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The Impact of Limited Water Availability on National Coal Policy Student Symposium - Selected Issues Concerning Increased Coal Use.

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STUDENT SYMPOSIUM: SELECTED ISSUES CONCERNING INCREASED COAL USE

THE IMPACT OF LIMITED WATER AVAILABILITY ON NATIONAL COAL POLICY

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Implementation of the objective of President Carter's National Energy Plan[1] to convert "from scarce fuels to coal wherever possible"[2] will be accomplished largely under the Powerplant and Industrial Fuel Use Act of 1978.[3] The specific purposes of the Act directly affecting future coal use are threefold: to "increase the nation's capability to use indigenous energy resources,"[4] to "encourage and foster the greater use of coal,"[5] and to "encourage the use of synthetic gas derived from coal . . . ."[6] The principal implementing provisions of the Act prohibit the use of natural gas or petroleum as a baseload fuel in any new electric powerplant,[7] the construction of new electric powerplants which lack the capability to burn coal,[8]

1. As announced by President Carter to Congress on April 20, 1977. Address by President Carter to a Joint Session of Congress, 13 WEEKLY COMP. OF PRES. DOC. 566 (Apr. 22, 1977).
2. *Id.* at 567, 570.
3. Pub. L. No. 95-620, 92 Stat. 3289, 42 U.S.C.A. §§ 8301-8483 (West Supp. 1978) (Fuel Use Act).
4. *Id.* § 102(b)(1), 42 U.S.C.A. § 8301(b)(1).
5. *Id.* § 102(b)(3), 42 U.S.C.A. § 8301(b)(3).
6. *Id.* § 102(b)(4), 42 U.S.C.A. § 8301(b)(4). Section 102(b)(8) requires also "that existing and new electric powerplants and major fuel-burning installations which utilize natural gas, petroleum, coal or other alternate fuels pursuant to this Act comply with applicable environmental requirements." *Id.* § 102(b)(8), 42 U.S.C.A. § 8301(b)(8).
7. *Id.* § 201(1), 42 U.S.C.A. § 8311(1).
8. *Id.* § 201(2), 42 U.S.C.A. § 8311(2).

and the use of natural gas as a primary energy source in existing electric powerplants after January 1, 1990.[9]

The President has set the goal of increasing United States coal production by more than two-thirds of its 1977 level and increasing coal use by utilities and industry from 600 million tons per year in 1977 to one billion tons by 1985.[10] Even without the impetus of a national coal conversion policy, however, the use of coal to generate electricity has risen sharply since 1975.[11] Meanwhile water, which is essential to the production and use of coal, is increasingly in short supply.[12] A recent Department of Energy

9. *Id.* § 301(a)(1), 42 U.S.C.A. § 8341(a)(1); *see* SENATE COMM. ON ENERGY AND NATURAL RESOURCES, POWERPLANT AND INDUSTRIAL FUEL USE ACT OF 1978, S. REP. No. 95-361, 95th Cong., 2d Sess. 28, *reprinted in* [1978] U.S. CODE CONG. & AD. NEWS 8173, 8174. The Act also extends the coal conversion provisions of the Energy Supply and Environmental Coordination Act (ESECA) by allowing the Secretary of Energy to prohibit the use of natural gas or petroleum in existing plants which have or previously had coal-burning capability. Fuel Use Act § 301(b), 42 U.S.C.A. § 8341(b) (West Supp. 1978); *see* Energy Supply and Environmental Coordination Act of 1974, 15 U.S.C. § 791 (1976). The Powerplant and Industrial Fuel Use Act incorporates a number of exemptions, exceptions, and compliance options in order to prevent undue hardship. Fuel Use Act, §§ 211-214, 42 U.S.C.A. §§ 8321-8324 (exemptions for new facilities), 311-314, 42 U.S.C.A. §§ 8351-8354 (exemptions for existing facilities), 501, 42 U.S.C.A. § 8391 (utility system compliance option) (West Supp. 1978); SENATE COMM. ON ENERGY AND NATURAL RESOURCES, POWERPLANT AND INDUSTRIAL FUEL USE ACT OF 1978, S. REP. No. 95-361, 95th Cong., 2d Sess. 27-29 (1978), *reprinted in* [1978] U.S. CODE CONG. & AD. NEWS 8173, 8173-8175. In addition, the Act authorizes loans and loan guarantees when normal financing is unavailable for air pollution equipment required by clean air regulations, and local impact assistance for public facilities, services or housing necessitated by expanded coal production. *See* Fuel Use Act, §§ 601-602, 42 U.S.C.A. §§ 8401-8402 (West Supp. 1978); SENATE COMM. ON ENERGY AND NATURAL RESOURCES, POWERPLANT AND INDUSTRIAL FUEL USE ACT OF 1978, S. REP. No. 95-361, 95th Cong., 2d Sess. 29-30, *reprinted in* [1978] U.S. CODE CONG. & AD. NEWS 8173, 8174-75.

10. Address by President Carter to a Joint Session of Congress, 13 WEEKLY COMP. OF PRES. DOC. 566, 567, 570 (Apr. 22, 1977).

11. *See* SENATE COMM. ON ENERGY AND NATURAL RESOURCES, POWERPLANT AND INDUSTRIAL FUEL USE ACT OF 1978, S. REP. No. 95-361, 95th Cong., 2d Sess. 33 (1978), *reprinted in* [1978] U.S. CODE CONG. & AD. NEWS 8173, 8179. The report projected an increased demand of about 400 million tons of coal per year by 1985 for electric generating plants, and a possible additional 100 million tons per year if nuclear powerplant construction is delayed. *Id.* at 33-34, *reprinted in* [1978] U.S. CODE CONG. & AD. NEWS at 8179-80. This estimate is substantially the same as the President's own stated goal for increased use of coal. *See* Address by President Carter to a Joint Session of Congress, 13 WEEKLY COMP. OF PRES. DOC. 566, 567, 570 (Apr. 22, 1977).

12. President Carter stated in his message to Congress of June 6, 1978: "Of 106 watershed subregions in the country, 21 already have severe water shortages. By the year 2000 the number could increase to 39 subregions. The Nation's cities are also beginning to experience water shortage problems. . . . In some areas, precious groundwater supplies are also being depleted at a faster rate than they are replenished." Message from President Carter to Congress: Federal Water Policy, 14 WEEKLY COMP. OF PRES. DOC. 1043 (June 12, 1978). *See generally Water Availability for Energy Development in the West: Hearings Before the Subcomm. on Energy Production and Supply of the Senate Comm. on Energy and Natural Resources*, 95th Cong., 2d Sess. 58-60 (1978) (statement of Alan Merson, Environmental Protection Agency (EPA)); *id.* at 186-87 (statement of John Stencel, Rocky Mountain Farm-

study observed that with or without implementation of the National Energy Plan, limitations on water resources may constrain energy development in certain regions.[13] Therefore, despite projected conservation of energy under the National Energy Plan, conversion to coal use will produce changes in patterns of water use which will in turn produce conflicts, at some times and locations, with existing water uses.[14] While coal conversion will create other problems, notably environmental, social, and economic,[15] this comment will be limited to consideration of consequences resulting from shifts of water resources from other uses to use in coal production and consumption of coal by electric utilities.[16] Discussion will focus on water requirements in the various stages of coal production and in several methods of cooling coal-fired generating plants; water availability problems at the national and western regional levels; the impact of water availability on increased coal use in Texas; and finally, means of increasing available water supplies.

I. USE OF WATER IN PRODUCTION AND COMBUSTION OF COAL

In any discussion of water use, distinction must be made between with-

ers Union); *id.* at 214 (statement of Mohamed El-Ashry, Environmental Defense Fund) [hereinafter cited as *Hearings on Water Availability for Energy Development in the West*]; FISH AND WILDLIFE SERVICE, UNITED STATES DEP'T OF INTERIOR, THE DROUGHT SITUATION (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 496, 497 (1977).

13. 2 DIVISION OF TECHNOLOGY IMPACTS, OFFICE OF TECHNOLOGY IMPACTS, UNITED STATES DEP'T OF ENERGY, AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, 8-1, 8-12 (Feb. 1979) (TID-2945) [hereinafter cited as AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION]. In contrast, agricultural interests in Western states express fears that their industry will not be able to compete economically for water against the energy industry. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 143 (statement of Ben Eastman, Colorado Agriculture Commission); *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 186 (statement of John Stencel, Rocky Mountain Farmers Union).

14. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-4 to -13. *See generally Hearings on Water Availability for Energy Development in the West, supra* note 12, at 42 (statement of Guy R. Martin, Dep't of Interior); Trelease, *The Changing Water Market for Energy Production,* 5 J. CONTEMP. L. 83, 83 (1978).

15. *See generally Hearings on Water Availability for Energy Development in the West, supra* note 12, at 58-59, 61 (statement of Alan Merson, EPA); *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 132 (statement of Charles Jarman, Arizona Public Service Co.); EXECUTIVE OFFICE OF THE PRESIDENT, ENERGY POLICY AND PLANNING, NATIONAL ENERGY PLAN II, APPENDIX, III-2 to -5 (1979); Trelease, *The Changing Water Market for Energy Production,* 5 J. CONTEMP. L. 83, 83 (1978).

16. In 1976 electric utilities accounted for 75 percent of total coal consumption in the United States. While industry consumed about as much electricity as utilities, it purchased most of its requirements from utilities. *See* SENATE COMM. ON ENERGY AND NATURAL RESOURCES, POWERPLANT AND INDUSTRIAL FUEL USE ACT OF 1978, S. REP. No. 95-361, 95th Cong., 2d Sess. 31-33, reprinted in [1978] U.S. CODE CONG. & AD. NEWS 8173, 8177-79.

drawals of water and consumption of water. Water merely withdrawn, used, and returned directly or indirectly to the source will remain available to other users dependent upon the same system.[17] Theoretically, such water can be recycled continually while it remains in the watershed,[18] so long as its quality remains acceptable and sufficient instream flow is maintained.[19] Practically speaking, however, much water may be lost to evaporation[20] or recharge of aquifers too deep to be pumped,[21] and water quality considerations may prevent the natural recycling of used water. For example, water used in coal washing becomes polluted and therefore unsuitable to other water users near the mine site.[22] Far more significant pollution occurs in electric generating plants which depend upon stack scrubbers or ash settling ponds to reduce air pollutants and particulates. As of 1978, Arizona Public Service Company in Phoenix discharged three million gallons of ash-pond and scrubber-polluted water per day into local water supplies.[23] Furthermore, the combination of strict air pollution and water

17. *See generally* Trelease, *The Changing Water Market for Energy Production,* 5 J. CONTEMP. L. 83, 85 (1978). In a description of the historical derivation of Western appropriative water law from the agricultural use of water, Trelease explains the recycling of water used for irrigation: "[O]nly a portion of the water diverted and applied to adjacent fields evaporates or is consumed by plants; the remainder seeps back into the stream where it becomes available downstream. Since water can be used and reused, many irrigators may have rights to the same molecules of water." *Id.* at 85. *But see* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1355 (1977) (about half of irrigation water from Bureau of Reclamation projects is wasted through over-irrigation).

18. *See* Trelease, *The Changing Water Market for Energy Production,* 5 J. CONTEMP. L. 83, 85 (1978).

19. *See* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 275-76 (1979). *See generally Hearings on Water Availability for Energy Development in the West, supra* note 12, at 211 (testimony of Mohamed El-Ashry, Environmental Defense Fund). Where downstream riparian uses exist, of course, both reasonable quality and flow must be maintained. Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 275-76 (1979).

20. Geological survey research shows that 57 percent of water withdrawn nationwide for irrigation use is consumed, while only 0.86 percent of water withdrawn by electric powerplants is consumed. GEOLOGICAL SURVEY, UNITED STATES DEP'T OF INTERIOR, GEOLOGICAL SURVEY PROFESSIONAL PAPER 1050, at 128-129 (1977). Agricultural interests, however, sometimes urge the opposite position. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 143 (statement of Ben Eastman, Colorado Agriculture Comm'n).

21. *See* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong, 1st Sess. 1321, 1355 (1977).

22. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 143 (statement of Ben Eastman, Colorado Agriculture Comm'n).

23. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 132 (statement of Charles Jarman, Arizona Public Service Co.).

pollution standards creates the temptation for coal-burning utility plants to simply evaporate dirty water, thus simplifying the compliance and disposal problems but simultaneously increasing water consumption.[24]

A. *Water Use in Mining Operations*

The extraction and initial processing of coal is the least significant phase of coal use in terms of water requirements.[25] The United States Geological Survey concluded in 1977 that total annual water consumption for coal mining in the United States is about the same as the water consumption of only two 1,000 megawatt thermoelectric power plants,[26] each of which is capable of serving the energy needs of 150,000 people.[27] In western surface mining, relatively small quantities of water are used for surface drilling fluids; dust suppression on roads, spoil piles, tipples,[28] and other coal-handling facilities; coal washing; equipment cleaning and maintenance; settling ponds for mine discharge; drinking and other on-site domestic uses; fire hazard protection; and revegetation of mined land.[29] The trans-

24. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-10, -11. *See generally* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 284 (1979).

25. *See* Greer, *Water Problems Encountered in Surface Coal Mining in the Western United States,* 22 ROCKY MTN. MIN. L. INST. 277, 277 (1976). The Department of Energy agrees, but points out that there may still be "significant local water shortages in western coal reserve areas." AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-2.

26. GEOLOGICAL SURVEY, UNITED STATES DEP'T OF INTERIOR, GEOLOGICAL SURVEY PROFESSIONAL PAPER 1050, at 131 (1977).

27. *See* Hoffman, Water for Lignite Development in Texas, 1-2 (June 3, 1976) (unpublished paper available from Texas Dep't of Water Resources) [hereinafter cited as Hoffman, Water for Lignite Development]. For purposes of comparison in this comment, a 1,000 MW steam-electric generating plant is assumed to consume 2.5 million tons of coal per year. The exact figure, of course, will vary depending on the powerplant design and the type of coal burned. For example, the 836 MW coal-fired powerplant in San Antonio, Texas consumes approximately three million tons of low sulfur western coal per year. Interview with Arthur J. von Rosenberg, City Public Service Co., in San Antonio (Jan. 16, 1980). The Department of Energy estimates that a 1,000 MW coal-fired powerplant operating at 65 percent load capacity and 39 percent plant thermal capacity using eastern bituminous coal with an average heat output of 22 million Btu's per short ton consumes 2.3 million tons per year. Interview with Oscar Straginer, Assistant Director, Office of Congressional Affairs, United States Dep't of Energy, by telephone, in Washington (Jan. 18, 1980).

28. Devices for emptying coal cars at a coal screening plant. *See* WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY 2398 (1966).

29. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 218 (statement of Darry A. Ferguson, Energy Fuel Corp.); *see* Greer, *Water Problems Encountered in Surface Coal Mining in the Western United States,* 22 ROCKY MTN. MIN. L. INST. 277, 277 (1976). The Geological Survey reports that surface mining consumes about 4.5 gallons per ton; waste disposal consumes over 8 gallons per ton; and, where reclamation of mined land is required in the West, revegetation consumes over 17 gallons per ton of coal mined. *See* GEOLOGICAL SURVEY, UNITED STATES DEP'T OF INTERIOR, GEOLOGICAL SURVEY PRO-

port of mined coal by slurry pipeline is a totally consumptive use from the standpoint of the state supplying the slurry water. A pipeline designed to move 25 million tons of coal per year is estimated to require 240 gallons per ton, or 18,240 acre-feet per year.[30] Another factor which water planners must consider is the increase in local population which results where coal is mined, processed, or consumed, and even where construction workers move in temporarily to build new generating plants. If each worker increases the local population by eight persons, and average per capita use is 200 gallons of water a day, the temporary or permanent burden on local domestic water supplies can become considerable.[31]

B. *Water Use in the Combustion Cycle*

The burning of coal in steam-electric generating plants places a far greater burden upon local water supplies than do surface mining uses.[32]

FESSIONAL PAPER 1050, at 131 (1977). Using these figures, one can conclude that approximately 29.5 gallons of water per ton of coal is consumed in western strip mining. *Id.* Using a different perspective on one aspect of this water use, the Environmental Defense Fund estimates that .5 to 4 acre-feet per acre mined per year is needed for re-establishment of vegetation and that some areas will take two years to re-establish. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 211 (statement of Mohamed El-Ashry, Environmental Defense Fund). Using the conversion factor of 326,000 gallons to 1 acre-foot, one reaches the result of 163,000 to 1,304,000 gallons per acre for reclamation. *See* GEOLOGICAL SURVEY, UNITED STATES DEP'T OF INTERIOR, I WATER RESOURCES DATA FOR TEXAS, WATER YEAR 1977, at 4 (1977). According to the Department of Energy, this water requirement may impede the National Energy Plan in the West, where water is scarce. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supr* note 13, at I-10.

30. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 62 (statement of Alan Merson, EPA). A somewhat lower estimate of 15,000 acre-feet per year is given by Clyde. Clyde, *Coal Mining, Development and Processing—The Associated Water Problems,* 21 ROCKY MTN. MIN. L. INST. 163, 165 (1975); and a somewhat higher estimate of 20,000 acre-feet per year is offered by the Environmental Defense Fund. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 211 (statement of Mohamed El-Ashry, Environmental Defense Fund). *See generally* EXECUTIVE OFFICE OF THE PRESIDENT, ENERGY POLICY AND PLANNING, NATIONAL ENERGY PLAN II APPENDIX, II-42 to -43 (1979). The prospective development of coal slurry lines is one of the most hotly debated and emotionally charged issues extant in western states, where coal mining is increasingly seen as a threat to traditional water supplies for irrigation of semi-arid croplands. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 189 (statement of John Stencel, Rocky Mountain Farmers Union) ("[W]e don't intend to surrender to these giants without a fierce battle.") In recent years, several states have passed legislation designed to prevent or obstruct the use of water in slurry lines moving coal out of state. *See, e.g.,* MONT. REV. CODES ANN. §§ 89-867, 89-892 (Supp. 1977); OKLA. STAT. ANN. tit. 27, § 7.6 (West Supp. 1979); WYO. STAT. § 41-2-301 (Supp. 1979).

31. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 193 (statement of J. Blaine Miller, Rio Blanco Oil Shale Co.). Average per capita water use in Texas is 144 gallons per day. DEP'T OF WATER RESOURCES, STATE OF TEXAS, TEXAS WATER FACTS 2 (Jan. 1979) [hereinafter cited as TEXAS WATER FACTS].

32. *See generally Hearings on Water Availability for Energy Development in the West, supra* note 12, at 188 (statement of John Stencel, Rocky Mountain Farmers Union). In

Water serves two basic functions in such plants; filling and cooling the steam boiler[33] and scrubbing the airborne emissions from high-sulfur coal.[34]

The five available cooling techniques vary markedly in water requirements.[35] Once-through cooling, in which water is withdrawn from a natural body of water, run through the plant and then discharged back to its source, requires the greatest withdrawals[36] but consumes the least through evaporation, three million gallons per day for a 1,000 megawatt plant.[37] Evaporation occurs in the receiving body of water when discharge of heated water from the cooling cycle raises the average temperature of the entire body.[38] Once-through cooling is preferable to other techniques if a river or existing reservoir can be used as water source,[39] but the large withdrawal requirements of this technique tend to make it adaptable to surface water supplies only.[40]

If a new, single-purpose impoundment must be built, total water consumption attributable to the generating plant rises because the collection of water in a reservoir increases the total water surface area from which evaporation will occur.[41] This method, the cooling pond, consumes fifteen

testimony before the Senate Committee, Stencel quoted Governor Richard Lamm of Colorado as preferring slurry line export of Colorado coal to local coal-fired generation of electricity for export, because the latter requires "6 to 10 times more water." *Hearings on Water Availability for Energy Development in the West*, *supra* note 12, at 188.

33. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-3 to -4. The DOE study reported that "this cooling function [of all types of steam-electric plants, not only coal-fired] accounts for 98% of the projected water consumption by the entire energy sector for 1985, and 96% of the 1990 requirement." AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-3 to -4.

34. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-4.

35. *See* GEOLOGICAL SURVEY, UNITED STATES DEP'T OF INTERIOR, GEOLOGICAL SURVEY PROFESSIONAL PAPER 1050, at 131 (1977). Estimates of water use are subject to measurement problems and differences in local water temperatures and wind speeds. *Id.*

36. Withdrawals are 830 million gallons per day for a 1,000 megawatt plant. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22. *See also* Hoffman, Water for Lignite Development, *supra* note 27, at 7.

37. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22.

38. *Hearings on Water Availability for Energy Development in the West*, *supra* note 12, at 59, 62 (statement of Alan Merson, EPA).

39. Hoffman, The Impact of Lignite Strip Mining and Use on Water Resources In Texas—A Brief Overview 14 (Oct. 19, 1978) (unpublished paper available from Texas Dep't of Water Resources) [hereinafter cited as Hoffman, Impact of Lignite Strip Mining].

40. Hoffman, Water for Lignite Development, *supra* note 27, at 7.

41. Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 14; *see Hearings on Water Availability for Energy Development in the West*, *supra* note 12, at 59 (statement of Alan Merson, EPA). Impoundment of water in single-purpose reservoirs has the added disadvantage of withdrawing such water from downstream uses. Hoffman, Water for Lignite Development, *supra* note 27, at 8.

million gallons per day to maintain a capacity of 1,000 megawatts.[42]

A third cooling technique is the wet tower. Water is pumped to the top of the tower and then falls through hot air drawn into the tower by fans.[43] The advantage of wet towers lies in the closed system of circulating water which reduces withdrawals.[44] This cooling method, however, requires a relatively high consumption rate of 10 million gallons[45] per day because it produces a concentrated effluent that must be disposed of, partially through evaporation in ponds.[46] Wet towers, however, are the only feasible cooling method available where groundwater must be used.[47]

The dry tower cooling method requires significantly lower withdrawals[48] and virtually no consumption,[49] since the system draws water from the boiler itself and from the in-plant circulation system.[50] The water does not come into contact with air, but remains within a series of coils. Hot air blown over the coils is cooled, and no water loss through evaporation occurs.[51] While dry towers are the least water-consumptive, two distinct disadvantages of this cooling method are an indeterminate reduction in overall plant efficiency and high construction costs.[52]

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42. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22. Overall withdrawals from the cooling pond are 25 million gallons per day. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22.

43. Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 14.

44. *See Hearings on Water Availability for Energy Development in the West, supra,* note 12, at 59, 62 (statement of Alan Merson, EPA). Withdrawals are reduced to 17 million gallons per day. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22.

45. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22.

46. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 59, 62 (statement of Alan Merson, EPA). Merson pointed out the other two disadvantages of wet cooling towers: cost of construction and cost in energy consumption. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 59, 62. The DOE study assumed that new generating plants added by 1985 and 1990 would use wet towers, since it is now the "tendency" to build them. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-4.

47. Hoffman, Water for Lignite Development, *supra* note 27, at 13.

48. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22. Withdrawals for a 1,000 megawatt plant are 0.2 million gallons per day. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22. *See generally* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 288 (1979).

49. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22.

50. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 59-60, 62 (statement of Alan Merson, EPA).

51. *See* Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 15.

52. *See* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 289 n.26, 290-92 (1979); *Hearings on Water Availability for Energy*

Finally, a combination wet/dry cooling tower system unites the cost advantage of wet towers with part of the water savings advantage of dry towers.[53] Costs still are projected to run quite high,[54] however, and government planners are assuming the almost exclusive use of wet towers in the near future.[55]

The second combustion-related use of water, stack scrubbers, adds another water requirement to any plant using coal or lignite.[56] Airborne combustion emissions are sprayed with water and chemical baths to remove pollutants and particulates which combine to form sludge; this sludge is then reduced by evaporation or the solids decanted and the water reused.[57] Scrubbers add up to one million gallons per day to both withdrawal and consumptive water requirements for a 1,000 megawatt plant.[58]

C. *Water Use in Synthetic Fuel Production*

Gasification and liquefaction of coal both potentially enhance the usefulness of coal as a fuel during the transition period from oil and gas to general coal use in powerplants.[59] Coal gas can supplement natural gas supplies, and synthetic liquid fuel can be used where oil is now burned.[60] Furthermore, both fuels emit only small amounts of pollutants when burned.[61] Both conversion processes, however, consume tremendous amounts of water. Conversion of solid coal to liquid or gaseous fuel occurs

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Development in the West, supra note 12, at 59-60, 62 (statement of Alan Merson, EPA), 133 (statement of Charles Jarman, Arizona Public Service Co.). Jarman stated that dry cooling technology "is in its infant stage." *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 133.

53. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 60, 62 (statement of Alan Merson, EPA). *See generally* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 288 (1979).

54. *See generally* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 291 (1979).

55. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-4.

56. *See* Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 17-19.

57. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 132 (statement of Charles Jarman, Arizona Public Service Co.).

58. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-4, 8-22. *But see* GEOLOGICAL SURVEY, UNITED STATES DEP'T OF INTERIOR, GEOLOGICAL SURVEY PROFESSIONAL PAPER 1050, at 131 (1977) (twenty percent estimated increase in water consumption occurs when scrubbers used).

59. *See generally* EXECUTIVE OFFICE OF THE PRESIDENT, ENERGY POLICY AND PLANNING, NATIONAL ENERGY PLAN II APPENDIX, II-41 to -42 (1979).

60. *Id.* at II-41. Coal gasification is encouraged by the 1978 Powerplant and Industrial Fuel Use Act, section 102, and both processes are encouraged by specific initiatives of the Carter Administration's National Energy Plan II. *See* UNITED STATES DEP'T OF ENERGY, NATIONAL ENERGY PLAN II, 105-07 (May 1979).

61. *See* EXECUTIVE OFFICE OF THE PRESIDENT, ENERGY POLICY AND PLANNING, NATIONAL ENERGY PLAN II APPENDIX, II-42 (1979).

when the ratio of hydrogen to carbon in the coal molecule is increased;[62] and the source of the added hydrogen is water.[63] Gasification of coal, by one estimate, consumes up to 7,000 gallons per ton of coal processed.[64] Actual combustion of either synthetic fuel requires about the same amounts of water as ordinary coal combustion.[65]

In summation, the production of strip-mined western coal sufficient to fire a 1,000 megawatt plant for one year[66] requires the consumption of about 32.85 million gallons of water.[67] Slurry line transport requires 600 million gallons.[68] Wet tower cooling requires 9,125 million gallons, and scrubbers add another 912.5 million gallons.[69] Assuming the use of all these methods, the total water consumption requirement for one year is about 10,670.35 million gallons, or over 32,731 acre-feet, per 1,000 megawatts.[70] In comparison, the quantity of water needed to support municipal needs of the same 150,000 population served by 1,000 megawatts[71] is about 7,884 million gallons, or over 24,184 acre-feet per year.[72]

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62. *See* ENERGY RESOURCES CONSERVATION AND DEVELOPMENT COMM'N OF CALIFORNIA, COAL UTILIZATION AND CONVERSION TECHNOLOGIES: STATE OF THE ART 59 (1977).

63. *See* Hoffman, Water for Lignite Development, *supra* note 27, at 4-5.

64. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 188 (statement of John Stencel, Rocky Mountain Farmers Union). The Environmental Protection Agency uses an estimate of 3,000 to 9,000 acre-feet per year for production of 250 million cubic feet of synthetic gas per day. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 62 (statement of Alan Merson, EPA). A partial solution to this problem is suggested by Melvin M. Eisenstadt, who proposes the electrolysis of water into hydrogen at a site where water is abundant, the transport of hydrogen to the gasification plant, and the substitution of hydrogen for water in the coal gasification process. Water consumption would remain the same, but the water availability problem would be solved. *See* Eisenstadt, *Water Law Problems of Solar Hydrogen Production,* 18 NAT. RESOURCES J. 521, 521-25, 542 (1978).

65. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-4.

66. The coal requirement is 2.5 million tons per year. See note 27, *supra.* Such a plant would support the power needs of 150,000 people. *See* Hoffman, Water for Lignite Development, *supra* note 27, at 1-2.

67. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22. This amount includes water needed for revegetation at current levels. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22.

68. At 240 gallons per ton. See materials cited at note 31, *supra.*

69. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-22.

70. One acre-foot equals about 326,000 gallons. GEOLOGICAL SURVEY, UNITED STATES DEP'T OF INTERIOR, I WATER RESOURCES DATA FOR TEXAS, WATER YEAR 1977, at 4 (1977).

71. *See* Hoffman, Water for Lignite Development, *supra* note 27, at 1-2.

72. This calculation uses the 144 gallons per capita per day figure used by the Texas Dep't of Water Resources. *See* TEXAS WATER FACTS, *supra* note 31, at 2.

II. Water Availability at the National and Western Regional Levels

The Department of Energy's 1979 water-for-energy study[73] concluded that by 1985 and 1990, coal extraction will create only slight impacts at the national, western regional, and water basin levels, although such activity might still create "significant" water shortages at the local level in western coal producing states;[74] that the National Energy Plan itself will reduce national water requirements slightly by reducing per capita energy demand;[75] that conversion to coal-fired generation of electricity will have no adverse effect on cooling water needs;[76] that scrubbers required for coal-fired plants will increase water requirements slightly where coal replaces other fuels;[77] and that the major impact of coal conversion will consist of redistribution of existing water resources among users within local areas.[78]

Of the 126 basins in the United States, 21 were found to present water availability problems for energy development by 1985 and 1990.[79] Eight basins, three of which are in Texas,[80] will experience severe water shortages and will require between one and ten percent of total available water for consumptive energy uses.[81] Furthermore, the present dominant water use in all eight areas is irrigated agriculture.[82] In a second group of seven basins, three of which are in Texas,[83] severe water shortages are projected

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73. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13.

74. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-2. *See generally* Abbey, *Energy Production and Water Resources in the Colorado River Basin*, 19 Nat. Resources J. 275, 291-300 (1979).

75. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-4.

76. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-4.

77. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-4.

78. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-4.

79. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-25. The Department of Energy divides the contiguous United States into 106 water basins. *See* An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-1.

80. The eight basins are: Southern Florida, Middle Missouri, Trinity-Galveston Bay, Brazos, Nueces-Texas, Colorado-San Juan, Lower Colorado Main Stem, and Southern California. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-25.

81. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-11.

82. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-11.

83. The seven basins are: S.W. Lake Michigan, Lower Missouri, Lower Arkansas, Red-Sulphur, Sabine-Neches, Colorado-Texas, and Little Colorado. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-25.

and energy needs will require more than ten percent of total water consumption.[84] A third group[85] consists of basins in which no severe shortages are predicted but supply may be threatened during periods of low stream flow.[86] Two results of these shortages will emerge: plant-siting problems[87] and conflicts between water requirements for energy and water traditionally applied to irrigated agriculture.[88]

Of the major categories of water use, namely municipal-domestic, industrial, electric utility, instream,[89] and irrigated agriculture, the latter is the most demanding.[90] It is also a principal industry in the semi-arid west-

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84. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-12, 8-25.

85. This group includes: Boston area, Delaware, Upper and Lower Chesapeake, Potomac, Roanoke-Cape Fear, and Upper Ohio. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-25.

86. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-12, 8-25.

87. Plant-siting difficulties will occur mainly in the third group of shortage basins, in the Susequehana Basin, and in Atlanta. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-6 to -8, -25. *See generally* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 309-11 (1979). Siting problems occur in locations where all or most water is already used, appropriated, or claimed. *See generally* Hoffman, Water for Lignite Development, *supra* note 27, at 14-15, 19-20. Possible pollution of surface water and groundwater supplies is another siting consideration in establishing strip mines. *See* Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 7.

88. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-7, 8-9. These conflicts will arise in the Southern Florida, Southern California, San Joaquin Tulare, Roanoke-Cape Fear, and San Francisco Basins and in the Rocky Mountain region generally. AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-7, 8-9. The study also identifies three basins (Monongahela, Upper Ohio, and Green River) in which "energy development threatens to create a water supply problem that is greater than a simple conflict between alternative uses." AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-8; *accord,* Trelease, *The Changing Water Market for Energy Production,* 5 J. CONTEMP. L. 83, 83 (1978).

89. Instream uses include fish and wildlife habitats, recreation, and esthetic values. *See* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 275-76 (1979).

90. *See* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1355 (1977). *See generally Hearings on Water Availability for Energy Development in the West, supra* note 12, at 188 (statement of John Stencel, Rocky Mountain Farmers Union). According to Geological Survey data, 33 percent of all water *withdrawn* in 1975 was applied to irrigated agriculture. *See* GEOLOGICAL SURVEY, UNITED STATES DEP'T OF INTERIOR, GEOLOGICAL SURVEY PROFESSIONAL PAPER 1050, at 128 (1977). The Survey found that about 57 percent of this water was *consumed. Id.* at 128. The President of the Rocky Mountain Farmers Union testified that it takes from 100,000 to 300,000 gallons of water to produce one ton of agricultural products. *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 188, 192 (statement of John Stencel).

ern states.[91] Water, however, is already over-appropriated in some western basins,[92] and many of these same areas are vulnerable to drought.[93] As implementation of the National Energy Plan creates more demand for low-sulfur western coal, conflicts in demand for water become inevitable.[94]

Two exacerbating factors in the energy-agriculture conflict are the economic incentives favoring energy[95] and emotional resistance among farmers to diversion of water from agriculture.[96] In Texas, while there is ample land for the continued expansion of irrigated farming,[97] it is apparent that coal production in nearby areas will curtail expansion and perhaps even

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91. *See* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1349 (1977); *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 142 (statement of Ben Eastman, Colorado Agriculture Comm'n). *See also* TEXAS WATER FACTS, *supra* note 31, at 2, 7.

92. One such basin is the Colorado River Basin. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 173 (statement of Harris Sherman, Colorado Dep't of Natural Resources). *See generally* Trelease, *Preferences to the Use of Water,* 27 ROCKY MTN. L. REV. 133, 158 (1955).

93. A White House study of the 1976-77 drought stated that the 37 million acres of irrigated cropland in the 17 western states affected by the drought normally account for over half of the domestic fresh vegetable production of the U.S. and have a gross crop value of $10 to $12 billion. EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1349 (1977).

94. *See, e.g.,* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-9; *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 175 (statement of Harris Sherman, Colorado Dep't of Natural Resources); *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 211 (statement of Mohamed El-Ashry, Environmental Defense Fund).

95. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 192 (statement of J. Blaine Miller, Rio Blanco Oil Shale Co.). The higher price and lower water requirements of energy production will enable the industry to outbid agriculture for scarce water. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 143 (statement of Ben Eastman, Colorado Agriculture Comm'n). *But see* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 275 (obstacles to free operation of water market); Trelease, *The Changing Water Market for Energy Production,* 5 J. CONTEMP. L. 83, 83-93 (1978) (water rights market works poorly).

96. *See Hearings on Water Availability for Energy Development in the West, supra* note 12, at 189 (statement of John Stencel, Rocky Mountain Farmers Union); Trelease, *The Changing Water Market for Energy Production,* 5 J. CONTEMP. L. 83, 86 (1978). *But see* Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 299 (possible advantage to farmers in shifting water use from irrigation to energy production).

97. *See* WATER DEVELOPMENT BOARD, STATE OF TEXAS, 1 CONTINUING WATER RESOURCE PLANNING AND DEVELOPMENT FOR TEXAS, DRAFT, 11-61 to -62 (May 1977) [hereinafter cited as CONTINUING WATER PLANNING FOR TEXAS].

invade agricultural use of water.[98]

Another factor which may affect availability of water for energy development in the western states is the still changing doctrine of federal reserved rights in water. As originally applied in 1908 in *Winters v. United States,*[99] the doctrine states that a federal reservation of land for Indians is accompanied by an implied reservation of water rights.[100] In succeeding years the doctrine has been extended to other types of federal reservations[101] and to groundwater as well as surface water.[102] The 1978 United States Supreme Court decision in *United States v. New Mexico,*[103] however, limited the implied reservation of water for a national forest to the original purposes for which the reservation of land was created.[104] Since one of these purposes was the enhancement of water supplies in the West,[105] the decision protects agricultural and domestic uses of water outside the national forest,[106] and may result in protection of other uses considered beneficial under state law. On the other hand, the effect of the decision is to limit sharply the amount of water which comes under direct federal control without resort to condemnation and compensation.[107] Before 1978 it was thought that the reserved rights doctrine could be used to promote federal energy policy by diverting federally reserved water to use in other states and other basins,[108] but *United States v. New Mexico* appears to cut off that possibility.

The most significant right arising under the doctrine is that implied in Indian reservations.[109] Because the uses to which such water may be put,

98. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-9.

99. 207 U.S. 564 (1908).

100. *Id.* at 577. *See generally* Loble & Loble, *The Rocky Road to Water for Energy,* 52 N.D. L. REV. 529, 546-50 (1976); Trelease, *Federal Reserved Water Rights Since PLLRC,* 54 DEN. L.J. 474-75 (1977).

101. *See, e.g.,* United States v. District Court, 401 U.S. 520, 523 (1971) (national forest); Arizona v. California, 373 U.S. 546. 597-98 (1963) (irrigation on Indian lands); FPC v. Oregon, 349 U.S. 435, 443-44 (1955) (federal power reservation). *See generally* Comment, *Federal Reserved Rights and Interstate Allocation of Water,* 13 LAND & WATER L. REV. 813, 815 (1978); Comment, *Federal Reserved Rights in Water: The Problem of Quantification,* 9 TEX. TECH L. REV. 89, 100-09 (1977); 19 NAT. RESOURCES J. 433, 434-35 (1979).

102. *See* Cappaert v. United States, 426 U.S. 128, 143 (1976).

103. 438 U.S. 696 (1978).

104. *Id.* at 700.

105. *Id.* at 713.

106. *Cf. id.* at 715 (reservation of additional water could substantially reduce amount of water available for irrigation and domestic use).

107. *See generally* Corker, *A Real Live Problem or Two for the Waning Energies of Frank J. Trelease,* 54 DEN. L.J. 499, 504 (1977); Trelease, *Federal Reserved Water Rights Since PLLRC,* 54 DEN. L.J. 473, 480-81 (1977).

108. *See generally* Clyde, *Coal Mining, Development and Processing—The Associated Water Problems,* 21 ROCKY MTN. L. INST. 163, 189 (1975).

109. *See generally* Corker, *A Real Live Problem or Two for the Waning Energies of Frank J. Trelease,* 54 DEN. L.J. 499, 504-05 (1977); Comment, *Federal Reserved Rights and Interstate Allocation of Water,* 13 LAND & WATER L. REV. 813, 814 (1978).

the time of measuring, and the means of measuring the reserved water right are all undetermined, the impact of such rights on other uses is uncertain.[110] In fact, the problem of indefiniteness of amounts of water reserved[111] faces all water users and planners sharing watersheds with any kind of federal reservation. Several solutions have been proposed, and nearly all are geared toward defining federal rights so that water users, investors, and planners will be assured some degree of certainty in their future water rights.[112]

Finally, restrictions accompanying wild and scenic river[113] designation may impede coal processing and combustion by limiting available water supplies.[114] Since the Wild and Scenic River Act now includes component or potential component rivers in almost every state west of the Mississippi,[115] and since the Act prohibits federal assistance in any water project that would directly and adversely affect the esthetic values of those rivers,[116] its effects on national energy policy, while presently unknown,[117] may prove to be significant.

III. Impact of Water Availability on Increased Coal Use in Texas

A. *Water Availability and Demand*

Availability of surface water in Texas varies greatly with rainfall and the character of the local terrain. For example, in the eastern part of the state, streams are generally deep, annual rainfall exceeds 50 inches, and annual runoff approaches 15 inches; while in West Texas, arroyos are dry most of the year, annual rainfall averages less than eight inches, and annual runoff may be less than 0.1 inch.[118]

Surface water supplies only thirty percent of Texas' annual water needs.[119] The remaining seventy percent is supplied by groundwater con-

110. *See* Comment, *Federal Reserved Rights in Water: The Problem of Quantification,* 9 Tex. Tech L. Rev. 89, 100-04 (1977). *See generally* Corker, *A Real Live Problem or Two for the Waning Energies of Frank J. Trelease,* 54 Den. L.J. 499, 504-05 (1977).

111. *See* Comment, *Federal Reserved Rights in Water: The Problem of Quantification,* 9 Tex. Tech L. Rev. 89, 95, 99 (1977).

112. *See* Comment, *Federal Reserved Rights and Interstate Allocation of Water,* 13 Land & Water L. Rev. 813, 829-32 (1978); Comment, *Federal Reserved Rights in Water: The Problem of Quantification,* 9 Tex. Tech. L. Rev. 89, 109-11 (1977).

113. *See* Wild and Scenic Rivers Act, 16 U.S.C. § 1271 (1976).

114. *See generally* An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-10; United States Dep't of Energy, Final Environmental Impact Statement, Fuel Use Act 4-17 (Apr. 1979).

115. *See* 16 U.S.C. §§ 1274, 1276(a) (1976).

116. *See id.* § 1278(a), (b) (1976).

117. An Assessment of National Consequences of Increased Coal Utilization, *supra* note 13, at 8-10.

118. Geological Survey, United States Dep't of Interior, 1 Water Resources Data for Texas, Water Year 1977, at 3 (1977); 1 Continuing Water Planning for Texas, *supra* note 97, at I-5.

119. Texas Water Facts, *supra* note 31, at 4.

tained in seven major and 17 minor aquifers which underlie more than half of the state.[120] The primary water availability problem in Texas is the continued depletion of these aquifers more rapidly than recharges from rainfall can replenish them.[121] In its 1977 study of water resources, the Texas Water Development Board found that the safe annual yield of both aquifers and existing surface reserviors was 14.9 million acre-feet, but that actual use was about 23 million acre-feet.[122] The depletion problem is especially urgent in the Ogallala Aquifer, which underlies about 14 counties in the Panhandle and High Plains areas of Texas.[123]

The Ogallala Aquifer[124] and the Canadian River Basin[125] of the Panhandle will be used as illustrations of Texas water availability problems throughout this section. The Ogallala supplied all but 169 acre-feet of groundwater used in the Canadian River Basin[126] in 1974, and recharge in that basin ranged from only 1/15 to 1/25 of the amount of water withdrawn.[127] This "mining" of the aquifer has already caused encroachment of saline water and declining well yields in some areas,[128] and is expected

120. TEXAS WATER FACTS, *supra* note 31, at 3; *see* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at Plate IV 1-2.

121. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at I-5 to -6. Serious depletion has occurred in aquifers in the Houston-Galveston area, the Dallas-Fort Worth area, the El Paso area, the Winter Garden area, and in the High Plains. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at I-5.

122. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at I-3. Future water demand is expected to exceed supply in 31 of Texas' 43 water planning areas. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-38.

123. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26. *See generally* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-39, -41 to -42, -44 to -50. The Ogallala occupies over 225,000 square miles in six states: Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas. It constitutes the largest irrigated farming area in the United States, represents 10% of national agricultural receipts, and supports with its products a $10 billion livestock industry in the same area. *See* Grubb, High Plains Study 1-2 (Dec. 5, 1978) (unpublished paper available from Texas Department of Water Resources).

124. In the 1977 water study, discussions of the Ogallala Aquifer include the minor Purgatoire-Dakota Aquifer, which lies under part of Dallam County. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26. The Ogallala underlies one of the principal irrigation areas of Texas. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-38. Total extraction from the aquifer in 1974 was 1.99 million acre-feet. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26.

125. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26. The Canadian River Basin coincides with the Northern High Plains area and includes all land north of the Canadian River. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-40; 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-21 to -22.

126. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26. The extra 169 acre-feet were pumped in the Red River Basin, but about 175 acre-feet were pumped in the Canadian River Basin and used in the Red River Basin. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26.

127. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26.

128. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-33.

to decrease the number of acres devoted to irrigated agriculture in the Canadian River Basin from 1.4 million acres in 1974 to 1.2 million in 2000 and only one million in 2030.[129] With adequate water supplies, however, irrigated acreage in the Basin could total 2.1 million acres in 2000,[130] and 13.2 million acres could be added to the 1974 statewide irrigated acreage of 8.6 million if sufficient water were made available.[131]

While groundwater supplies are declining, several factors contribute to increased water demand. The population of Texas is projected to grow from 12.8 million in 1979[132] to 18.3 million in 2000 and 30.5 million in 2030.[133] Population growth produces increases in municipal-domestic[134] and recreational uses[135] of water and places greater demand for employment on industry, another water user.[136] Finally, development of lignite coal[137] and

129. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-35. Some cropland around the edges of the irrigation area is already being allowed to go dry, although other farms are being added simultaneously. Reversion will continue south of Lubbock, since the aquifer is thinner in that region and has been pumped longer. Interview with Dr. Herbert W. Grubb, Director of Planning and Development, Texas Department of Water Resources, by telephone, in Austin, (Oct. 31, 1979); *cf.* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-79 (thickness and development of the Ogallala Aquifer).

130. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-35.

131. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-61 to -62. The Water Development Board found that 62 percent of crop yield in Texas comes from irrigated land, that the gross value of these crops in 1974 was $2.85 billion, and that irrigated agriculture is "extremely important to the Texas economy" not only in producing essential food and fiber but also in providing employment "for a significant portion of the labor force." 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-61. Irrigation in Texas uses an average 1.49 acre-feet of water per acre of crops annually. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-16. Two of the most important crops are cotton, in the production of which Texas leads the nation, and livestock feed, which supports an entirely separate industry. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-16. The trend in the Canadian River Basin has been toward expanding irrigated agriculture; acreage devoted to irrigated cropland rose from 356,000 in 1958 to 1,400,000 in 1974. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-25.

132. TEXAS WATER FACTS, *supra* note 31, at 2.

133. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at I-1.

134. The Board projected municipal use to rise from 1,931,400 acre-feet per year in 1974 to 7,733,500 acre-feet in 2030. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-803. Per capita consumption is estimated to be 144 gallons per day. TEXAS WATER FACTS, *supra* note 31, at 2.

135. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-63. For example, recreational use of Army Corps of Engineers projects in Texas increased about 44 percent from 1973 to 1976. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-63.

136. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-11. Use of water in manufacturing is projected to rise from 1,599,100 acre-feet in 1974 to 9,290,400 acre-feet in 2030. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-803.

137. Consumptive use of water in the mining of Texas lignite is projected to rise from 227,100 acre-feet in 1974 to 357,600 acre-feet in 2030. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-803. Water will be required for dust control, both in the mine area and on nearby roads; land reclamation and revegetation; and domestic activities asso-

expansion of steam-electric generating capacity[138] will place additional strains upon Texas water supplies. Water used in Texas steam-electric generating plants is projected to increase dramatically from 201,000 acre-feet in 1974 to 1,768,700 acre-feet in 2030.[139] One reason for the increase is the projected population growth over the next fifty years, but another is a continuing increase in per capita consumption of electricity.[140] Per capita consumption is expected to remain stable after 1995, however.[141] Overall, the total state water requirement for all use categories is projected to

ciated with the mine. Hoffman, Water for Lignite Development, *supra* note 27, at 3-4. Washing and slurry line transport of lignite are probably not practicable because of the consistency of the substance. Hoffman, Water for Lignite Development *supra* note 27, at 5.

Total lignite production in Texas is projected to rise from 24,656,000 tons per year in 1979 to 87,750,000 tons in 1985; bituminous coal production will rise from 66,000 tons to 6,850,000 tons in the same period. RAILROAD COMM'N OF TEXAS, TEXAS COAL AND LIGNITE DEVELOPMENT, SURFACE MINE OPERATIONS, Chart 731.14(h)(8) (1979). The most accessible lignite deposits in Texas cross the state diagonally from the Northeast to the Rio Grande Valley and cross three climatic regions. Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 1-2. In East Texas, although some unappropriated surface water is still available, reservoirs may be needed to provide a dependable source of water for mining. Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 1-2, 4. In Central Texas, less unappropriated surface water is available, but groundwater may be used, depending on the location of the mine. *See* Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 6. In South Texas, lignite developers will probably have to buy water from existing permit holders. Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 6-7. Of particular concern in Texas, where aquifer depletion is already a serious problem, are the destructive effects of strip mining on size and water quality of aquifers which lie *over* lignite deposits. *See* Hoffman, Impact of Lignite Strip Mining, *supra* note 39, at 8-12. A gasification and liquefaction plant processing 25,000 tons of lignite per day may require 300 to 3,000 acre-feet of water per year, depending on the process used and the moisture content of the lignite. *See* Hoffman, Water for Lignite Development, *supra* note 27, at 1, 5. A steam-electric generating plant using Texas lignite and supplying power for 300,000 people is expected to consume about 2,200 acre-feet of water per year in boiler make-up, ash handling, and stack scrubbing. Hoffman, Water for Lignite Development, *supra* note 27, at 4. Cooling will consume about 10,000 to 20,000 acre-feet per year in lignite-fired plants and 3,000 to 15,000 acre-feet per year in gasification and liquefaction plants. Hoffman, Water for Lignite Development, *supra* note 27, at 6-7. In addition, a plant-caused increase in local population of 2,000 to 6,000 people may increase municipal consumptive use by 150 to 450 acre-feet per year. Hoffman, Water for Lignite Development, *supra* note 27, at 9.

138. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-29 to -30. As of December 1975, electric utilities in Texas had an installed capacity of 39.4 thousand megawatts. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-30. Installed steam-electric generating capacity is expected to increase to 68.7 megawatts in 1985 and 222.5 megawatts in 2030. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-30.

139. *Compare* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-803 (present and projected water use for steam-electric power) *with* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-30, -31 to -33 (projected water consumption by steam-electric generating plants).

140. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-41. Per capita consumption stood at 12,300 kilowatt hours per year in 1975, up 30 percent from the 1970 level. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-41.

141. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-41.

increase from 17.3429 million acre-feet per year in 1974 to 41.8447 million acre-feet per year in 2030.[142]

In the Canadian River Basin, population is expected to increase by nineteen percent by 2030.[143] Municipal-domestic use of water will rise by over sixty percent,[144] and industrial use by over 300 percent of the present amount.[145]

No lignite mining occurs in the Basin, but 4,900 acre-feet of fresh water was used in the extraction of oil and gas in 1974.[146] The quantity projected for 2030 is 5,500 acre-feet.[147] Livestock watering accounted for 15,000 acre-feet in 1974 and should reach 25,700 acre-feet by 2030.[148]

Irrigated agriculture is the greatest user of water in the Basin, but is expected to decline over the next 50 years because of groundwater depletion.[149] In 1974, 1.93 million acre-feet of water was used in the Basin, mainly to produce wheat, grain sorghum, and corn; but the figure is expected to decline to 1.22 million acre-feet by 2030.[150] A basin total of 1.82 million additional acre-feet per year would be needed by 2030 to develop irrigated agriculture to its economically feasible potential.[151]

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142. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-803 (municipal, livestock, manufacturing, steam-electric power, irrigation, and mining). This estimate includes water needed for expansion of irrigated agriculture but does not include water required to maintain the fresh water estuarine system. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-803.

143. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-33. Population stood at 156,600 in 1974 and should reach 167,500 by 2000. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34.

144. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-33. The figures are: 30,800 acre-feet in 1974, 44,400 in 2000, and 51,800 in 2030. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34.

145. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34. Industrial use of water was 34,200 acre-feet in 1974 and is expected to reach 113,600 acre-feet by 2030. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34. The study reports that a substantial proportion of water withdrawals for municipal and industrial use will be returned to the basin for reuse. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26, -37.

146. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-25, -34.

147. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34.

148. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34.

149. See text at notes 129-131, *supra*.

150. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34. All but 2,000 acre-feet was drawn from the Ogallala Aquifer. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-25.

151. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34. The only significant source of surface water in the Basin is the Canadian River itself, which is the subject of a compact among New Mexico, Texas, and Oklahoma. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26; *see* TEX. WATER CODE ANN. § 43.001 (Vernon 1972). Texas rights to most waters of the Basin are restricted only by maximum storage provisions which protect Oklahoma's rights to Canadian River waters. TEX. WATER CODE ANN. § 43.006 (Vernon 1972) (Art. V(a)); *see* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26.

Steam-electric generating capacity in the Canadian River Basin was 936 megawatts in 1978, and the generation of all but 29 megawatts depended exclusively upon the Ogallala Aquifer for water supplies.[152] Only 6,000 acre-feet was drawn in 1974,[153] but by 2000, when generating capacity will have reached 2,728 megawatts, 26,300 acre-feet will be needed; and by 2030, generation of 3,288 megawatts will require 37,000 acre-feet.[154] It is estimated that 2,500 acre-feet of the latter amount will be consumed.[155] There are five powerplants in the Canadian River Basin, and all five use wet tower cooling at present. One, River View in Hutchinson County, draws water from sewage effluent discharged by the city of Amarillo, and the other four use groundwater directly from the Ogallala Aquifer.[156]

Partly because of present and anticipated water conservation efforts in the municipal, industrial, and agricultural sectors,[157] water supplies within the Canadian River Basin are expected to decline slightly but remain adequate for most purposes to 2030.[158] The great exception is in irrigated agriculture, where potential demand for 1,816,200 acre-feet per year by 2030 cannot be met under present and projected conditions.[159] While water-

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Two major Texas reservoirs have been built in the Basin: Rita Blanca, which is operated for recreational purposes, and Lake Meredith, which was built by the U.S. Bureau of Reclamation and which supplies 11 cities with a total of 103,000 acre-feet per year for municipal and industrial uses. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26, -30. For a discussion of water rights in impounds built by the Bureau of Reclamation, see McCall, *Rights in Impounded Water,* in PROCEEDINGS, WATER LAW CONFERENCES 251, 253 (1954).

152. *See* Dep't of Water Resources, State of Texas, Existing and Planned Thermo Electric Power Plants in Texas as of April 1978 with Steam Electric Generating Capacity Listed by River and Coastal Basin, Table 2 (1978) (unpublished material available from Texas Dep't of Water Resources).

153. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-25.

154. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-36.

155. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-36. Water requirement projections were based on actual designs for future powerplants where available. It was assumed that half of all new capacity would be nuclear and that all coal- and lignite-fired plants would have to use stack scrubbers. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-41.

156. *See* Dep't of Water Resources, State of Texas, Existing and Planned Thermo Electric Power Plants in Texas With Steam Generating Capacity as of April 1978, Table 3 (1978) (unpublished material available from Texas Dep't of Water Resources). Use of effluent for cooling is a progressive use because it saves on consumption of fresh water needed elsewhere. *See generally* WATER DEVELOPMENT BOARD, STATE OF TEXAS, TEXAS WATER PLAN, SUMMARY 12 (1968); Abbey, *Energy Production and Water Resources in the Colorado River Basin,* 19 NAT. RESOURCES J. 275, 306 (1979). Only the Harrington plant in Potter County uses coal as fuel at present; the other four plants in the Basin use gas. Dep't of Water Resources, State of Texas, Existing and Planned Thermo Electric Power Plants in Texas With Steam Generating Capacity as of April 1978, Table 3 (1978).

157. The study assumed savings of about 4 percent of present use by 2000. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-46.

158. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-43.

159. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-43. A more

for-energy use will increase more than 600 percent by 2030, water available for irrigation will decline by roughly one third.[160] Although this decline is not primarily attributable to increased energy demand within the Basin, the projected statewide increase in water used by steam-electric generating plants—an additional 1,567,700 acre-feet per year by 2030[161]—will make interbasin transfers[162] an unreliable solution. Present planning does rely upon such transfers but stresses the importance of procuring water from out-of-state sources as well.[163]

recent (1979) publication by the Department puts the problem more urgently, stating that "Municipal and industrial water supplies are becoming more difficult to obtain and more expensive as the water table declines. Some cities of the [High Plains and Pecos Valley] will need additional supplies by 1990." TEXAS WATER FACTS, *supra* note 31, at 8. The 1968 Texas Water Plan foresaw the threat to irrigated agriculture and stated that without large-scale importations of water by 1985, the High Plains "will have begun an area-wide retrogression to dryland farming which will have profound economic consequences throughout the State." WATER DEVELOPMENT BOARD, STATE OF TEXAS, TEXAS WATER PLAN, SUMMARY 27 (1968).

160. *Compare* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-25 (6,000 acre-feet for electric generation in 1974) *and* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-3 (37,000 acre-feet for electric generation in 2030) *with* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34 (1,933,900 acre-feet for irrigated agriculture in 1974) *and* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-34 (1,222,900 acre-feet for irrigated agriculture in 2030).

161. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-803.

162. Interbasin transfers are "diversions of water from basins of surplus to water deficient areas." 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-38. Such transfers can be made so long as water needs of the donor basin are considered protected for the following 50 years. TEX. WATER CODE ANN. § 16.052 (Vernon Supp. 1979). Many such transfers are made among coastal basins, and Lake Meredith in the Canadian River Basin supplies water to cities as many as four basins away. Interview with Dr. Herbert W. Grubb, Director of Planning and Development, Texas Dep't of Water Resources, by telephone, in Austin (Oct. 31, 1979).

163. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-38. The 1968 Texas Water Plan envisioned the importation of 12 to 13 million acre-feet per year from the Mississippi River "at a point below diversions from the River in Louisiana." *See* WATER DEVELOPMENT BOARD, STATE OF TEXAS, TEXAS WATER PLAN SUMMARY 12 (1968). In 1973, however, the Army Corps of Engineers and the Bureau of Reclamation determined that the diversion was economically infeasible. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-51. Current study of out-of-state water sources focuses on Arkansas, Missouri, and the Dakotas. Under congressional authorization, the Army Corps of Engineers is currently considering six or seven possible routes for delivery of such water to Texas and is expected to have reached its conclusions by early 1982. Interview with Dr. Herbert W. Grubb, Director of Planning and Development, Texas Department of Water Resources, by telephone, in Austin (Oct. 31, 1979); *see* Water Resources Development Act of 1976, Pub. L. No. 94-587, 90 Stat. 2917 (codified in scattered sections of 16, 33, 42 U.S.C.). While much imported water would be used for irrigation in Texas, municipalities and industries along the transport route would also share in the water. Technology already exists for transporting water hundreds of miles and lifting it hundreds of feet (here, to the High Plains area) by means of open, concrete-lined canals arranged in a series of stairsteps. Other devices, such as reflective covers, may be used to reduce evaporation and produce solar energy for pumping purposes. Interview with Dr. Herbert W. Grubb, Director of Planning and Development, Texas Department of Water Resources, by telephone, in Austin (Oct. 31, 1979).

B. Means of Procuring Water for Energy

Under Texas water law, all percolating water is subject to the surface landowner's unlimited right of capture,[164] while all surface water in water courses belongs to the state.[165] Persons seeking to obtain large quantities of water have several means at their disposal: securing a permit to appropriate stream water or water in state or federal impounds,[166] securing a permit to build an impound,[167] contracting for water with an existing per-

164. TEX. WATER CODE ANN. § 52.002 (Vernon 1972) (ownership of underground water); *id.* § 52.001 (underground water defined); *id.* § 52.003 (surface water laws not applicable); *see, e.g.,* Corpus Christi v. Pleasanton, 154 Tex. 289, 293, 276 S.W.2d 798, 801 (1955); Bartley v. Sone, 527 S.W.2d 754, 760 (Tex. Civ. App.—San Antonio 1975, writ ref'd n.r.e.); Pecos County W.C. & I. Dist. No. 1 v. Williams, 271 S.W.2d 503, 506 (Tex. Civ. App.—El Paso 1954, writ ref'd n.r.e.). *See generally* W. HUTCHINS, THE TEXAS LAW OF WATER RIGHTS 565-70 (1961). Statutory provision has been made, however, for the establishment of groundwater districts which hold legal authority to regulate groundwater use. TEX. WATER CODE ANN. § 52.021 (Vernon Supp. 1979).

165. TEX. WATER CODE ANN. § 11.021 (Vernon Supp. 1979); *see, e.g., In re* Water Rights of Cibolo Creek, 568 S.W.2d 155, 158 (Tex. Civ. App.—San Antonio 1978, no writ); South Texas Water Co. v. Bieri, 247 S.W.2d 268, 272 (Tex. Civ. App.—Galveston 1952, writ ref'd n.r.e.); Goldsmith & Powell v. State, 159 S.W.2d 534, 535 (Tex. Civ. App.—Dallas 1942, writ ref'd n.r.e.). *See generally* W. HUTCHINS, THE TEXAS LAW OF WATER RIGHTS 77-78 (1961). Water in identifiable underground streams is now also claimed by the state. TEX. WATER CODE ANN. § 52.001(3) (Vernon 1972); *see* Bartley v. Sone, 527 S.W.2d 754, 760 (Tex. Civ. App.—San Antonio 1974, writ ref'd n.r.e.). *See generally* Castleberry, *Proposal For Adoption of a Legal Doctrine of Ground-Stream Water Interrelationship in Texas,* 7 ST. MARY'S L.J. 503 (1975); Tyler, *Underground Water Regulation in Texas,* 39 TEX. B.J. 532, 536 (1976).

166. TEX. WATER CODE ANN. § 11.022 (Vernon Supp. 1979) (acquisition of state water by appropriation); *id.* § 11.023(a)(2) (appropriation for development of electric power); *id.* § 11.024(2) (appropriation for electric power second in priority to municipal-domestic use); *id.* § 11.025 (scope of appropriative right); *id.* § 11.026 (perfection of appropriative right); *id.* § 11.030 (forfeiture); *id.* §§ 11.121-.143 (procedures for obtaining permit to appropriate state water). State law generally controls appropriations of waters impounded within state boundaries, but there are important exceptions and restrictions on waters under federal control. *See generally* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at I-21 to -30 (federal water resources legislation); McCall, *Rights in Impounded Water,* in PROCEEDINGS, WATER LAW CONFERENCES 251, 252-56 (1954) (federal impoundments); Loble & Loble, *The Rocky Road to Water Development for Energy,* 52 N.D. L. REV. 529, 551-53 (1976) (water in federal reservoirs). During the 1976-77 drought, water storage facilities were "near normal" in supplies in most of Texas but were projected to be inadequate if the drought continued in the Panhandle, West Texas, and Rio Grande areas. *See* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1333 (1977). *See also* TEX. WATER CODE ANN. § 11.039 (Vernon Supp. 1979) (distribution during shortage). As of October 1976, Texas had about 160 major reservoirs with combined storage capacity of about 29,000,000 acre-feet. TEXAS ALMANAC 1978-79, at 108 (1977).

167. *See* TEX. WATER CODE ANN. § 11.023 (Vernon Supp. 1979) (appropriation purposes); *id.* § 11.121 (permit required for storage); *id.* §§ 11.124, .125 (application requirements). *See generally* W. HUTCHINS, THE TEXAS LAW OF WATER RIGHTS 244-48 (1961).

mit holder,[168] and pumping or buying groundwater.[169] Both groundwater and surface sources are and will continue to be used for cooling purposes in Texas steam-electric generating plants, even though groundwater use contributes to aquifer depletion.[170] Other means which may be available in some cases are: purchase of out-of-state water by the State of Texas,[171] further federal development of Texas water resources,[172] and use of the municipal power of eminent domain.[173] The eminent domain statute gives

168. *See* TEX. WATER CODE ANN. § 11.036 (Vernon Supp. 1979) (supply contract for stored or conserved water); *id.* § 11.037 (rules and regulations applicable to water suppliers).

169. *See generally* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-34, -36, -38. For a discussion of the economics of water used for energy development see Trelease, *The Changing Water Market for Energy Production,* 5 J. CONTEMP. L. 83 (1978).

170. For example, the Ogallala Aquifer is expected to be supplying from 51,485 to 141,419 acre-feet per year for cooling by 2030. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III -36, -38.

Where surface stream water is used, the once-through method consumes the least water, but is not feasible in most areas of Texas because of varying flow rates in streams. Existing or multi-purpose reservoirs solve that problem so long as sufficient water remains in the impound to supply the powerplant, even in time of drought. Single-purpose impounds withdraw water from other beneficial uses and threaten downstream users in time of drought, but are preferable to wet towers in amounts of water consumed. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-34; Hoffman, Water for Lignite Development, *supra* note 27, at 7-8. By 2030, 11 of 43 Texas basins are projected to be impounding between 2,543,400 and 7,596,500 acre-feet of surface water in single-purpose cooling reservoirs; this water will not be available for other uses. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-35. Ten basins, five of which belong to the first group as well, will be drawing 170,911 to 526,501 acre-feet of groundwater per year for cooling purposes. 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-36. The Canadian River Basin will, according to these projections, have no single-purpose reservoirs but will be drawing 21,430 to 71,623 acre-feet per year from the Ogallala Aquifer for powerplant cooling. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-35, -36.

171. See note 163, *supra,* for discussion of past and present studies of water importation. The initial estimated cost of diversions from the Lower Mississippi River was $16.6 billion in 1972. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-51. The cost was updated to $31.4 billion in 1976 dollars and projected to run $53.5 billion in 1985 dollars. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-51. For cost reasons the Mississippi Import Plan is considered infeasible; current studies focus on the importation of water from Arkansas. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-51. *See generally* TEX. WATER CODE ANN. § 11.021(b) (Vernon Supp. 1979) (imported water considered surface water under control of the state).

172. Reservoirs are built by the Bureau of Reclamation of the Interior Department under the Reclamation Act of 1902 and/or the Flood Control Act of 1944 or by the Army Corps of Engineers under the Flood Control Act. *See* Flood Control Act of 1944, 33 U.S.C. §§ 701, 701-1 (1976); Reclamation Act of 1902, 43 U.S.C. §§ 371, 411 (1976); *cf.* TEX. WATER CODE ANN. § 12.051 (Vernon Supp. 1979) (state approval of federal water projects); *id.* §§ 16.091, .092 (state cooperation with federal agencies in developing water projects). *See generally* McCall, *Rights in Impounded Water,* in PROCEEDINGS, WATER LAW CONFERENCES 251, 252-56 (1954); Clyde, *Coal Mining, Development and Processing—The Associated Problems,* 21 ROCKY MTN. MIN. L. INST. 163, 183-94 (1975).

173. TEX. WATER CODE ANN. § 11.033 (Vernon Supp. 1979).

all political subdivisions and constitutional agencies exercising legislative powers the right to take water for all purposes authorized by the Texas Water Code.[174] Electric power is an authorized purpose, and is second only to municipal-domestic uses in the statutory order of preferences.[175]

Obstacles to future appropriations, purchases, or comdemnation of water for powerplant purposes do exist, but will probably affect siting of plants rather than construction per se.[176] One such obstacle is the existence of unused but "vested" riparian rights downstream from a planned large-scale diversion or impound.[177] The Water Rights Adjudiciation Act,[178] passed in 1967, provides for the extinguishment of riparian rights not in actual use between 1963 and 1967.[179] As of August 31, 1979, adjudication of water rights had begun in all but the Red River Basin, and final judgment had been issued for six rivers in four basins.[180] Adjudication of rights on the Canadian River began on June 24, 1979.[181] Although the Act provides, in effect, for an uncompensated cancellation of water rights, its constitutionality has not yet been tested in the courts.[182]

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174. *Id.* § 11.033. Uses for which state water may be appropriated include: domestic-municipal, industrial (including electric power), and irrigation. *Id.* § 11.023(a).

175. *Id.* § 11.023(a)(2) (industrial uses include development of electric power); *id.* § 11.024 (statutory order of preference). No provision for compensation is made if the water is used for domestic-municipal purposes. *See id.* § 11.028. Whether paying compensation or not, a taker must obtain an appropriation permit before condemning water. *See id.* §§ 11.022, 11.121. *See generally* McCall, *Rights in Impounded Water,* in PROCEEDINGS, WATER LAW CONFERENCES 251, 257-70 (1954); Trelease, *Preferences to the Use of Water,* 27 ROCKY MTN. L. REV. 133, 141-59 (1955). Shareholder owned electric utilities may obtain private lands needed for impounds by statutory condemnation proceedings. *See* TEX. WATER CODE ANN. § 11.035 (Vernon Supp. 1979).

176. *See generally* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-12. See text at note 87, *supra.*

177. In general, vested riparian rights are not affected by provisions of the Water Code relating to state control of waters. TEX. WATER CODE ANN. § 11.001 (Vernon Supp. 1979); *see* Motl v. Boyd, 116 Tex. 82, 108, 286 S.W. 458, 467 (1926). *See generally* W. HUTCHINS, THE TEXAS LAW OF WATER RIGHTS 293-309 (1961). A number of commentators have called for the stabilization of riparian rights in the West. *See generally* Hutchins, *History of the Conflict Between Riparian and Appropriative Rights in the Western States,* in PROCEEDINGS, WATER LAW CONFERENCES 106 (1954); Rollins, *The Need for a Water Inventory in Texas,* in PROCEEDINGS, WATER LAW CONFERENCES 67 (1954); Trelease, *Coordination of Riparian and Appropriative Rights to the Use of Water,* 33 TEXAS L. REV. 24, 60-67 (1954).

178. TEX. WATER CODE ANN. §§ 11.301-.409 (Vernon Supp. 1978).

179. *Id.* § 11.302 (conservation and best use of water resources require limitation of riparian claims to those in actual use); *id.* § 11.303 (recording and limitation of certain riparian claims); *id.* § 11.315 (final determination of claims to water rights under adjudication).

180. Dep't of Water Resources, State of Texas, Pertinent Dates in Adjudication Program (1979) (unpublished material available from the Texas Dep't of Water Resources).

181. *Id.; see* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-11.

182. The constitutional issue has been raised on appeal of an adjudication, but has not yet been addressed by an appellate court. *See In re* Water Rights of Cibolo Creek Watershed,

Federal restrictions on development of streams included in the Wild and Scenic Rivers Act pose another potential obstacle to large water appropriations.[183] Of Texas rivers, only the Rio Grande is affected now, but more rivers may be included in the future.[184] Although other restrictions do exist—restrictions such as federal reserved rights,[185] interstate river compacts,[186] and state concerns for social, economic, and environmental effects on the public welfare[187]—probably none of these restrictions will affect Texas water development significantly. The familiar problem of water shortage remains.

IV. Development of Water Resources for Energy

Proposed solutions to the water shortage problem fall into three categories: conservation of available water supplies, expansion of water resources, and intensification of water management practices and planning efforts. Water conservation can be applied to all of the major water uses. In the municipal-domestic area,[188] conservation can take the forms of restrictions on outdoor uses of water, changes in building code specifications regarding indoor fixtures, and promotion of voluntary conservation measures, such as the use of flow restrictors in shower heads.[189] The use of low-flush toilets

568 S.W.2d 155, 157 (Tex. Civ. App.—San Antonio 1978, no writ). *See generally* Comment, *Riparian Rights Under the Texas Water Rights Adjudication Act—A Constitutional Analysis*, 9 St. Mary's L.J. 87 (1977).

183. *See* 16 U.S.C. § 1278 (1976) (licensing construction of dams, reservoirs on rivers designated by the Act prohibited). *See generally* Loble & Loble, *The Rocky Road to Water for Energy*, 52 N.D. L. Rev. 529, 543 (1976).

184. 16 U.S.C.A. § 1274(17) (West Supp. 1979) (Texas portion of the Rio Grande River); *see* 16 U.S.C. § 1276 (1976) (proposed additions).

185. See text at notes 99-112, *supra*. In Texas, less than 2 percent of total acreage is federal land. *See* Texas Water Facts, *supra* note 31, at 2. *See generally* Trelease, *Coordination of Riparian and Appropriative Rights to the Use of Water*, 33 Texas L. Rev. 24, 54-55 (1954).

186. *See* Trelease, *Preferences to the Use of Water*, 27 Rocky Mtn. L. Rev. 133, 135-36 (1955). Texas is a party to compacts concerning the Rio Grande, Pecos, Canadian, Sabine, and Red Rivers. *See* Tex. Water Code Ann. §§ 41.001-45.007 (Vernon 1972); 1 Continuing Water Planning for Texas, *supra* note 97, at I-31, -32.

187. *See* Tex. Water Dev. Bd., Rule 156.01.05.001, 2 Tex. Reg. 4885 (1977).

188. Municipal-domestic water use in Texas currently accounts for 1.9 million acre-feet per year, or about 12 percent of total water withdrawals. *See* Texas Water Facts, *supra* note 31, at 2. In the western United States generally, such uses account for 4 to 13 percent. Executive Office of the President, Drought Study Report (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works*, Part I, 95th Cong., 1st Sess. 1321, 1360 (1977).

189. Use restrictions would apply to outdoor uses such as car washing and lawn sprinkling. It is estimated that such restrictions could reduce total domestic use by 30 percent. *See* Executive Office of the President, Drought Study Report (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works*, Part I, 95th Cong., 1st Sess. 1321,

in all Texas housing built after 1979, for example, could save 324,000 acre-feet per year by 2030,[190] about four percent of all domestic water use projected for that year.[191] The White House Drought Study Report of 1977 estimated that simple individual conservation measures could reduce average domestic use by fifty percent.[192] In Texas, municipal-domestic withdrawals could be reduced from 12 to 6 percent of total state water use.[193]

Although industry uses only one to eight percent of all water in the West generally[194] and nine percent in Texas,[195] increasing scarcity and cost of water supplies may encourage conservation and the substitution of saline or treated effluent water for fresh water, especially in cooling functions.[196]

The largest water user in the West, irrigated agriculture,[197] accounts for considerable water waste. A General Accounting Office report estimated that over half the water delivered by Bureau of Reclamation projects to farms in 1973 was wasted through over-irrigation.[198] The amount was about 36,000 acre-feet *per day.*[199] If productive use of irrigation water could be

1360-62 (1977). Indoor water saving devices range in sophistication from the "brick-in-the-toilet" technique to recirculation of laundry water through the toilet system. *See id.;* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-68 to -72.

190. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-70.

191. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-803 (municipal use projected to be 7,733,500 acre-feet in 2030).

192. *See* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1360 (1977).

193. *See* TEXAS WATER FACTS, *supra* note 31, at 2 (current municipal-domestic water use approximately 12 percent of total water use).

194. *See* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1363 (1977).

195. *See* TEXAS WATER FACTS, *supra* note 30, at 2.

196. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-74. *See generally* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1363 (1977).

197. *See* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1355 (1977).

198. UNITED STATES GENERAL ACCOUNTING OFFICE, BETTER FEDERAL COORDINATION NEEDED TO PROMOTE MORE EFFICIENT FARM IRRIGATION (1976), *quoted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1382 (1977).

199. UNITED STATES GENERAL ACCOUNTING OFFICE, BETTER FEDERAL COORDINATION NEEDED TO PROMOTE MORE EFFICIENT FARM IRRIGATION (1976), *quoted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1382 (1977). Texas water planner Dr. Herbert Grubb disputes this estimate with the observation that the GAO report

doubled in Texas, over one-third of the agricultural water shortage predicted for 2030 would be eliminated.[200]

Among remedies proposed to prevent such waste and increase irrigation efficiency are: changing cropping patterns, controlling undesired vegetation, switching to less water-intensive crops, increasing efficiency of water delivery systems, reducing seepage to deep aquifers and leakage from unlined ditches, timing application of water to critical plant growth periods, and implementing new types of irrigation systems and agricultural techniques.[201] Raising the cost of water would provide an incentive to increase irrigation efficiency.[202] Since it is generally assumed that the energy industry will be able to outbid farmers for water supplies,[203] this competition for

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was made by persons who do not fully understand the irrigation process. More significantly, Dr. Grubb points out that throughout Texas, irrigation farmers are lining canals, installing pipe, and investing in sophisticated pumping and sprinkling systems to minimize water waste. The Texas Agricultural Experiment Station and several other state agencies are working to educate farmers and are studying the use of sub-irrigation and less water-intensive crops. For purposes of water planning, the Department of Water Resources now assumes that irrigation will be 80 percent efficient. Interview with Dr. Herbert W. Grubb, Director of Planning and Development, Texas Department of Water Resources, by telephone, in Austin (Oct. 31, 1979). *See generally* HIGH PLAINS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1 AND DEP'T OF WATER RESOURCES, STATE OF TEXAS, A SUMMARY OF TECHNIQUES AND MANAGEMENT PRACTICES FOR PROFITABLE WATER CONSERVATION ON THE TEXAS HIGH PLAINS, Rep. No. 79-01, II-1 to -14 (1979) (irrigation techniques); *id.* at III-1 to -27 (irrigation management); 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-75 to -77 (improved irrigation efficiency).

200. This shortage is projected to be 16,196,800 acre-feet per year by 2030, and actual use of water for irrigation is projected to be 6,027,500 acre-feet. Doubling the efficiency of the latter amount would reduce the shortage by about one-third. *See* 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-803.

201. *See, e.g.*, HIGH PLAINS UNDERGROUND WATER CONSERVATION DISTRICT NO. 1 AND DEP'T OF WATER RESOURCES, STATE OF TEXAS, A SUMMARY OF TECHNIQUES AND MANAGEMENT PRACTICES FOR PROFITABLE WATER CONSERVATION ON THE TEXAS HIGH PLAINS, Rep. No. 79-01, II-1 to -14 (1979); EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1356 (1977); 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-75 to -77 (improved irrigation efficiency).

202. *See* EXECUTIVE OFFICE OF THE PRESIDENT, DROUGHT STUDY REPORT (1977), *reprinted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1321, 1356 (1977); *cf.* UNITED STATES GENERAL ACCOUNTING OFFICE, BETTER FEDERAL COORDINATION NEEDED TO PROMOTE MORE EFFICIENT FARM IRRIGATION, *quoted in To Establish a National Water Policy: Hearings Before the Subcomm. on Water Resources of the Senate Comm. on Environment and Public Works,* Part I, 95th Cong., 1st Sess. 1382 (1977) (overuse of low-cost water in irrigated farming).

203. *See, e.g., Hearings on Water Availability for Energy Development in the West, supra* note 12, at 143 (statement of Ben Eastman, Colorado Agriculture Comm'n); *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 186 (statement of John Stencel, Rocky Mountain Farmers Union); *Hearings on Water Availability for Energy*

water may help to reduce inefficiency in irrigation.

Water conservation can be practiced in coal mining and in coal combustion also. One commentator who is particularly concerned with the fate of western agriculture recommends the diversion of only limited water supplies for the extraction of coal one project at a time, thereby minimizing water loss to irrigation.[204] In all types of steam-electric powerplants, saline water or effluent can be substituted for fresh water cooling;[205] and as the requisite technology improves, dry towers can be substituted for wet towers.[206] Location of some powerplants on sites where once-through cooling is available, that is, on a stream or existing reservoir, will reduce water demand even more.[207] Stack scrubbers will continue to demand modest additional amounts of water where high-sulfur coal is burned,[208] and as new powerplants subject to increasingly stringent environmental regulations are built, scrubbers will become necessary even where low-sulfur coal is burned.[209]

A second approach to the water shortage problem is to increase water supplies. The building of large multi-purpose reservoirs is one means,[210] and it has been suggested that the present 160-acre limitation on a farmer's irrigation water allocation from Bureau of Reclamation projects should be raised.[211] Texas water planning has focused partly on water importation for

Development in the West, supra note 98, at 214 (statement of Mohamed El-Ashry, Environmental Defense Fund). *See generally* Trelease, *The Changing Water Market for Energy Production*, 5 J. CONTEMP. L. 83, 83-93 (1978); AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-12 to -14.

204. *See* Clyde, *Coal Mining, Development and Processing—the Associated Water Problems*, 21 ROCKY MTN. MIN. L. INST. 163, 166-67 (1975).

205. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-72 to -74; Abbey, *Energy Production and Water Resources in the Colorado River Basin*, 19 NAT. RESOURCES J. 275, 314 (1979). When saline water or effluent is used for cooling, concentrations of dissolved solids must be limited in order to prevent corrosion, fouling, and scaling of equipment. *See* Abbey, *Energy Production and Water Resources in the Colorado River Basin*, 19 NAT. RESOURCES J. 275, 280 (1979).

206. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-14.

207. See text at notes 36-40, *supra*.

208. See notes 56-58, *supra*.

209. 44 Fed. Reg. 33580 (June 11, 1979); *see* Truitt & Abeles, *Coal-Fired Generating Facilities: Impediments Under Federal Environmental Legislation*, 11 ST. MARY'S L.J. 609, 627 (1980). *See generally* Interview with Joe Fulton, Environmental Engineer, City Public Service Co., by telephone, in San Antonio (Nov. 6, 1979).

210. *See* Clyde, *Coal Mining, Development and Processing—The Associated Water Problems*, 21 ROCKY MTN. MIN. L. INST. 163, 183 (1975).

211. *See* WATER DEVELOPMENT BOARD, STATE OF TEXAS, TEXAS WATER PLAN, SUMMARY 36 (1968). The Reclamation Act of 1902 provides that no right in water impounded in Bureau of Reclamation projects shall be sold to any one landowner for use on privately owned tracts exceeding 160 acres. 43 U.S.C. §§ 371, 431 (1976); *see* United States v. Imperial Irrigation Dist. 559 F.2d 509, 527, 540 (9th Cir. 1977) (upholding acreage limit), *cert. granted sub nom.*

at least a decade,[212] and state-sponsored experiments in desalinization and weather modification are underway.[213]

A third answer lies in improved water management practices. For example, the Texas Department of Water Resources estimates that operating several reservoirs as a system rather than individually could increase total yield of those impounds ten to twenty percent by reducing evaporation.[214] Similar effects may be realized by storing surface water in aquifers.[215]

V. CONCLUSIONS

According to the 1979 Department of Energy study, several factors important to an estimation of future water-for-energy needs are not yet known. Among these are the amount of groundwater available for energy use in the eastern United States; the precise locations and extent of areas that will be affected by the federal reserved rights doctrine, the Wild and Scenic Rivers Act, and Indian water rights; and environmental and technological problems presented by the use of saline water for energy purposes.[216]

In the western United States the issues of coal slurry pipelines and competition between agriculture and energy development remain unresolved.[217] In Texas, water planners are optimistic about the state's ability to meet water needs of most sectors, including mining and steam-electric power, by 2030 if surface water development proceeds as planned. If not, shortages are anticipated by 2000 and 2030 in some areas, and population growth may be limited by water shortages in any case.[218] Furthermore, total acreage devoted to irrigated agriculture is expected to diminish[219] and this loss is expected to injure the state economically[220] unless out-of-state

Bryant v. Yellen, 48 U.S.L.W. 3367 (Dec. 4, 1979) (No. 79-421). *See generally* 18 NAT. RESOURCES J. 933 (1978); 17 NAT. RESOURCES J. 673 (1977).

212. See notes 163, 171, *supra*.

213. *See* 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-66.

214. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-67 (systems operation of surface-water projects).

215. 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at II-67 to -68 (conjunctive use of surface and ground water supplies).

216. *See* AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION *supra* note 13, at 8-10 to -11.

217. *See generally* EXECUTIVE OFFICE OF THE PRESIDENT, ENERGY POLICY AND PLANNING, NATIONAL ENERGY PLAN II APPENDIX, I-36 to -38 (1979) (western water shortage areas); *id.* at II-42, -43 (slurry pipeline legislation); *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 142-43 (statement of Ben Eastman, Colorado Agriculture Comm'n); *Hearings on Water Availability for Energy Development in the West, supra* note 12, at 175 (testimony of Harris Sherman, Colorado Dep't of National Resources).

218. *See* TEXAS WATER FACTS, *supra* note 31, at 6.

219. *See* TEXAS WATER FACTS, *supra* note 31, at 6-7.

220. *See* TEXAS WATER FACTS, *supra* note 31, at 6; 1 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at III-6 to -11.

water supplies can be found to replace declining aquifer reserves.[221]

Texas water planners are striving diligently to augment state water supplies and to increase efficiency of irrigation methods. The energy industry too can be expected to intensify research and application of less water-consumptive technologies as the cost of water is driven upward by competition.

Federal water and energy policy can complement such efforts in a variety of ways: by encouraging interstate cooperation in solving problems such as depletion of the Ogallala Aquifer, slurry pipeline water needs, and other interstate deliveries of water; by raising the acreage limitation on reclamation project sales in order to relieve pressure on groundwater supplies; by issuing estimates for the amounts of water to be claimed by Indian reservations and other federal reservations; by coordinating the objects of the Wild and Scenic Rivers Act with nationwide water planning.

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221. *See* TEXAS WATER FACTS, *supra* note 31, at 7; AN ASSESSMENT OF NATIONAL CONSEQUENCES OF INCREASED COAL UTILIZATION, *supra* note 13, at 8-7; 2 CONTINUING WATER PLANNING FOR TEXAS, *supra* note 97, at IV-26.