterey	332	4,672,643	347,978	75,379,533
Orange	1,310	6,062,842	2,839,050	74,505,595
Riverside	0	0	0	0
Sacramento	70	0	16,417,457	338,901
San Benito	30	12,216	21,963	185,560
San Bernardino	21	11,708	160	993
San Joaquin	73	0	5,354,093	59,186
San Luis Obispo	154	717,190	–119,079	5,504,578
San Mateo	14	898	2,025	254
Santa Barbara	718	3,725,392	4,282,380	71,753,976
Santa Clara	7	28,880	5,824	26,623
Solano	185	0	18,242,645	624,571
Stanislaus	0	0	0	0
Sutter	180	0	6,857,704	93,496
Tehama	73	0	3,320,921	125,247
Tulare	73	38,259	47,491	3,350,477
Ventura	1,887	8,624,069	9,042,980	54,287,271
Yolo	74	0	9,481,280	112,971
Total[a]	**47,608**	**271,511,064**	**333,222,321**	**2,163,245,914**
[a] Individual entries do not sum to the "total" entries due to inconsistent reporting methods.				

The quantity of produced water from oil wells is known to vary over the lifetime of the well and the formation that is being tapped. It has been reported that in 2002 the average water-to-oil ratio was approximately 9.5 (Veil et al. 2004). The total water production from onshore oil wells was estimated at approximately 14 billion barrels, although the authors of the report felt confident that this underestimated the actual volume.

Coal bed methane wells are drilled into coal seams to reduce the hydrostatic pressure on the coal seams by withdrawing groundwater. This also allows methane to migrate to the well bore where it can be collected. In some parts of the United States, this water is treated and discharged into streams or other surface water bodies, but in some cases it is reinjected, reused, or evaporated (Veil 2002).

CBM production creates significant volumes of produced water — on the order of millions of gallons per day in many basins. Reinjection of this water is often not appropriate, due to the quantity of water involved and/or its quality. To illustrate the quantities involved, the average daily production of a coal-bed methane production well in the Powder River Basin at the end of 2001 was approximately 100,000 cubic feet of gas and more than 7,400 gallons of water (ARI 2002). Based on a projected 30,000 production wells, this implies almost 250 million gallons of CBM water per day for the state of Wyoming alone.

The long-term sustainability of CBM water supplies is an issue that will greatly impact the potential applications of these waters and their associated economics. Advanced Resources International (ARI) reports that from 1998 until the end of 2001, the quantity of CBM water from the Powder River Basin increased from 229,000 to 1,440,000 barrels per day. However, this dramatic increase came largely from the introduction of additional wells; average water production actually dropped from 396 barrels per well per day in 1999 to 177 barrels per day at the end of 2001 (ARI 2002). Detailed analyses suggest that water production per well will continue to drop off significantly until there is little or no water production from a given well in less than 7–10 years.

There are at least two factors that could be contributing to the decline in water production per well as described above. First, the migration of water to a given well may be declining due to geologic and hydrologic conditions in the immediate vicinity of the well. If this is the principal cause of declining water production, it is conceivable that total water production could be maintained by drilling more CBM wells. This of course requires that CBM recovery remains profitable.

A second potential cause of the declining water production is that the local aquifer providing the water is gradually depleting. If this is the major cause, then drilling more wells may not maintain total water production and the long-term sustainability of this resource becomes problematic.

It should be noted that the management of these waters can be important in determining the total cost of producing the oil or gas product. For example, ARI (2002) includes information that suggests that the quantity of economically recoverable CBM is significantly reduced as the treatment requirements for CBM water become more stringent, causing an increase in treatment costs. A loss of profitable oil or gas production would result in a decrease in tax revenues to state and local governments. Federal tax revenues could also be impacted, depending on where alternative sources of oil or gas were developed.

Some of the water considered here is only mildly saline and falls within the U.S. Environmental Protection Agency’s (EPA’s) definition of an underground source of drinking water having less than 10,000 mg/L of total dissolved solids. For example, CBM water from the Powder River Basin is generally less than 3,000 mg/L in total dissolved solids (Srinivasan 2004). Desalination of these waters is feasible, but could be impacted by the presence of organic compounds that could make the treatment process more complicated and expensive and waste disposal more difficult and costly.

IV Potential Applications

There are at least four general categories of potential applications for this water. They are: cooling water used for electric power production, potable water, agricultural water, and industrial water elsewhere than in the electric power industry (possibly including municipal applications such as street cleaning and fire protection). As discussed below in Section V, major barriers to be overcome in using these waters include the cost of treatment, the practicality of transporting the water to the point of use, and the sustainability of water volume over the lifetime of the project. Although site-specific conditions may create some differences, it is likely that the use of these waters as drinking water is more problematic (i.e., more costly) than the other three applications. Another way of enhancing the supply of potable water is to recharge aquifers using these water resources. All four general use categories are considered in this effort, and potential government incentives are incorporated into the identification of potential scenarios.

Earlier work on mine pool water identified several applications for the use of this water in power plant cooling (Veil et al. 2003a). Such waters also could potentially be used in other industrial or agricultural applications for which final water quality needs are not too restrictive and infrastructure needs would be minimal. Selected applications of these waters are briefly described in the following paragraphs.

The electric power industry is the second largest user of freshwater in the U.S., with about 135 billion gallons of water taken from freshwater sources every day. This quantity represents about 39% of all freshwater withdrawals, with only the agricultural industry drawing more (137 billion gallons per day) (USGS 2004).

Three examples from different parts of the country are described below in which the electric power industry uses treated sewage as its water supply for cooling and other plant purposes. The first example is that of a 49-MW natural gas-fired combined-cycle unit in Lodi, California (Power 2004). For the past eight years, this plant has been using the secondary effluent from a municipal wastewater treatment plant as its sole source of feed water. This water is treated in an ultrafiltration system with thin-film composite reverse osmosis membranes to remove residual salts. This system typically provides 200 gallons per minute (gpm) of treated water for the cooling tower, 65 gpm for general plant usage, and 290 gpm of demineralized boiler feed water.

The second example of treated sewage being used for power plant cooling is the Panda Brandywine plant outside of Washington, D.C., at Brandywine, Maryland. This facility is a 248-MW combined-cycle plant using natural gas as its primary fuel. Its cooling water is the effluent from the Mattawoman wastewater treatment plant (MWWTP) that is supplied through a 17-mile pipeline. It uses five mechanical-draft cooling towers, and all effluent from the towers is returned to the MWWTP. This action saves about 400 million gallons of groundwater per year and also reduces the quantity of water discharged from the sewage treatment plant to Mattawoman Creek. Groundwater can be used at the power plant only when the MWWTP effluent is not available, such as during an emergency outage (MPPRP 2001, Maryland DNR 1997).

The third example of the use of treated sewage in the electric power sector can be found in Phoenix, Arizona. The 3,810-MW Palo Verde Nuclear Generating Station is the only nuclear energy facility in the world that uses treated sewage effluence for cooling water. The plant uses effluent water from the city of Phoenix, where it is treated in an 80-acre reservoir for use in the plant's cooling towers. More than 20 billion gallons of this water are recycled each year (EPA 2002, PNM 2004).

Several other power plants have used or are proposing to use mine pool water for cooling. In 2003, the Limerick nuclear power plant in Pennsylvania began using approximately 10,000 gallons per day (of a total water demand of 40 million gallons per day) of mine pool water that was pumped from a coal mine into the Schuylkill River at a point about 78 miles upstream from Limerick. This water is not acidic and is not treated prior to its discharge into the Schuylkill (Philadelphia Inquirer 2003). Results of this test have not yet been made publicly available.

Longview Power LLC has proposed to use mine pool water from the Shannopin coal mine as cooling water for a 600-MW coal-fired power plant to be located near Morgantown, West Virginia. One feature of this proposal is an innovative agreement between several agencies of the Commonwealth of Pennsylvania, a company specializing in coal mine reclamation, and a mining company to treat this water so as to allow its use as cooling water (Veil et al. 2003a). The proposed facility is in the process of obtaining the necessary environmental permits before the project is initiated.

While all of the examples cited above deal with the use of these waters in the electric power sector, other similar industrial applications may also be feasible. Using these waters in agriculture (e.g., irrigation or barn sanitation) is also possible. As noted earlier, recharging aquifers to maintain water pressure is a way of increasing the supply of fresh water. In groundwater recharge projects, recycled water can be spread or injected into groundwater aquifers to augment groundwater supplies and prevent saltwater intrusion in coastal areas. For example, since 1976, the Water Factory 21 Direct Injection Project in Orange County, California, has been injecting highly treated recycled water into an aquifer to prevent saltwater intrusion while augmenting the potable groundwater supply (EPA 2002).

Other applications of these water resources could be patterned after uses of reclaimed water from other sources, including (State of Utah 2001):

- *Landscape irrigation:* Reclaimed sewage effluent could be used to irrigate parks, golf courses, highway medians, and residential landscapes. For example, Koele Golf Course, on the Island of Lanai, has used recycled water for irrigation since 1994. Recycled water is the only water used to irrigate this world-class golf course in the state of Hawaii.
- *Industrial process water:* Industrial facilities and power plants could use reclaimed water for cooling and other manufacturing processes.
- *Wetlands:* Reclaimed water could be used to create, restore, and enhance wetlands and artificial lakes. As an example, Incline Village, Nevada, uses a constructed wetland to dispose of wastewater effluent, expand the existing wetland habitat for wildlife, and provide an educational experience for visitors.

- *Commercial toilet flushing:* Reclaimed water could be used to flush toilets in industrial and commercial buildings, including hotels and motels. An example is the Irvine Ranch Water District, which provides recycled water for toilet flushing in high-rise buildings in Irvine, California. For new buildings over seven stories tall, the additional cost of providing a dual system added only 9% to the cost of plumbing (EPA 2002).

Other nonpotable applications include cooling water for oil refineries, industrial process water for such facilities as paper mills and carpet dyers, dust control, construction activities, and concrete mixing. In some communities of the West, homes have a water line for drinking water and a second water line with nonpotable water for irrigation. In Colorado, many large landscaped sites (e.g., golf courses, parks, and industrial sites) are irrigated with nonpotable water (CSU 2002).

Each of the various general applications will have different water quantity and quality requirements, and each application will have its own circumstances that determine its technical and economic feasibility. Each application will also have its unique benefits. These will include providing greater flexibility in siting electric power plants or other industrial facilities, making better use of a natural resource, postponing or eliminating the contamination of surface water bodies, and other site-specific benefits. Because these benefits may be very significant on environmental and/or economic scales, there may be sufficient cause for government (federal, state, and/or local) to promote the development and use of these waters.

V Issues/Barriers to Water Use

A broad range of issues must be addressed and barriers overcome if these water resources are to be utilized in an effective and efficient manner. Technical, economic, legal, regulatory, environmental, and public perception issues must be identified and resolved. Some of these issues are briefly described in the following paragraphs.

Water rights and ownership are important considerations in the development of these water resources, particularly in the Western United States. Does the oil, gas, or coal producer own the water that is produced in these fields or does the landowner, state, or some other entity own it? In the Powder River Basin, for example, as long as the CBM water was perceived to be a waste, the landowners did not want the responsibility for managing it. However, once the water is considered to have value, there could be legal battles with gas producers over ownership of the water. A discussion of the ownership of CBM from abandoned mines in Virginia is presented by McClanahan (1997). Arguments for CBM ownership on the part of the oil, gas, or coal owner and the landowner are presented. Although the McClanahan paper deals with CBM itself rather than the associated water, a summary of several legal findings is presented that could be relevant to the ownership of the water, as well. The ownership issue is one in which water policy and law must be developed to allow these water resources to be used effectively.

The use of gray water (water from showers/baths or washing machines) for agriculture purposes can be extremely complex, with issues of water rights (controlled by a given state) and wastewater treatment (controlled by a given state's department of health). For example, in

Colorado, it is illegal to use gray water for landscape irrigation. While most people would likely consider water going down the bath drain as “wasted” water, it will, in fact, be used again downstream. This wastewater becomes someone else’s water right, legally belonging to someone downstream. In most Colorado watersheds, water is reused a number of times before it finally leaves the state (CSU 2002). Issues regarding the water resources considered in this report may be similar to some of those concerning the use of gray water.

Regulatory and legal issues must also be resolved to make the widespread use of these water resources feasible. Any company using mine pool water would need to meet the provisions of their National Pollutant Discharge Elimination System (NPDES) permits as well as any other discharge requirements that might be imposed at any level of government. Measures needed to meet regulatory requirements on water discharge and their associated cost are perhaps the leading barriers to wider use of these water sources. Many regulatory agencies at all levels of government have not traditionally addressed these waters in a way that reflects their potential use as a valuable resource.

Economic regulatory policy is another issue that must be addressed. Typically regulated by state public utility commissions, investor-owned water utilities face potentially strong disincentives for the use of alternative water supplies. The traditional model of utility regulation favors supply-side investment over demand-side investment in terms of cost recovery. Regulated utilities also might require approval to implement alternative supply measures, especially changes in rate design.

Another issue that could arise with some of these waters involves radium. Many produced water samples taken throughout the United States have average radium concentrations in excess of 50 picoCuries per liter (pCi/L). Data from other sources suggest that the average radium concentration from some wells can be as high as 3,000 pCi/L. As a point of reference, it may be noted that the radium concentration limit for water discharges from nuclear facilities in the United States is 60 pCi/L. Concern about radium in produced water has prompted some states to limit the quantity of radium that can be discharged under permits granted under the NPDES.

Technical issues to be resolved include methods of effectively collecting, treating, and distributing the water and its long-term sustainability. The issue of subsidence following the withdrawal of mine pool or coal bed methane waters could also be an important consideration.

While each of the above issues represents a potential barrier to developing these water resources, the cost of using these waters is considered to be the greatest general barrier that must be overcome. It is also the barrier against which government incentives are likely to be most effective. For this reason, potential government incentives directed toward reducing user costs are the focus of the efforts described in this report.

Although there are source-specific and use-specific conditions that can impact the cost components, the overall cost of using these waters can be considered to have four major components. These are:

- *Collection:* The water from these sources must be collected for treatment and/or transport. This activity will typically involve a number of pumps and pipes and perhaps one or more storage facilities. Some governments may require a fee for significant water withdrawals. Financial and/or regulatory incentives addressing the collection of these waters could be effective in controlling these costs, and thus promoting the use of these waters.

- *Treatment:* This component is potentially the most costly of all and is an area where incentives might be most effective. Depending on the quality of the water source and its intended use, the water may have to be treated to remove contaminants that would interfere with the water's subsequent use or its ability to be discharged. Each of these alternatives could have significant cost implications for the use of these waters.

  The treatment process and its cost will be functions of initial water quality and the requirements for the water's use and/or discharge. For example, mine pool water from Pennsylvania and West Virginia tends to be either acidic or near-neutral, with high levels of total dissolved solids (TDS) and metal ions. Support for the development and testing of treatment technologies is an area where government incentives might be very effective in promoting the use of these water resources.

- *Transportation/distribution:* Depending on the relative locations of the source, use, and discharge, there may also be costs associated with transporting and/or distributing these waters. Typical means include pipelines, aqueducts, or existing streams or rivers. While truck transport may be feasible during initial phases of smaller-scale applications, it is unlikely that this mode of transport would be cost effective for long-term, larger-scale projects. Transport and distribution costs are not typically of the same order as collection or treatment costs, but could be areas for government incentives under special conditions.

- *Disposal/discharge:* Some costs might be incurred that depend on the use of these waters and the physical conditions with respect to rivers, lakes, or other ways of discharging the water. An example would be the construction of evaporative cooling towers if the water could not be discharged in another manner. Financial and/or regulatory incentives might be effective in addressing this issue.

VI Identification of Potential Government Incentives

In recognition of the importance of water supply issues, some government agencies currently provide funding for water conservation programs. A partial list of federal funding sources is located on the EPA Web site at http://www.epa.gov/owm/water-efficiency/wave0319/append_e.htm. To promote the development and use of the water resources considered here, other types of government incentives could be considered; some of these are described below.

There are several reasons why various levels of government might see fit to offer incentives for the use of these waters. These include:

- Reducing the demand on existing, conventional water resources;
- Developing a new water source to supplement or replace existing supplies;
- Eliminating the threat of having these waters contaminate a freshwater aquifer or surface body water (the biggest threat in western Pennsylvania is the overflow of contaminated mines into nearby streams);
- Conducting research and development on treatment or collection options, the long-term sustainability of the resource, or other areas of technical and economic uncertainty; and
- Enticing industry to provide or keep local jobs.

A variety of governmental incentives are available and could help promote the use of these waters. Such incentives include:

1. *Direct grants:* This type of incentive involves the government (typically at the state or federal level) paying the full or partial cost of constructing and/or operating an entire facility or a process within a facility. An example of this type of incentive at the federal level is that of cost sharing in the demonstration of new fossil-fuel electric generating technologies.
2. *Tax/royalty subsidies or reductions:* This type of incentive is most typical of a local or state government that wishes to entice new business to an area or to maintain an existing business. Underlying motives for providing this type of incentive include providing local jobs or developing or maintaining a tax base to support local government, school districts, or other entities. These subsidies are generally negotiated to last for a specified period of time.
3. *Reduced water costs to the user:* A government entity may take on the construction and operation of the facilities needed to develop and distribute this resource. To assure a market for these waters and to protect the government's investment, an incentive to use these waters may take the form of reduced rates to the water user. With a contract for a fixed quantity and quality of water at a fixed cost, users can proceed with their plans for developing businesses or other endeavors where these waters would be applied.
4. *Assured market:* A private company may elect to construct and operate the required collection, treatment, and transport/distribution equipment and facilities to allow use of these water resources. The government could offer an incentive for this development in the form of a guaranteed market for the water. With a contract for a fixed quantity and quality of water at a fixed cost, the company can proceed with greater assurance that it will get an appropriate return on its investment for at least the length of the contract.
5. *Regulatory relief to the extent possible for environmental requirements, water quality restrictions, permitting, etc.:* This type of incentive is probably the least likely to be used and would probably be the most controversial of those considered here. Easier permitting would be an incentive for construction of facilities, in that the planning and preconstruction time could be reduced, thereby saving money. Easing environmental requirements or water quality restrictions could reduce capital investment and operating costs and thus make the overall investment more attractive to potential operators. A difficulty in these types of incentives is that more than one government agency can be involved, thereby making agreements more difficult to develop. For example,

environmental requirements may be promulgated at all levels of government and by multiple agencies within a given level, so agreements to provide this sort of incentive would have to involve the cooperative efforts of many governmental entities.

The above incentives are intended to represent a spectrum of incentives that might be effective in promoting the use of waters from any or all of the sources considered here. They include incentives typically granted by local or federal government agencies, as well as by the federal government. They also include incentives to both the developers of these water resources and the users. Based on these incentives, the water resources, and potential applications described above, a set of scenarios for using incentives to encourage the development and use of these resources will be identified and discussed in the next section of this report.

VII Incentive Scenarios

There are three basic water resources that exist in quantities sufficient to potentially merit the institution of government incentives for their development: produced water from conventional gas/oil wells, CBM water from the recovery of coal bed methane from coal mines, and mine pool water that has accumulated in underground mines. As with most resources, these water resources are not uniformly distributed throughout the United States, but rather are found in those regions of the country where there is significant oil/gas production or coal mining. For this reason, most of the scenarios identified in this report are focused on the parts of the U.S. where these waters are most prevalent. However, one set of scenarios (i.e., those set in California) is intended to be representative of those areas where the demand or application is potentially greater than the supply of these waters.

Several criteria were used in developing potential scenarios for effective government incentives. These include:

- Water Type
  - Produced water
  - Coal bed methane (CBM) water
  - Mine pool water
- Physical Location
  - South-Central United States
  - Mid-Atlantic United States
  - Powder River Basin
  - California
- Potential Application
  - Electric
  - Other industrial
  - Agricultural
  - Recharge groundwater supply
- Incentive Recipient
  - Private
  - Local government

- Type of Incentive
  - Direct grant
  - Tax/royalty subsidies or reductions
  - Reduced water costs
  - Assured market
  - Regulatory relief

Not all of the 480 possible combinations of the above criteria are realistic scenarios. We have made a first cut to reduce the number of scenarios to a more workable number and offer a small number of scenarios believed to be representative of the spectrum of realistic conditions.

The linear logic illustrated in Figure 1 was used in identifying possible scenarios for consideration. As shown in this figure, scenarios were developed by first defining the water resource to be examined. The next steps were to identify the location and applications, respectively, of this resource. Consistent with the NETL programmatic objectives described in Sections I and II of this report, each of the three water sources includes an electric power industry application. As noted above, however, other applications for these waters are also possible, and some of them are noted in the identification of these scenarios. The type of organization to receive the incentive, e.g., a private company or a government agency, was then identified. The final step in developing the scenario was to identify various types of incentives that might be appropriate. At the current time, CBM water is most closely associated with the Powder River Basin and mine pool water with the Mid-Atlantic United States. For this reason, the scenarios presented in this report are focused on matching these resources and geographic region. However, the applications and incentives presented here could be matched with other water resources and geographic areas, should water resources of sufficient quantity be found. Figures 2, 3, and 4 show the scenarios that were developed for produced water, CBM water, and mine pool water, respectively.

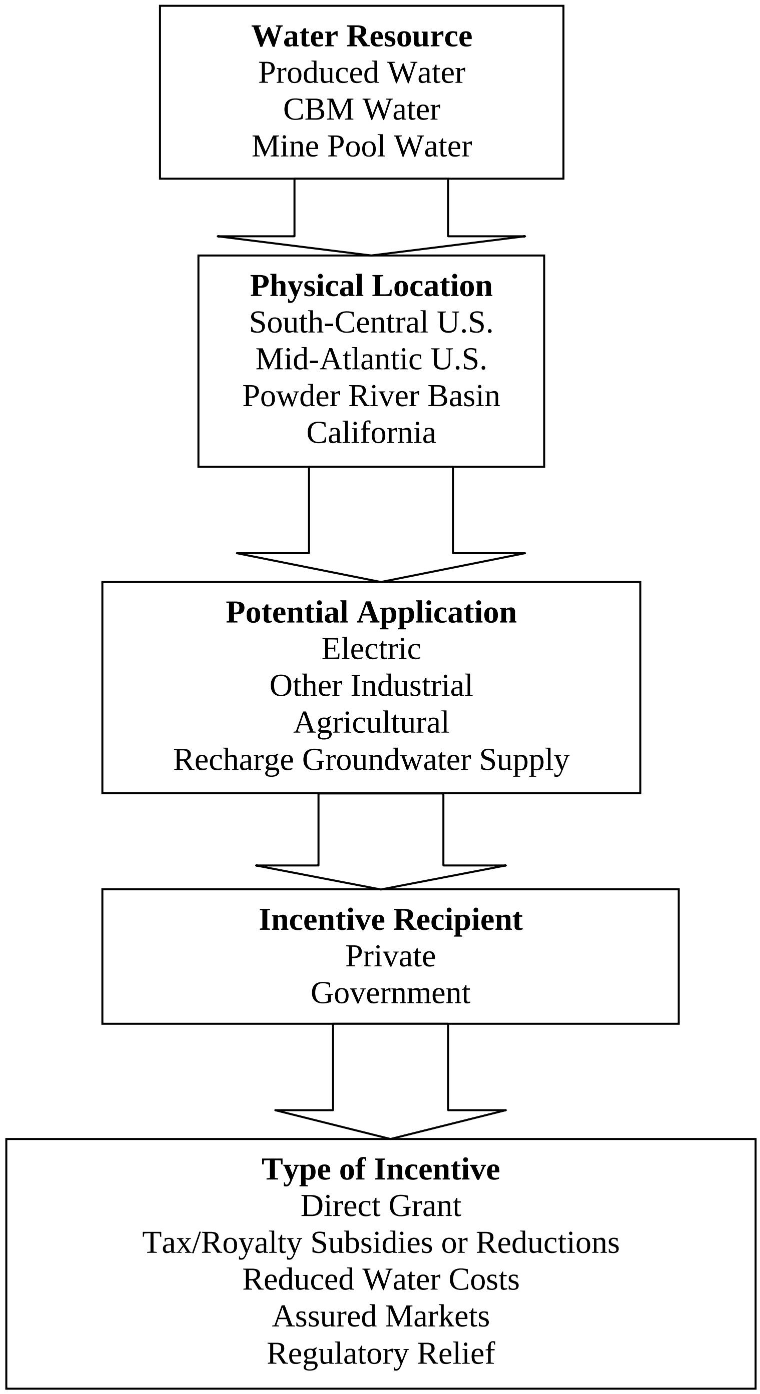

FIGURE 1 Schematic for Scenario Identification

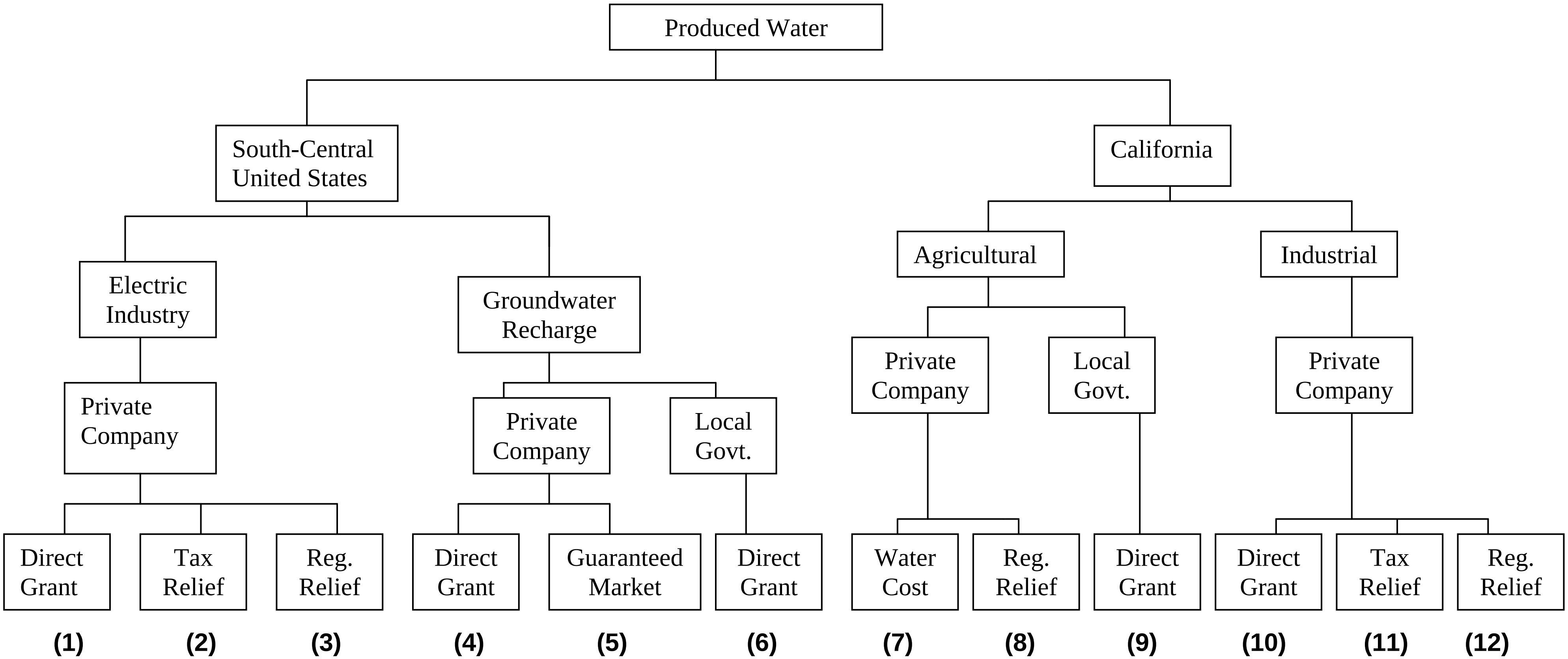

FIGURE 2 Selected Incentive Scenarios for Produced Water

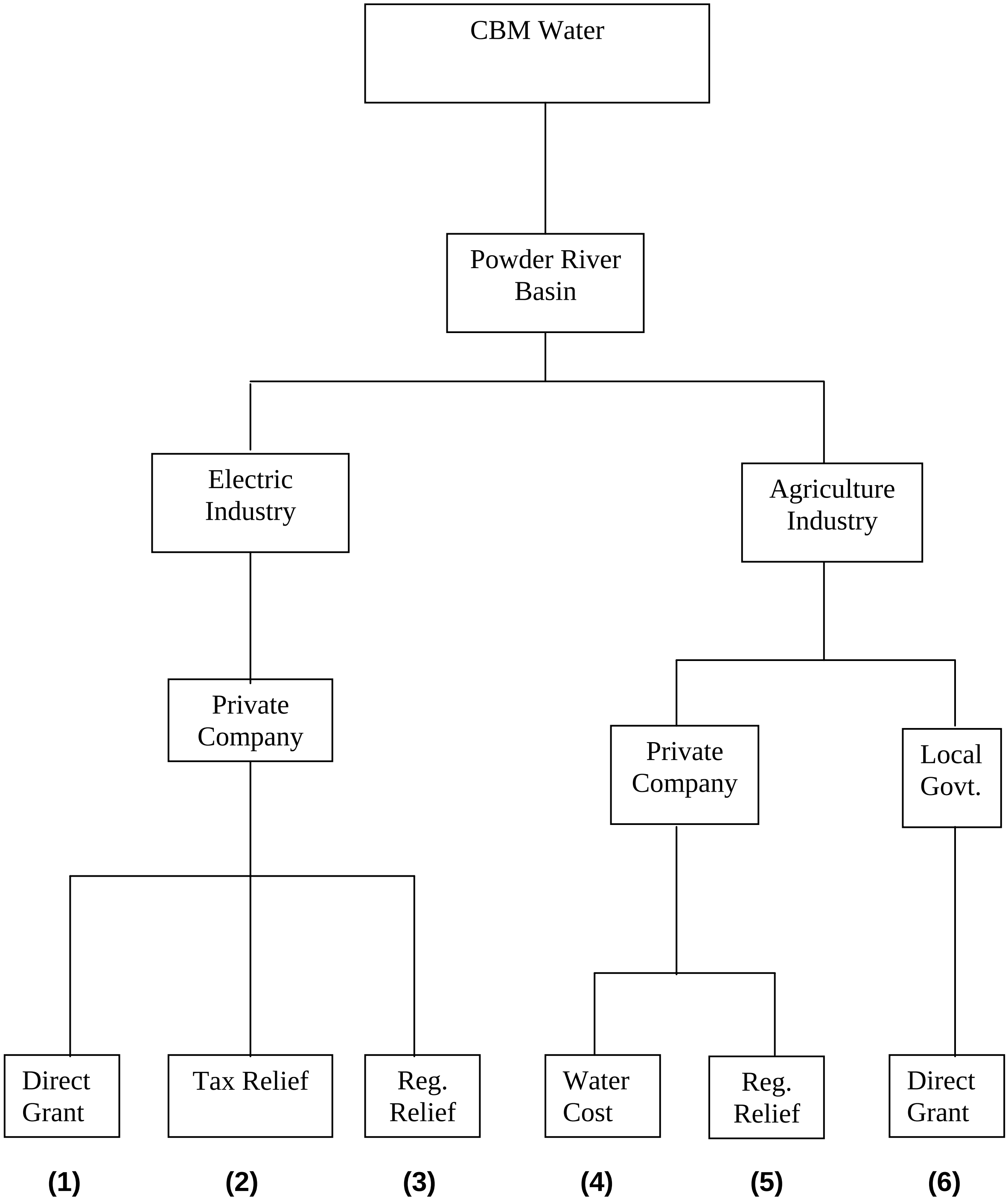

FIGURE 3 Selected Incentive Scenarios for Coal Bed Methane Water

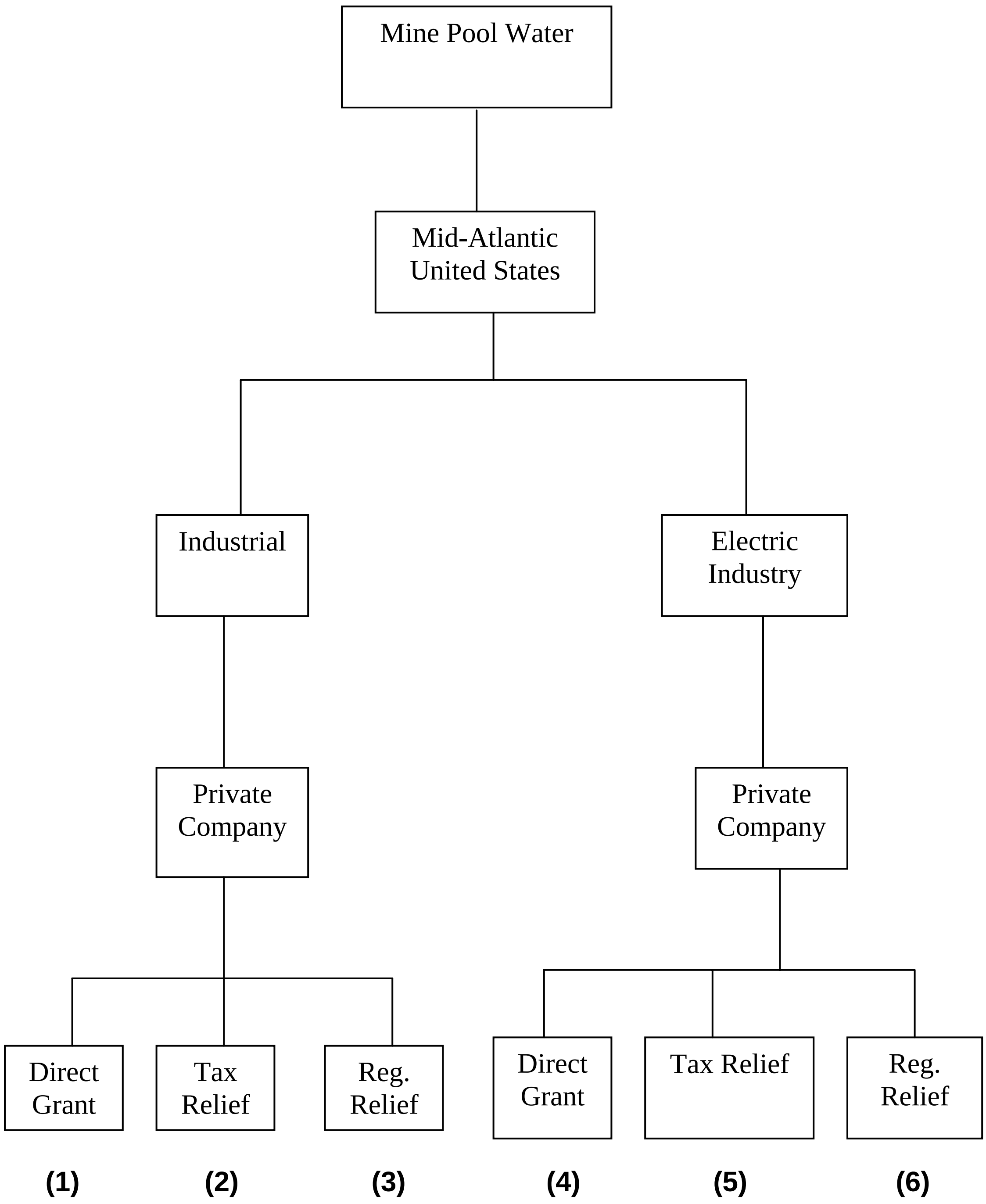

FIGURE 4 Selected Incentive Scenarios for Mine Pool Water

Scenario Descriptions

Produced Water Scenarios (Scenarios 1-6 apply to a hypothetical location in South-Central United States and scenarios 7-12 apply to a hypothetical location in California)

Produced Water Scenario 1: This scenario involves the federal, state, or local government providing a direct grant to a private company to supply produced water from South-Central U.S. oil wells for use as cooling water in the electric power sector. This grant money could be used for capital expenditures for any of the four basic steps in developing and delivering this resource. Grant money could also be used to develop and install improved ways of using produced waters in the electric power industry. Advances in heat exchanger performance or water quality maintenance represent general technological improvements that might promote the use of produced water on a large scale.

NETL is currently supporting an effort to investigate the use of produced water at the San Juan Generating Station, in New Mexico. This effort, undertaken jointly by the Electric Power Research Institute (EPRI) and Public Service of New Mexico, is investigating the feasibility of using water from oil and gas wells in the vicinity in this generating plant. A recent report (EPRI 2004) details the infrastructure availability and transportation requirements of this application. The incentives described in this scenario could be used to develop the infrastructure appropriate for this application as well as others of a similar nature.

Produced Water Scenario 2: Two variations within this scenario may be feasible. The first involves the federal government providing income tax relief to a company supplying produced water to the electric industry (this company may be the electric power company, but need not be). Another variation is that a local government provides property tax relief to a private company that agrees to develop this resource. Incentives in each case would typically be negotiated with respect to the percentage of tax relief to be granted (e.g., 100% or some lesser percentage) and its duration. A tax reduction structure that was initially at a high level but decreased with time could also be an option within this scenario.

The above-noted EPRI report on the NETL-supported project states that tax credits to support the use of produced waters in power plants and the development of the necessary infrastructure have been considered by the New Mexico legislature. The legislation authorizing such credits has not been passed.

Produced Water Scenario 3: In this scenario, the federal or state government provides regulatory relief (less stringent requirements) for discharging produced water that has been used for cooling electric power plants. This would allow the private company receiving the relief to clean the produced water to meet its operational requirements, which are assumed to be less stringent (i.e., less costly) than is typical for water that is discharged back into the environment. One form of regulatory relief involves designating the reuse of produced waters in power plants as an alternate means of disposal rather than as a beneficial use of the water. This action has been approved by the New Mexico legislature for the case described in Scenarios 1 and 2 above (EPRI 2004). Another form of regulatory relief may take the form of a less stringent interpretation of effluent limitation guidelines for water from coal seams. As with all scenarios involving an easing of environmental regulations, this one is considered to have a lower probability of being used than the other scenarios. This and the other environmental incentive scenarios are included for consideration for two reasons:

1) They represent a family of incentives that could be provided by various levels of government; and
2) They offer an opportunity to test, on a limited basis, some of the technical and economic issues associated with these waters while eliminating (or reducing) the uncertainties associated with stringent environmental compliance requirements.

<u>Produced Water Scenario 4:</u> The federal or state government provides a direct grant to a private company to provide produced water to be used in recharging local groundwater aquifers. This money could be invested in capital equipment used to collect, treat, and deliver the produced water to the aquifer. In this scenario, the grant money could also be used to develop and install injection systems to pump the produced water into the aquifer and for monitoring equipment to evaluate the response of the aquifer to the injected water.

<u>Produced Water Scenario 5:</u> The federal, state, or local government agrees to purchase a fixed quantity of produced water that has been cleaned to agreed-upon standards. The produced water will then be pumped into local aquifers to recharge the local groundwater resource. This scenario is similar to Scenario 4 above except that in this case a company or organization must make the initial capital investments on its own. Once these investments have been made, the company or organization will be guaranteed a return on its investment as long as the contractual terms are met.

<u>Produced Water Scenario 6:</u> The federal or state government provides a direct grant to a local government to collect, clean, and deliver produced water that will be used to recharge local groundwater aquifers. This scenario is also similar to Scenario 4 except that in this case a local government entity receives the grant money. This scenario would likely be most applicable for those cases in which the aquifer to be recharged served a number of communities or regions within a state or in two or more states.

<u>Produced Water Scenario 7:</u> In this scenario, a governmental entity purchases, installs, and operates the equipment and facilities needed to collect, clean, and deliver produced water for agricultural applications. The water is then sold to a private agricultural company or organization at a price lower than what the private concern would normally have to pay for water. The private company or organization is thus assured of a continuous supply of water for the term of any contractual agreements with the governmental entity. An alternative within this scenario is that a fixed quantity of water would be provided at a nominal cost where no other water resource is available for agricultural applications.

Produced Water Scenario 8: The federal or state government provides regulatory relief that eases the standards for discharging produced water into surface water sources, provided that the produced water has been used for agricultural purposes. This relief allows the private company to clean the produced water to meet agricultural requirements, which may be less stringent (i.e., less costly) than is typical for agricultural waters that are discharged back into the environment. In those cases where the discharge of agricultural water is not currently regulated, this scenario would allow this water resource to be developed and applied for agricultural purposes without requiring the private company or organization to risk the promulgation of future regulations that might inhibit the use of these waters in this way.

Produced Water Scenario 9: The federal or state government provides a direct grant to a local government to collect, clean, and deliver produced water that will be used for agricultural purposes. This scenario would likely be most applicable in those cases where the agricultural sector places a heavy demand on the existing water supply capabilities of the local government or where agricultural demands are indirectly impacting municipal water services because both demands are currently being supplied by the same source.

Produced Water Scenario 10: This scenario involves the federal, state, or local government providing a direct grant to a private company to provide produced water to industry. The grant money could be used for capital expenditures for any of the four basic steps in developing and delivering this resource. Similar to Scenario 1, the grant money could also be used to demonstrate methods for attaining improved water efficiency in the industrial sector. The private company could be the consumer of this water, or it could be allowed to sell the water to other industrial concerns.

Produced Water Scenario 11: This scenario is similar to Scenario 2 except that the application in this case is the industrial sector. One variation within this scenario involves the federal government providing income tax relief to a company providing produced water for use in the industrial sector. A second variation is that a local government provides property tax relief to a private company providing produced water to industry. Incentives in each case would typically be negotiated with respect to the percentage of tax relief to be granted (e.g., 100% or some lesser percentage) and its duration. A tax reduction structure that was initially at a high level but decreased with time could also be an option within this scenario.

Produced Water Scenario 12: Similar to Scenario 3, the federal or state government provides regulatory relief for discharging produced water that has been used in the industrial sector. This relief allows the private company to clean the produced water to meet its operational requirements, which are assumed to be less stringent (i.e., less costly) than is typical for water that is discharged back into the environment. A specific form of regulatory relief may take the form of a less stringent interpretation of effluent limitation guidelines for water from coal seams.

Coal Bed Methane Water Scenarios (Scenarios 1-6 apply to a hypothetical location in the Powder River Basin)

Coal Bed Methane Water Scenario 1: This scenario involves the federal, state, or local government providing a direct grant to a private company to provide CBM water from Powder River Basin coal seams for use in the electric power sector. It is similar to Scenario 1 for produced water. Grant money could be invested in capital equipment used to collect, treat, or deliver the CBM water to the power plant. Advances in heat exchanger performance or water quality maintenance represent general technological improvements that might promote the use of produced water on a large scale.

Coal Bed Methane Water Scenario 2: This scenario is similar to Scenario 2 for produced water. As in the produced water scenario, two variations within this scenario may be feasible. The first involves the federal government providing income tax relief to a company providing CBM water to the electric industry (this company may be the electric power company, but need not be). Another variation is that a local government provides property tax relief to a private company that agrees to develop this resource. Incentives in each case would typically be negotiated with respect to the percentage of tax relief to be granted (e.g., 100% or some lesser percentage) and its duration. A tax-reduction structure that was initially at a high level but decreased with time could also be an option within this scenario.

Coal-Bed Methane Water Scenario 3: As in Produced Water Scenario 3, the federal or state government provides regulatory relief for discharging CBM water that has been used for cooling electric power plants. This relief allows the private company to clean the CBM water to meet its operational requirements, which are assumed to be less stringent (i.e., less costly) than is typical for water that is discharged back into the environment. A specific form of regulatory relief may take the form of a less stringent interpretation of effluent limitation guidelines for water from coal seams.

Coal bed Methane Water Scenario 4: In this scenario, a governmental entity purchases, installs, and operates the equipment and facilities needed to collect, clean, and deliver CBM water for agricultural applications. The water is then sold to a private agricultural company or organization at a price lower than what the private concern would normally have to pay for water. The private company or organization is thus assured a continuous supply of water for the term of the contractual agreements with the governmental entity. An alternative within this scenario is that a fixed quantity of water would be provided at a nominal cost where no other water resource is available for agricultural applications.

Coal bed Methane Water Scenario 5: The federal or state government provides regulatory relief to a private company that eases the standards for discharging CBM water into surface water sources, provided that the water has been used for agricultural purposes. This relief allows the private company to clean the CBM water to meet agricultural requirements, which may be less stringent (i.e., less costly) than is typical for agricultural waters that are discharged back into the environment. In those cases where the discharge of agricultural water is not currently regulated, this scenario would allow CBM water to be developed and applied for agricultural purposes without requiring the private company or organization to risk the promulgation of future regulations that might inhibit the use of these waters in this way.

Coal Bed Methane Water Scenario 6: The federal or state government provides a direct grant to a local government to collect, clean, and deliver CBM water that will be used for agricultural purposes. This scenario would likely be most applicable in those cases where the agricultural sector places a heavy demand on the existing water supply capabilities of the local government or where agricultural demands are indirectly impacting municipal water services because both demands are currently being supplied by the same source.

Mine Pool Water Scenarios (Scenarios 1-6 apply to a hypothetical location in the Mid-Atlantic region of the United States)

Mine Pool Water Scenario 1: This scenario involves the federal, state, or local government providing a direct grant to a private company to provide mine pool water to industry. The grant money could be used for capital expenditures for any of the four basic steps in developing and delivering this resource, and/or it could be used to demonstrate methods for attaining improved water efficiency in the industrial sector. The private company could be the consumer of this water, or it could be allowed to sell the water to other industrial concerns. This scenario could lead to greater use of mine pool water in the electric power sector beyond the applications noted in Section IV of this report.

Mine Pool Water Scenario 2: This scenario is similar to Produced Water Scenario 2 except that the application in this case is the industrial sector. One variation within this scenario involves the federal government providing income tax relief to a company providing mine pool water for use in the industrial sector. A second variation is that a local government provides property tax relief to a private company providing mine pool water to industry. Incentives in each case would typically be negotiated with respect to the percentage of tax relief to be granted (e.g., 100% or some lesser percentage) and its duration. A tax reduction structure that was initially at a high level but decreased with time could also be an option within this scenario.

Mine Pool Water Scenario 3: This scenario is similar to Produced Water Scenario 3 except that the application in this case is the industrial sector. The federal or state government provides regulatory relief for discharging mine pool water that has been used in the industrial sector. This relief allows the private company to clean the mine pool water to meet its operational requirements, which are assumed to be less stringent (i.e., less costly) than is typical for water that is discharged back into the environment. Regulatory relief may take the form of a less stringent interpretation of effluent-limitation guidelines for water from coal seams.

Mine Pool Water Scenario 4: The federal or state government provides a direct grant to a private company to provide mine pool water to be used in the electric power sector. As discussed in

Section IV of this report and in referenced documents, there are already several instances involving the use of mine pool water in the electric sector. An objective of this scenario could be to investigate the effectiveness of direct grants, restrictions on grant money use (e.g., money could be used for water treatment but not collection or distribution), and similar conditions in promoting the expanded use of these waters in electric power applications.

Mine Pool Water Scenario 5: Two variations within this scenario may be feasible. The first involves the federal government providing income tax relief to a company providing mine pool water to the electric industry (this company may be the electric power company, but need not be). Another variation is that a local government provides property tax relief to a private company that agrees to develop this resource. Incentives in each case would typically be negotiated with respect to the percentage of tax relief to be granted (e.g., 100% or some lesser percentage) and its duration. A tax reduction structure that was initially at a high level but decreased with time could also be an option within this scenario.

Mine Pool Water Scenario 6: In this scenario, the federal or state government provides regulatory relief for discharging mine pool water that has been used for cooling electric power plants. This relief allows the private company to clean the water to meet its operational requirements, which are assumed to be less stringent (i.e., less costly) than is typical for water that is discharged back into the environment. Regulatory relief may take the form of a less stringent interpretation of effluent limitation guidelines for water from coal seams.

The twenty-four scenarios identified above are not intended to exhaust the realm of governmental incentives that could be effective in promoting the use of one or more of these water resources. Instead, they are intended to provide a sense of those situations that might be conducive to this end. Nor do the identified scenarios have any implied likelihood of effectiveness or probability of acceptability. As noted elsewhere, the scenarios involving relief from environmental regulations have a low probability of being implemented.

Once a set of scenarios has been selected for more detailed evaluation, a methodology will be developed and applied to more quantitatively assess each scenario. The next two sections of this report provide initial considerations regarding the development of an assessment approach and the metrics to be used in evaluating the effectiveness of the selected scenarios in promoting the use of these waters.

IX Assessment Approach

As noted earlier, the overall objective of this effort is to define a set of scenarios from which a smaller set will be selected for more detailed analyses. In order to select this smaller set, an idea of the methods to be used in such analyses would be valuable. Although the assessment details have yet to be developed, a potential basic approach is outlined as follows.

A set of basic characteristics will be developed for each water resource, location, application, and recipient combination (e.g., the top four tiers of Figures 2–4). These characteristics will be as consistent as possible among these combinations, but a recognition of fundamental differences in location, application, etc., will be made. The characteristics will include the costs of developing and delivering these waters to the various applications, typical costs of potential alternative water sources, the estimated time to develop these resources, interest rates and loan periods, and other parameters describing the physical and financial conditions typically encountered in each of the applications.

Financial terms associated with government incentives have a wide range of values and stipulations. For the purposes of these assessments, a set of "typical" assumptions will be made for each type of grant. These assumptions will include, as appropriate, the amount of money in a direct grant, the number of years that tax relief will be granted and the extent of this relief, the value of water to be purchased or provided as an incentive, and the time period over which such agreements are to be in effect. Quantitative analyses will then be conducted to evaluate the benefits (if any) of the various incentives relative to those costs that would be incurred without them. Because of the wide range of conditions associated with both the indicated markets and the incentives, parametric analyses will be conducted for many of the variables thought to be most influential in impacting the comparisons.

Nonmonetary objectives of the use of these water sources (such as those noted in Section IV of this report) will also be described for each scenario. These nonmonetary benefits will be evaluated in a more subjective manner to provide insight into the relative benefits of the scenarios.

X Metrics for Success

Following the quantitative evaluation of the incentive scenarios and a qualitative discussion of some of the nonmonetary issues, a set of metrics will be used to measure the likelihood of success of each incentive type and to determine which of them might be the most effective in promoting the use of these water resources. As with the assessment methodology, the metrics have yet to be determined, but could potentially include the measures below. As noted earlier, some of the metrics are quantitative in nature, while others are expected to be more subjective or qualitative. Methods of combining these metrics into an overall rating or scoring process will be determined as part of the development of the overall assessment methodology. It is also noted that some of these metrics may be correlated, so care must be taken to not "double count" some benefits. Possible metrics are:

- Effect on cost of product,
- Return on investment of government funds,
- Jobs created or maintained,
- Potable water replaced,

- Environmental impacts (some possibly averted by the actions and some caused by new applications),
- Tax revenues lost via the incentive versus those gained by new business,
- Likelihood that additional applications will follow without incentives,
- Sustainability of the water resource, and
- Likelihood of achieving research goals.

XI Recommended Actions

The quantities of water generated through the production of gas, oil, and coal represent largely untapped resources that can potentially be used in beneficial ways. Management of these waters currently adds significantly to the cost of developing the energy resources and is becoming an increasingly important environmental issue, as these waters threaten to pollute surface and groundwater supplies. Some efforts have been initiated to use these waters in electric power production, but these efforts represent only a minute fraction of the potential uses for these waters.

Government incentives can potentially provide sufficient impetus to use these waters in different ways and in greater quantities. Several such incentives have been suggested in this report. It is recommended that these potential incentives be reviewed by knowledgeable people to verify that they are representative of the types of incentives that could be provided. A number of potential applications for these waters are also presented in this report. These uses should also be reviewed by people familiar with this issue. The incentives and applications combine to form scenarios for uses these waters.

Once a set of scenarios has been agreed upon, quantitative analyses should be conducted to determine which incentives might be most effective in promoting the use of these waters. Such analyses would include consideration of the cost of the incentive, its duration, the quantity of water used (annually and over the expected lifetime of a given project), environmental factors, local jobs, and other economic, environmental, and social factors. A set of metrics for determining the "best" incentives would be developed as part of the analytical process. A preliminary set of metrics is provided in this report, but it is recommended that the experts reviewing the incentives and applications also provide insight as to the appropriate metrics to be used in evaluating the incentives and applications.

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