



Winter 1983

## Prior Appropriation, Impairment, Replacements, Models and Markets

William C. Schaab

### Recommended Citation

William C. Schaab, *Prior Appropriation, Impairment, Replacements, Models and Markets*, 23 Nat. Resources J. 25 (1983).

Available at: <https://digitalrepository.unm.edu/nrj/vol23/iss1/5>

This Article is brought to you for free and open access by the Law Journals at UNM Digital Repository. It has been accepted for inclusion in Natural Resources Journal by an authorized editor of UNM Digital Repository. For more information, please contact [amywinter@unm.edu](mailto:amywinter@unm.edu), [lsloane@salud.unm.edu](mailto:lsloane@salud.unm.edu), [sahrk@unm.edu](mailto:sahrk@unm.edu).

William C. Schaab\*

## Prior Appropriation, Impairment, Replacements, Models and Markets

Water law is the doctrine on which we rely to provide enough water for those who need it. Legal doctrine, however, only defines entitlements, rights to take and use, and procedures for resolving conflicts; it does not match demand and supply. But market transactions, which allow available supplies to meet effective demands for water, depend upon legal doctrine to establish ownership. A reasonable buyer will not pay the price unless the seller has the right to sell, and the buyer can enjoy what he pays for. Theoretically, a free and open water rights market would measure the available supply and identify needs according to ability to pay the market price. As scarcity increased, prices would rise, less valuable uses would give way to the more valuable, and water would always be available for new, high-value purposes.

In fact, though, markets capable of allocating water to satisfy all demands throughout the west have not developed,<sup>1</sup> and one important reason is the prior appropriation doctrine itself. This doctrine, which was concerned primarily with new appropriations, ignored established uses. These

---

\*B. A. and M. A. Wesleyan University, J. D. Yale Law School; member of Rodey, Dickason, Sloan, Akin & Robb, P. A. and its predecessors in Albuquerque, New Mexico since 1959.

1. Economic analysts have found that "the existence of market transactions for water reflecting the free play of forces of supply and demand are rare, although not nonexistent." R. YOUNG & S. GRAY, *ECONOMIC VALUE OF WATER: CONCEPTS AND EMPIRICAL ESTIMATES* 80-81 (1972) (Nat'l Water Comm'n Study). In the absence of market indications of value, they analyzed economic "models" created by WOLLMAN & BONEM, *OUTLOOK FOR WATER QUALITY, QUANTITY AND NATIONAL GROWTH* (1971). C. MEYERS & R. POSNER, *MARKET TRANSFERS OF WATER RIGHTS* 8 (1971) (Nat'l Water Comm'n, Legal Study No. 4), found market transfers "extremely rare" with no record of any activity in California between 1959 and 1969; however, some Colorado municipalities had purchased water rights. Khoshkhalagh, Brown & DuMars, *FORECASTING FUTURE MARKET VALUES FOR WATER RIGHTS IN NEW MEXICO*, N.M. Water Resources Research Inst. Rept. No. 092, Las Cruces (1977), found some data on market sales of New Mexico water rights between 1970 and 1975, but Brown, *Conflicting Claims to Southwestern Water: The Equity and Management Issues*, 1 SW. REV. OF MGMT. AND ECON. 35, 59-60 (1981), found "sparse" evidence of water rights markets and water rights values. Ellis & DuMars, *The Two-Tiered Market in Western Water*, 57 NEB. L. REV. 333, 357 n. 83 (1978), noted that a jurisdictional conflict between the State Engineer and a local conservancy district had "destroyed" a market for the district's excess water. Constructing the "value" of water rights with abstract and theoretical mathematical "models," as in several National Water Commission studies, is of doubtful usefulness: W. BUTCHER, N. WHITTLESEY & J. ORSBORN, *ECONOMIC VALUE OF WATER IN A SYSTEMS CONTEXT* (1972); R. THOMPSON, M. L. HYATT, J. McFARLAND, & H. P. YOUNG, *FORECASTING WATER DEMANDS* (1971); and R. DAVIS, *PRICING AND EFFICIENCY IN WATER RESOURCES MANAGEMENT* (1971).

private property rights became subject to supervening public control; water rights, unlike land,<sup>2</sup> were not freely transferable.

In the absence of systematic adjudication of existing rights and scientific measurement of available supplies,<sup>3</sup> no one knew how much should be bought or from whom.<sup>4</sup> Thus, negotiated sales might be limited to financial settlements to dispose of damage actions. The solution to inadequate supplies was usually not purchase of existing rights but political efforts to obtain massive public investment programs to augment natural supplies with storage and distribution systems. As long as the government stood ready to finance such projects, significant private markets were not likely to develop.

In the last few years, development of digital, computer-operated simulations has made it possible to create water basin "models" that plot requirements against available resources and project the long-term consequences of development and use. The need to quantify federal and Indian water rights throughout the West is producing adjudications of existing and foreseeable diversions and depletions. With such public assistance to the supply and demand sides of water use coupled with legal devices to escape the undesired consequences of the prior appropriation doctrine, effective markets may at last be created with a corresponding reduction in the control of state bureaucracies over water allocation.

The prior appropriation doctrine allowed the staking of a claim against a water supply, regardless of the extent of the resource, and was therefore helpless to prevent "over appropriation" of the available supply.<sup>5</sup> In times of shortage, the doctrine would compel complete curtailment of all junior uses, regardless of importance, to ensure the complete fulfillment of a senior right. In most western states, few "water rights" have been ad-

---

2. Grant, *Reasonable Groundwater Pumping Levels Under the Appropriation Doctrine: The Law and Underlying Economic Goals*, 21 NAT. RES. J. 1, 29-32 (1981), notes that theoretical insecurity of rights did not impede water development in states, like Texas, that failed to apply the prior appropriation doctrine to groundwater.

3. Ten years ago Professor Charles E. Corker recommended, ". . . there can be no higher priority for study . . . than the subject of water supply determination." C. CORKER, *GROUNDWATER LAW, MANAGEMENT AND ADMINISTRATION* 29 (1971) (Nat'l Water Comm'n Rept. No. 6). The same judgment is true today.

4. The prior appropriation system did not encourage market-created adjustments of priorities without major economic dislocations. A junior user who wished to strengthen the security of his right by upping its priority would have to obtain waivers or covenants not to sue from all senior interests, yet he had no reliable way to identify such interests. Declarations of vested rights are typically not mandated, and they may be filed in vague and general terms, if the stream system had not been adjudicated. N.M. Stat. Ann. § 72-1-3 (1978). Therefore, his only remedy would have been purchase of an entire senior right, typically forcing agricultural land out of production when the actual need could have been satisfied by less drastic and less costly action.

5. By far the best analysis of the prior appropriation doctrine is CHARLES J. MEYERS, *A HISTORICAL AND FUNCTIONAL ANALYSIS OF THE APPROPRIATION SYSTEM* (1971) (Nat'l Water Comm'n Legal Study No. 1).

judicated, and a prospective buyer could not be certain of the seller's priority and entitlement, or the buyer's ability to enjoy the purchased rights. Because supplies were indefinite and the effects of others' long-term uses on his rights could not be forecast, the buyer could not accurately estimate the risk of future curtailment. Moreover, the doctrine could not, in all situations, prevent waste; in the name of protecting the senior rights of the first user, it could prevent full or optimum use of some streams and groundwater reservoirs. A resource specialist recently concluded: "State laws and policies not only allow an inefficient use of western water, they ensure it by reducing or eliminating the incentives and opportunities for transferring water to high-value uses."<sup>6</sup> In retrospect, adoption of prior appropriation as basic, constitutional doctrine was unfortunate.<sup>7</sup>

The prior appropriation doctrine developed in California in the first decade after the American conquest.<sup>8</sup> Congress had failed to prescribe legislative rules to govern water use on the new public domain, and miners without title based their use of water from streams on their being first on the scene.<sup>9</sup> The prior appropriation doctrine merely validated necessary water use by gold miners who extended "flumes and ditches . . . along the canyon walls to turn great wheels and creaking pumps."<sup>10</sup> By 1855 the state supreme court had approved the "customary" rule of a mere seven years' standing, regulating water use among the gold miners on the basis of an equitable maxim: *Qui prior est in tempore, potior est in jure*.<sup>11</sup> Both ownership of land and riparian use of flowing streams, the premises of common law rules for water use, were ignored or subordinated. "Mining was paramount to all other interests in the early days, and its followers could wash away roads and soils, undermine houses, and honey-comb or remove entire towns."<sup>12</sup> The miners' control of water was the compelling justification. Neither the parties nor the courts were concerned with "policy" questions; no one asked whether the miners'

6. Frederick, *The Future Role of Western Irrigation*, 1 SW. REV. OF MGMT. AND ECON. 19, 31 (1981).

7. Burness & Quirk, *Water Law, Water Transfers, and Economic Efficiency: The Colorado River*, 23 J. LAW & ECON. 111, 121 (1980), purport to demonstrate that "equal sharing leads to greater aggregate profits than does the appropriation doctrine."

8. Wiel's attempt to anchor the appropriation doctrine to early English precedents failed. Compare Wiel, *Waters: American Law and French Authority*, 33 HARV. L. REV. 133 (1919), with Maass & Zobel, *Anglo-American Water Law. Who Appropriated the Riparian Doctrine*, 10 PUB. POLICY YR. BOOK, HARV. SCH. PUB. ADMIN. 120 (1960).

9. 1 WIEL, WATER RIGHTS IN THE WESTERN STATES, 66-117 (3d ed. 1911).

10. 6 BANCROFT, HISTORY OF CALIFORNIA 387 (San Francisco 1888).

11. *Irvin v. Phillips*, 5 Cal. 140, 147 (1855). 1 WIEL, *supra* note 9, § 77.

12. BANCROFT, *supra* note 10, at 402. The miners gave us the phrase "cleaned up" from their practice of collecting gold flakes from the cleats and riffles of sluice boxes. WELLS & PETERSON, THE '49ers 160 (1949).

"custom" would be the best rule to allocate unreckoned resources against varied needs as the population and the economy grew.

In the century that followed, the prior appropriation rule was adopted throughout the western states with local variations.<sup>13</sup> The doctrine, however, did not govern groundwater under common law,<sup>14</sup> the rights of Indian tribes and pueblos under federal law,<sup>15</sup> municipal "pueblo" rights based on Spanish law,<sup>16</sup> the proprietary rights of the federal government,<sup>17</sup> and "private" water in possession of the landowner.<sup>18</sup> Nor did it govern water pollution; the diligent appropriator did not acquire the right to pollute.<sup>19</sup>

The appropriation doctrine was popular because it invited rapid development and use of western surface supplies, but new appropriations could not be limited unless a senior interest sought an injunction. The senior appropriator had to prove his priority, the likelihood of imminent and irreparable damage to his use by defendant's proposed diversion, and that an action for damages would be inadequate. Such evidence would normally be expensive and difficult to obtain. Without any effective method of matching new appropriations against available supplies, the doctrine theoretically required curtailments in inverse order of priority, terminating all junior uses to permit the senior use to obtain a full supply. But rigid application of the doctrine would produce unacceptable results if socially essential junior uses could thus be terminated. Since the priorities of competing users had rarely been determined, and scientific information was not readily available to measure available supplies and predict the

13. 1 WIEL, *supra* note 9, §§ 112, 117, 118. See generally, HUTCHINS, *WATER RIGHTS LAWS IN THE NINETEEN WESTERN STATES* (1971); DEWSNUP & JENSEN, *A SUMMARY-DIGEST OF STATE WATER LAWS* 243-257 (1973) (Nat'l Water Comm'n). If Hawaii is classed as a "western state," its traditional water law does not recognize the prior appropriate doctrine.

14. 2 WIEL, *supra* note 9, 970-1094; Clark, *Ground Water Legislation in the Light of Experience in the Western States*, 22 MONT. LAW. REV. 42 (1960); Trelease, *Legal Solutions to Groundwater Problems—A General Overview*, 11 PAC. L. J. 863 (1980).

15. 1 WIEL, *supra* note 9, § 207. Some of the better recent articles on Indian water rights are: Hundley, *The "Winters" Decision and Indian Water Rights: A Mystery Reexamined*, 13 W. HIST. Q. 17 (1982); Shrago, *Emerging Indian Water Rights: An Analysis of Recent Judicial and Legislative Developments*, 26 ROCKY MTN. MIN. L. INST., 1105 (1980); Note, *Indian Claims to Groundwater: Reserved Rights or Beneficial Interest*, 33 STAN. L. REV. 103 (1980).

16. 1 WIEL, *supra* note 9, § 68. The municipal "pueblo" right is recognized judicially in California, *City of Los Angeles v. City of San Fernando*, 14 Cal. 3d 199, 537 P.2d 1250, 123 Cal. Rptr. 1 (1975); Gleason, *Los Angeles v. San Fernando: Ground Water Management in the Grand Tradition*, 4 HAST. CONST. L.Q. 703 (1977); and in New Mexico, *Cartwright v. Public Service Co. of New Mexico*, 66 N.M. 64, 343 P.2d 654 (1958), and by statute in Texas. TEX. WATER CODE ANN. § 11.028 (Vernon Supp. 1982).

17. 1 WIEL, *supra* note 9, §§ 152-156. Among numerous interesting articles on this area of water rights law, Meyers, *Federal Groundwater Rights: A Note on Cappaert v. United States*, 13 LAND & WATER L. REV. 377 (1978), stands out as a useful memorandum.

18. 1. WIEL, *supra* note 9, note to § 53, at 61.

19. C. MEYERS, *supra* note 5, at 22-23.

effects of new diversions and depletions, the risks inherent in the doctrine were difficult to assess.

As long as the principal water use was gold and silver mining, such defects were of small concern. Those mining uses were temporary; when the mine played out, the miner moved on with no thought of long-term consequences. As irrigated agriculture developed in the post-Civil War West,<sup>20</sup> water use changed from privately-financed, temporary, mainly non-consumptive mining uses to publicly-financed, permanent, heavily depleting irrigation projects.<sup>21</sup> Water rights became permanent appurtenances to irrigated land.<sup>22</sup>

Once the widely fluctuating supply furnished by most western streams was fully committed, needs began to be met from stored groundwater. The landowner's right to extract and use such water followed from his fee simple title under the common law maxim, *Cujus est solum ejus est usque ad caelum et ad inferos*.<sup>23</sup> Changes in points of diversion or in the method, place or purpose of use were allowed by the courts under another ancient maxim, *sic utere tuo ut alienum non laedas*.<sup>24</sup> A change would be allowed if it did not injure others. But without full adjudication of water rights no one precisely knew who held senior or junior rights, the location of points of diversion, or the nature of existing uses. Without reliable hydrological information, no one could be certain whether he would be injured by a change or by a new appropriation. The judicial system, based upon the adversary procedures of the common law, could not protect existing users who were not parties to a legal action.<sup>25</sup>

Over the long run, the West's expanding population and economy developed and used water resources for all kinds of purposes, but the most important uses often developed more slowly. If such uses were

20. The significant federal statutes were the Homestead Act of 1862, 12 Stat. 392; the Pacific Railway Acts, 12 Stat. 489 (1862); the Act of July 26, 1866, ch. 262, § 9, 14 Stat. 251, 253; the Act of July 9, 1870, ch. 235, § 17, 16 Stat. 217, 218; the Act of March 3, 1877, ch. 107, 19 Stat. 377; and the Reclamation Act of 1902, 32 Stat. 388.

21. Sax, *Federal Reclamation Law*, in 2 WATERS AND WATER RIGHTS 111 (R. Clark ed. 1967); E. HEADY, H. MADSEN, K. NICOL, & S. HARGROVE, AGRICULTURAL WATER DEMANDS (1971) (Nat'l Water Comm'n Study); Burness, Cummings, Gorman & Lansford, *United States Reclamation Policy and Indian Water Rights*, 20 NAT. RES. J. 807 (1980); Howe, *New Procedures for the Evaluation of Federal Water Projects*, 1 SW. REV. OF MGMT. AND ECON. 115 (1981).

22. To improve free transferability of water rights, Frederick, *supra* note 6, at 31-32, recommends abrogation of the appurtenance of an irrigation right to the irrigated tract.

23. 2 WIEL, *supra* note 9, § 1039; Moses, *Basic Groundwater Problems*, 14 ROCKY MTN. MIN. L. INST. 501 (1968).

24. *Maeris v. Bicknell*, 7 Cal. 261 (1857); *Kidd v. Laird*, 15 Cal. 161, 180-81 (1860); 1 WIEL, *supra* note 9, § 498.

25. 1 WIEL, *supra* note 9, §§ 625-627. "The rights of such persons will not, of course, be injuriously affected by the decree in this cause, and *non constat* but that they may yet intervene for their own protection. . . ." *Gutierrez v. Albuquerque Land and Irrigation Co.*, 188 U.S. 545, 557 (1903).

governed by prior appropriation requirements, they would be the most junior rights and the most in danger of curtailment by an unexpected insufficiency. Essential domestic and municipal uses could not be held in such jeopardy; nor could they be required to incur the high cost of acquiring a senior priority by purchase or condemnation.

Despite a constitutional mandate in many western states, the prior appropriation doctrine had exhausted its usefulness by the end of the 19th century, when surface supplies in most areas were fully appropriated. Before the doctrine precipitated a curtailment crisis, it was superseded by a system of administrative control. In the early years of the present century, Elwood Mead and Clarence T. Johnston in Wyoming developed an administrative system to provide continuous attention to water resources beyond the capabilities of the courts.<sup>26</sup> After the Wyoming "water code" was enacted in 1907, it was widely emulated in prior appropriation states. Now all states rely in varying degrees on a state office to achieve an acceptable allocation of water to meet both existing and future needs.<sup>27</sup>

Creation of the "water bureaucracies" based on executive rather than judicial authority halted the growth of the court-created prior appropriation doctrine. Determination of relative priorities was obviously a judicial function requiring the evidentiary adjudication of rights beyond the administrative authority of the State Engineer. The statutes governing new appropriations and transfers therefore required the Engineer to assume parity among all valid and existing rights, both "vested" and permitted,<sup>28</sup> because most streams were assumed to be fully appropriated, and forced curtailment of necessary junior uses could not be risked. The key concept shifted from "priority" to "impairment." Universal non-impairment was intended to protect all existing users equally against the possibility of curtailment compelled by the prior appropriation doctrine. In addition, many states denied the prior appropriation doctrine by adopting "preference" laws, requiring industrial uses to abate regardless of priority to prevent curtailment of supplies for domestic and municipal uses.<sup>29</sup> In New

26. 2 WIEL, *supra* note 9, §§ 1184, 1428; 1 WIEL, *supra* note 9, § 124. That establishment of state administrative offices began within five years after enactment of the federal reclamation law was not coincidental. State administrators were an equipoise in the age of great federal reclamation projects.

27. C. MEYERS, *supra* note 5, at 13. See CLYDE & JENSEN, ADMINISTRATIVE ALLOCATION OF WATER (1971) (Nat'l Water Comm. Legal Study No. 3). Montana and Colorado rely on adjudication procedures more than administrative control. DEWSNUP & JENSEN, *supra* note 13, at 155-173, 449-460.

28. N.M. Stat. Ann. § 72-5-24 (1978). Existing rights entitled to protection under the non-impairment policy possibly include federal, Indian, and municipal pueblo rights not based on beneficial use. See *Cartwright v. Public Service Co. of New Mexico*, 66 N.M. 64, 80-85, 343 P.2d 654, 665-669 (1958).

29. COLO. CONST. art. XVI, § 6; IDAHO CONST. art. XV, § 3; NEB. CONST. art. XV § 6; ALASKA STAT. §§ 46.15.090, .150 (1977); TEX. WATER CODE ANN. §§ 11.024, 11.028, 11.123 (Vernon Supp. 1982); UTAH CODE ANN. §§ 73-3-21, 73-3-8 (1980); WYO. STAT. § 41-3-102

Mexico's San Juan Basin extensive dewatering of mineral-bearing formations led the legislature to find in 1980 that "existing principles of prior appropriation . . . may cause severe economic hardship and impact to persons engaged in mineral production. . . ." <sup>30</sup> Thus, the doctrine created by miners first on the scene proved inadequate to their needs a century later when other miners were the most recent arrivals.

Creation of a governing administrative office charged with examining closely all transfers of water rights impeded creation of active and open markets for water rights. "Impairment" was not precisely defined in the statutes that created the apparatus to prevent it. Although the statutes spoke of impairing "rights," rather than a physical supply, a right to take and use water was obviously impaired by preemption of the supply by those who had no legal right to take it. Hence, the new rule of non-impairment required strict administrative control of water supplies. In practice, the administrators rigidly prohibited increased use; even senior appropriators were required to prove that their transfer of rights would not "impair" the most junior rights on the system. The courts' uncertain response to the new system caused additional confusion. <sup>31</sup> The states paid insufficient attention to both supply (scientific studies) and demand (adjudication of rights); public funds went into storage and delivery projects which made markets unnecessary. In many instances, purchase and re-

---

(1977). Irrigation is usually ranked in preference behind domestic use. WASH. REV. CODE ANN. § 90.03.040 (1962), 8.12.030, 35.92.010 (1961). Usually, low-preference senior rights must be compensated if their priority is taken for a high-preference use. See Alaska, Colorado, Idaho, Nebraska, Washington, and Wyoming statutes cited above. Otherwise, abatement of a senior, low-preference right is uncompensated as an exercise of the state's police power to protect the health and safety of the community. TEX. WATER CODE ANN. § 11.028 (Vernon Supp. 1982); UTAH CODE ANN. § 73-3-21 (1980).

30. N.M. STAT. ANN. § 72-12A-2(A)(3) (1978).

31. In the same year, the New Mexico Supreme Court, in *Templeton v. Pecos Valley Artesian Conservancy Dist.*, 65 N.M. 59, 332 P.2d 465 (1958), permitted a senior surface right to drill wells to obtain a supplementary supply from the alluvial fill of the Pecos River, thus encroaching on the groundwater available for well-established junior pumpers, but in *Re Hobson*, 64 N.M. 462, 330 P.2d 547 (1958), denied a requested change in location of a junior well on the grounds that the same basin was over-appropriated, while *Application of Brown*, 65 N.M. 74, 332 P.2d 475 (1958), permitted such a change despite a proven drop in the groundwater level. In *Kelly v. Carlsbad Irrigation Dist.*, 71 N.M. 464, 379 P.2d 763 (1963), 76 N.M. 466, 415 P.2d 849 (1966), the Court held that any transfer affecting the Roswell Artesian Basin must be treated as a new appropriation. Comment, *The Rise and Fall of New Mexico's Templeton Doctrine*, 6 NAT. RES. J. 325 (1966). Flint, *Groundwater Law and Administration: A New Mexico Viewpoint*, 14 ROCKY MTN MIN. L. INST. 545, 557 (1968), explains the confused decisions as expedients designed to avoid "priority calls" to cut off junior appropriators: "Some would argue that it would have been inequitable to close down the surface-water diversions of an appropriator with a 1910 priority for the benefit of a surface-water user with a priority of 1890, and at the same time permit groundwater appropriators in the vicinity to continue pumping their wells despite the fact that thousands of acres of groundwater uses were developed as late as the 1930's. On the other hand, it would be perhaps equally unreasonable to close down as much as 15,000 to 20,000 acres of groundwater irrigation to restore the flow of surface water to the extent that would permit the irrigation of a 160-acre downstream farm. At the same time, it is patently unfair, if not unlawful under the doctrine of prior appropriation, to subject the 1890 water right to regular water shortages."



tirement of irrigation rights were administratively required to permit necessary municipal or industrial uses to develop.<sup>32</sup> Such transactions were clearly coerced. There was no "free market" where neither buyer nor seller was under compulsion.

Whether a new or different diversion or use of water would "impair" the water supply available to an existing use required the administrative officer, like a gypsy fortuneteller, to foretell the future effect of the proposed appropriation or change. The courts, following tort concepts, would have demanded proof of proximate cause and actual loss, or, on equitable grounds, would have refused injunctions to prevent impairment without proof of grave and irreparable harm.<sup>33</sup> Administrative discretion, however, was able to impose restrictions on water use without precise measurements of available supplies or existing demands, and without verifiable scientific forecasts of future interference with water supplies already allocated.<sup>34</sup>

The engineers and hydrologists resolved all doubts in favor of impairment and relied on general notions of a critical water shortage to win political acceptance of their authority. Impairment was administratively predicated on assumed hydrological relationships of surface and ground-water,<sup>35</sup> ignoring the complete absence of proof that any existing right would in fact be deprived of its supply.<sup>36</sup> Pumping anywhere within a basin would eventually reduce the flow of streams; since water rights are legally deemed to be permanent and timeless, the time lag was administratively ignored and the calculated ultimate effect on streamflow was accepted as an actual, immediate effect.<sup>37</sup> New uses could only be substituted for old uses, with no increase in calculated depletion of supply. Thus, irrigation rights had to be retired to permit municipal and industrial rights to develop.<sup>38</sup> Green farm land was thereby sacrificed for urban growth and industrial development.

32. *City of Albuquerque v. Reynolds*, 71 N.M. 428, 379 P.2d 73 (1962).

33. *Maestas v. Elephant Butte Irrigation Dist.*, No. 78-138B (D.N.M. May 11, 1979).

34. Due process requirements were satisfied by administrative hearings in which applicants could theoretically prove non-impairment, or protestants could prove impairment, but the necessary evidence was expensive and difficult to obtain, and the administrative view usually prevailed. Compare *Heine v. Reynolds*, 69 N.M. 398, 401, 367 P.2d 708 (1962), with *City of Roswell v. Berry*, 80 N.M. 110, 452 P.2d 179 (1969).

35. The scientific basis for administrative control was C. V. Theis' equation. Theis, *The Significance and Nature of the Cone of Depression in Ground-Water Bodies*, 33 *ECONOMIC GEOLOGY* No. 8 (1938); *The Source of Water Derived From Wells*, 10 *CIVIL ENGINEERING* No. 5 (1940); *The Effect of a Well on the Flow of a Nearby Stream*, 22 *TRANSACTIONS, AMERICAN GEO-PHYSICAL UNION*, 734 (1941).

36. *Hall v. Kuiper*, 181 Colo. 130, 510 P.2d 329, 330-1 (1973).

37. The recent Colorado cases have measured the time lag, rather than ignoring it. *District 10 Water Users Ass'n v. Barnett*, 198 Colo. 291, 599 P.2d 894, 896 (1979). Scheduled depletion of non-recharging reservoirs has also recognized their estimated useful life. *Mathers v. Texaco, Inc.*, 77 N.M. 239, 421 P.2d 771 (1966).

38. Under Colorado's 1969 Water Rights Determination and Administration Act Colo. Rev. Stat. 1973 § 37-92-201 such requirements may be part of a "plan for augmentation." *Kelly Ranch v. Southeastern Colo. Water Conservancy Dist.*, 191 Colo. 65, 550 P.2d 297 (1976).

The rigid administrative prohibition of necessary uses without a convincing scientific basis inevitably led to adjustments in the non-impairment requirement. First, the courts' interpretation and application of the standard in actual conflicts produced more realistic results than the administrators' prohibitions based on general, unverifiable predictions. Second, the legislatures in many states recognized that non-impairment requires some leeway; only "unreasonable" impairment should be prohibited.

In early well interference cases the courts both over-protected and under-protected senior rights. New appropriators were often enjoined from interfering to any extent with existing supplies, in effect conferring a vested interest in "historical" or pristine groundwater levels.<sup>39</sup> Yet, where groundwater was subducted by mine dewatering, the courts denied the aggrieved senior appropriator any remedy.<sup>40</sup> Dewatering was treated as a permissible incident of land ownership under the common law principle (or its American variants) that an owner of land is entitled, absolutely, to use its groundwater. Property rights precluded recovery of damages under tort doctrines of nuisance or negligence.<sup>41</sup>

Damages for proven well interference were sometimes determined on an inverse condemnation theory (the difference in market value of the land before and after the interference); sometimes, particularly where ample groundwater was available, damages were determined according to the value of lost crops or the increased cost of obtaining an adequate

---

39. *Forbell v. City of New York*, 164 N.Y. 522, 58 N.E. 644 (1900); *Duckworth v. Watsonville Water & Light Co.*, 150 Cal. 520, 89 P. 338 (1907); *Pima Farms Co. v. Proctor*, 30 Ariz. 96, 245 P. 369 (1926); *Noh v. Stoner*, 53 Idaho 651, 26 P.2d 1112 (1933); *Joseph W. Bowles Reservoir Co. v. Bennett*, 92 Colo. 16, 18 P.2d 313 (1932); *Faden v. Hubbell*, 93 Colo. 358, 28 P.2d 247 (1933); *Justesen v. Olsen*, 86 Utah 158, 40 P.2d 802 (1935); *Canada v. City of Shawnee*, 179 Okla. 53, 64 P.2d 694 (1937); *Hanson v. Salt Lake City*, 105 Utah 404, 205 P.2d 255 (1949); *Lodi v. East Bay Municipal Utility District*, 7 Cal. 2d 316, 60 P.2d 439 (1939); *Trussell v. City of San Diego*, 172 Cal. App. 2d 593, 343 P.2d 65 (Cal. Dist. Ct. App., 1959). Injunctive relief was based on the continuing nature of the wrong. 2 HUTCHINS, *supra* note 13, at 225-245.

40. Pumping to the point of inducing subsidence of nearby property may also be a privilege of ownership in some states. Note, *Subsidence: An Emerging Area of the Law*, 22 ARIZ. L. REV. 891 (1980); Note, *Sinking Fortunes: Texas Remedies For Victims of Land Subsidence*, 20 NAT. RES. J. 375 (1980); Teutsch, *Controls and Remedies For Ground Water-Caused Land Subsidence*, 16 HOUS. L. REV. 283 (1979).

41. *Silver King Consolidated Mining Co. v. Sutton*, 85 Utah 297, 39 P.2d 682 (1934); *N.M. Long & Co. v. Cannon-Papanikolos Constr. Co.*, 9 Utah 2d 307, 343 P.2d 1100 (1959); *Evans v. City of Seattle*, 182 Wash. 450, 47 P.2d 984 (1935); *Sloss-Sheffield Steel & Iron Co. v. Wilkes*, 231 Ala. 511, 165 So. 764, 770 (1936); 236 Ala. 173, 181 So. 276 (1938); *Sycamore Coal Co. v. Stanley*, 292 Ky. 168, 166 S.W.2d 293 (1942); *Finley v. Teeter Stone, Inc.*, 251 Md. 428, 248 A.2d 106 (1968); *Bayer v. Nello L. Teer Co.*, 256 N.C. 509, 124 S.E.2d 552 (1962); *Jarvis v. State Land Dep't*, 106 Ariz. 506, 479 P.2d 169 (1970). However, in California the "correlative rights" principle required the dewaterer to provide a substitute supply. *Eckel v. Springfield Tunnel & Dev. Co.*, 87 Cal. App. 617, 262 P. 425 (Cal. Dist. Ct. App., 1927). See Annot., 55 A.L.R. 1385, 1408-1412, 1425-1427, 1444-1451 (1928) (*Subterranean and Percolating Waters*). In New Mexico, recovery of damages based on a nuisance theory was undoubtedly barred by the Mine Dewatering Act, 1980 N.M. Laws 599, which authorized dewatering as neither an appropriation nor a waste. N.M. Stat. Ann. § 72-12A-11(B) (1978) denies injunctive relief but does not deny damages; under ordinary nuisance principles, dewatering authorized by statute could not be a nuisance.

supply, including increased electricity expense.<sup>42</sup> *Tevis v. McCrary*<sup>43</sup> sustained a jury's award, which was probably based on the cost of enlarging and deepening the affected well. In *City of Enid v. Crow*,<sup>44</sup> the plaintiff, whose domestic supply had been reduced from "three faucets to one faucet," recovered the value of that loss (\$3,811.41) on an inverse condemnation theory. In *Tucksinger v. Loup River Public Power Dist.*<sup>45</sup> the court fixed damages for impairment of subirrigation by defendant's tail-race at the value of crops that could have been grown on the irrigated land and any loss in land value.

The courts were able to modify the non-impairment rule to foster maximum use of water resources. In surface water cases, a prior appropriator was not permitted, by using inefficient methods of diversion, to command the entire flow of the stream.<sup>46</sup> Surface flows varied; diminutions attributable to the requirements of existing rights were inescapable. In the case of groundwater reservoirs, the courts refused to allow the first pumper to prevent later pumpers from lowering the water level below the depth of his well. Such circumstances developed the notion of a permissible burden judicially imposed on a senior right to permit expanded or "optimum" use of the resource. In the language of the New Mexico Supreme Court, the burden was the inevitable result of "beneficial use by the public."<sup>47</sup>

Yet, in the absence of statutory provisions authorizing judicial flexibility in applying the strict non-impairment rule, the courts were reluctant to use a *de minimis* concept in granting relief, treating some junior encroachments as a technical trespass.<sup>48</sup> In *Heine v. Reynolds*,<sup>49</sup> the court rejected the contention that "impair" should be construed to mean "substantially impair" on the basis of reasonableness and an implied exclusion of *de minimis* impairments. ". . . [T]he question of impairment of existing rights is a matter which must generally depend upon each appli-

42. Note, *Ground Water Preferences in Nebraska*, 59 NEB. L. REV. 831 (1980). See also Annot., 35 A.L.R. 1222 (1925), Annot., 55 A.L.R. 1385, 1482 (1925); 2 HUTCHINS, *supra* note 13, at 216-245.

43. 75 N.M. 165, 402 P.2d 150 (1965).

44. 316 P.2d 834 (Okla. 1957).

45. 140 Neb. 179, 299 N.W. 549 (1941).

46. *Natoma Water & Mining Co. v. Hancock*, 101 Cal. 42, 35 Pac. 334, 337 (1894); *Schodde v. Twin Falls Land & Water Co.*, 161 Fed. 43 (9th Cir. 1908) (Idaho), *aff'd* 224 U.S. 107 (1912); *Warner Valley Stock Co. v. Lynch*, 215 Or. 523, 336 P.2d 884 (1959); *State ex rel. Crowley v. Dist. Ct.*, 108 Mont. 89, 88 P.2d 23 (1939).

47. *Mathers v. Texaco, Inc.*, 77 N.M. 239, 246, 421 P.2d 771, 776 (1966).

48. Professor Corker has suggested that, "Relief should not be granted where the amount of damages is less than the cost of administering the award." In an action to enjoin well interference, however, he suggested that, "if water supply is adequate, a junior appropriator's water use will not be enjoined solely because of interference with pump lift or artesian pressure." CORKER, *supra* note 3, at 183.

49. 69 N.M. 398, 401, 367 P.2d 708 (1962).

cation, and to attempt to define the same would lead to severe complications."<sup>50</sup> That decision was followed in *Duran v. Reynolds*,<sup>51</sup> but was later criticized in *Langenegger v. Carlsbad Irrigation District*<sup>52</sup> where supplementary irrigation wells were allowed in an aquifer that was a source of the Pecos River, despite recognition that "some changes in the waters of the aquifer and also of the river" would result. The court concluded that "change alone is not to be equated with impairment of the rights of others."

In *City of Roswell v. Berry*,<sup>53</sup> the State Engineer approved the City's proposed new well field because the expected lowering of the water level in the Roswell Artesian Basin would be offset by retirement of 1500 acre feet of other water rights in the Basin. He also determined that the expected lowering of the water level in a protester's wells would have a "negligible effect" on water quality. On appeal, the court rejected the protester's argument that any degradation, however negligible, constituted an impairment, holding that the "finding of 'negligible effect' does not require a determination, as a matter of law, that the chemical quality of the water in Berry's artesian wells was impaired by a lowering of the water level . . . by less than 0.16 feet."<sup>54</sup>

In *City of Roswell v. Reynolds*,<sup>55</sup> the court cited *Mathers v. Texaco, Inc.*,<sup>56</sup> and *Application of Brown*<sup>57</sup> in support of its holding that "the lowering of the water table does not necessarily constitute an impairment of the water rights of adjoining appropriators," but it cautioned that "it does not follow that the lowering of the water table may never in itself constitute an impairment of existing rights."<sup>58</sup> The court refused to consider waivers by owners of nearby wells, the City's senior priority, or its offer to reduce its water rights by 25% as grounds for overturning the conditions fixed by the State Engineer for approval of the City's application to move certain wells in the Roswell Underground Water Basin. In *Brown*, the protester had claimed impairment because the water level

---

50. *Id.* at 402, 367 P.2d at 711. In Colorado, where surface streams and "tributary" groundwater are legally distinguished from "designated groundwater," which is not sufficiently hydraulically connected to a stream or its alluvium, the courts have held that the tributary character of "water taking over a century to reach the stream . . . is *de minimis* and that this is not a part of the surface stream as contemplated by our Constitution." *Kuiper v. Lundvall*, 187 Colo. 40, 529 P.2d 1328, 1331 (1974), *appeal dismissed*, 421 U.S. 996 (1975). The Court noted: "By the time the rivers are affected by the pumping from this basin, we have little doubt but what scientific progress will have solved many of the problems caused by the failure of this water to reach the stream."

51. 75 N.M. 497, 406 P.2d 817 (1965).

52. 82 N.M. 416, 421, 483 P.2d 297, 302 (1971).

53. 80 N.M. 110, 452 P.2d 179 (1969).

54. *Id.* at 116, 452 P.2d at 185.

55. 86 N.M. 249, 522 P.2d 796 (1974).

56. 77 N.M. 239, 421 P.2d 771 (1966).

57. 65 N.M. 74, 332 P.2d 475 (1958).

58. 86 N.M. 249, 253, 522 P.2d 796, 800.

in his well would be reduced 3.9 feet, while in *Mathers* the court held that lower water levels and increased pumping costs were "inevitable results of the beneficial use by the public" of the waters of a non-rechargeable basin to which the State Engineer had assigned a 40-year life, allowing the lowest one-third for domestic uses.<sup>59</sup>

The *Brown*, *Mathers*, and *Roswell* decisions established that the holder of a New Mexico groundwater right has no vested interest in pristine water levels, or even in a stable water table, at least within a declared groundwater basin that by definition is subject to depletion by existing appropriators. In the only New Mexico case of well interference outside a declared basin, the federal court denied an injunction against the drilling of wells where plaintiffs' proof showed only a "loss of efficiency" in their existing wells and a slight increase in salinity. The court held that adverse effects on well performance did not constitute an impairment of water rights and retained jurisdiction to reconsider the issue if the degree of interference with plaintiffs' wells reached the level of "water right impairment."<sup>60</sup>

By holding that a groundwater right is not "necessarily" impaired by a drop in water levels, just as a surface water right is not impaired by changes in the natural flow of a stream, the New Mexico courts have held, in effect, that a water right does not guarantee the continuous use of an existing method of diversion. Since a water right is merely an "usufructuary estate" entitling the owner to capture, take, and use water for a beneficial purpose,<sup>61</sup> the means of capture and diversion must be efficient and non-wasteful; they may have to be changed to meet different conditions of the supply.<sup>62</sup>

In many western states, as groundwater has become more widely used and the practical consequences of the rigid protection of senior claims has become more clearly understood, "impairment" has been defined by statute as an "unreasonable" lowering of the water or pumping level.<sup>63</sup> The "reasonableness" of such a decline may be decided strictly on economic grounds, or according to hydrological estimates of the level of pumping required to use the resource efficiently. Some states, like Mis-

---

59. 77 N.M. 239, 246, 421 P.2d 771, 776.

60. *Mestas v. Elephant Butte Irrigation Dist.*, No. 78-138B (D.N.M. May 11, 1979), as discussed in Comment, *Protection of the Means of Groundwater Diversion*, 20 NAT. RES. J. 625, 646-648 (1980).

61. *Coffin v. Left Hand Ditch Co.*, 6 Colo. 443, 446-47 (1882).

62. See cases cited *supra*, note 46.

63. ALASKA STAT. § 46.15.050 (1977); COLO. REV. STAT. §§ 37-90-102, -107(3) and (5) (1973), -111(1)(b); IDAHO CODE § 42-226, -237(a)(g) (Supp. 1980); KAN. STAT. ANN. § 82a-711 (Supp. 1981); MO. REV. CODES ANN. § 85-2-401 (1979); MONT. CODE ANN. § 85-2-401(1), -508, -511 (1981); NEV. REV. STAT. § 534.110(4), (5), (7) (1979); OR. REV. STAT. § 537.525(7), (8), .620(3), .685(2) (1979); WASH. REV. CODE ANN. § 90.44.070 (1962); WYO. STAT. § 41-3-933 (1977).

souri, have applied an economic criterion in denying a senior appropriator the right to stop junior pumping if he could "reasonably exercise" his water rights under the changed conditions. Under the Colorado statute, "reasonable" pumping levels, within "reasonable economic limits of withdrawal and use," are protected, but not the "historic water levels" necessary to preserve every senior's original means of extraction.<sup>64</sup> Wyoming, like Montana, has followed the resource management approach by providing that water levels will not be maintained above the level required for "maximum beneficial use" of groundwater. Such statutes require senior appropriators to bear the costs of adapting their methods of diversion—the size and depth of wells and pumps—to declining groundwater levels, to the point where full development and use of the resource will be possible. The cost of further measures would presumably be attributable to pumping by junior appropriators.

Where a statute permitting some degree of infringement of senior rights is unavailable, many courts have found unflinching application of the priority doctrine impossible in practice; therefore, they have used a variety of practical remedies to achieve a reasonable accommodation among conflicting uses and thus permitted desirable junior uses to begin or continue. Even where an injunction was held to be proper, the order was usually qualified to permit the junior use to continue with practical protection for the senior right. However, the cost fell on the junior user predominantly, if not solely.

Most of the decisions are in California. In *Montecito Valley Water Co. v. City of Santa Barbara*<sup>65</sup> the city had diverted nearly one-third of the flow of a creek covered by a senior water right. The court awarded damages for water previously taken and directed that an injunction be issued against the illegal diversion "if any and all other forms of relief should be found inadequate," suggesting "restoration of the given amount of water, or in some other manner which shall meet in equity." The ruling in *Eckel v. Springfield Tunnel & Development Co.*<sup>66</sup> similarly authorized restoration of "an equal quantity of water of like quality" as an acceptable condition of an injunction against the infringing junior use. In *City of Lodi v. East Bay Municipal Utility District*<sup>67</sup> the California Supreme Court directed the trial court to consider possible "physical solutions" to the impairment of the city's senior rights by the district's upstream storage, which blocked flood flows that had maintained the groundwater level for the city's wells, suggesting that the district supply the city's requirements by pipeline from surface storage, with all expenses to be borne by the

---

64. *Fundingsland v. Colorado Ground Water Comm'n*, 171 Colo. 487, 468 P.2d 835, 839 (1970).

65. 144 Cal. 578, 77 Pac. 1113 (1904).

66. 87 Cal. App. 617, 262 P.425 (Cal. Dist. Ct. App., 1927).

67. 7 Cal. 2d 316, 60 P.2d 439 (1936).

district as junior appropriator. Although stating that the "prior appropriator . . . cannot be compelled to incur any material expense in order to accommodate the subsequent appropriator," the court held that the senior interest could be "required to make minor changes in its method of appropriation" to avoid waste of the resource and directed the trial court to define a water level to which the city would be required to deepen its wells, with the district required to maintain the water level above that depth or to provide a substitute supply. Similarly, in *Rancho Santa Margarita v. Vail*<sup>68</sup> the court directed the trial court to try to find a "physical solution" to reductions in stream flow caused by upstream riparian use, which lowered water levels in the river valley and interfered with plaintiff's shallow stock wells. The court held that "the lower owner cannot be expected or required to endure an unreasonable inconvenience or to incur an unreasonable expense in order to make more water available for the use of the upper riparian," and that the upper user must bear "a fair proportion of the expense of providing an alternative supply for the downstream ranch or face an injunction." In *Gerlach Livestock Co. v. United States*,<sup>69</sup> the federal courts interpreted California law as placing on the junior user the full expense of the "physical solution" to "preserve existing prior rights."

However, in *MacArtor v. Graylyn Crest III Swim Club, Inc.*,<sup>70</sup> the Delaware court conditioned an injunction on the defendant's paying one-half the cost of deepening plaintiff's shallow well, or one-half the expense of transporting water from defendant's well to the swimming pool. Damages were recovered (for the cost of a pump, cement, and 10 years' electricity) for a stock well dried up by a junior appropriation in *Dep't of Natural Resources v. Crumpled Horn*,<sup>71</sup> but the court denied damages for replacement of a pump that was more than 30 years old because "wells of this type are depreciated out by this time."<sup>72</sup>

In Colorado, the 1961 decision in *Colorado Springs v. Bender*<sup>73</sup> required senior appropriators to bear the cost of modifying their means of diversion to adapt to declining water levels as long as "water still can be economically extracted when the total economic pattern of the particular desig-

---

68. 11 Cal. 2d 501, 81 P.2d 533, 562-63 (1938).

69. 76 F. Supp. 87, 95 (Ct. Cl. 1948), aff'd 339 U.S. 725, 752-755 (1950).

70. 41 Del. Ch. 26, 187 A.2d 417 (1963).

71. Interlocutory Findings of Fact and Conclusions of Law, *Dep't Natural Resources & Conservation v. Crumpled Horn*, No. 7076 (Mont. 9th Jud. Dist. May 16, 1978) (Discussed in Grant, *supra* note 2, at 10-15).

72. Grant, *supra* note 2, at 13.

73. 148 Colo. 458, 366 P.2d 552 (1961); COLO. REV. STAT. § 37-92-102(2)(b) (1973). Carlson, *Has the Doctrine of Appropriation Outlived Its Usefulness*, 19 ROCKY MTN. MIN. L. INST. 529, 534-547 (1974); Hannay, *Recent Developments In Colorado Groundwater Law*, 58 DEN. L. J. 801, 820 (1981).

nated groundwater basin is considered.”<sup>74</sup> The “economic reach” of the senior appropriator, which marked the limit of his duty to improve his extraction facilities under the court’s opinion, is shorter for small users than for larger users. Domestic and stock wells would thus have a preferred claim to indemnity because their water is of relatively low value, compared to large municipal, agricultural, or industrial uses.<sup>75</sup> The same comparison was involved in *State v. Michels Pipeline Construction, Inc.*<sup>76</sup> on the basis of § 858A of the Restatement (Second) of Torts. The court said: “Later users with superior economic resources should not be allowed to impose costs upon smaller water users that are beyond their economic capacity.”

In Wyoming, a preference for “adequate” domestic and stock wells is established by statute,<sup>77</sup> while Nevada directed its State Engineer to prohibit new domestic wells if water could be furnished by a municipal system.<sup>78</sup> Interference with domestic or stock wells might entail payment of full indemnity under a statute similar to the Oregon statute which prohibits “undue interference” with existing wells,<sup>79</sup> while interference with wells owned by interests with greater “reach” might not require indemnity, particularly if such wells were not sufficiently large or deep to achieve maximum utilization of the resource.

Judicial and legislative recognition that non-impairment cannot be absolute, that some infringements or burdens upon senior rights are necessary or permissible, led naturally to the idea that new uses may be initiated if established uses are indemnified. In Utah, a 1933 statute granted “the right of replacement,” at the “sole cost and expense of the applicant” and subject to the State Engineer’s approval, to any junior appropriator who lowered the quantity or quality of groundwater.<sup>80</sup>

Although *Current Creek Irrigation Co. v. Andrews*<sup>81</sup> imposed the entire increased cost of extraction on the junior pumper, the Utah Supreme Court in *Wayman v. Murray City Corp.*<sup>82</sup> held that the statute required “an analysis of the total situation. . . . All users are required where necessary to employ reasonable and efficient means in taking their own

74. COLO. REV. STAT. § 37-90-111(1)(a) (1973).

75. Comment, *South Dakota Ground Water and the Artesian Pressure: Is the Use of Water For Domestic Purposes Still the Highest Use?*, 24 S.D. L. REV. 772 (1979).

76. 63 Wis.2d 278, 217 N.W.2d 339 (1974).

77. WYO. STAT. § 41-3-911 (1977).

78. NEV. REV. STAT. § 534.120(2), (3)(a) (1979).

79. OR. REV. STAT. § 537.620(3), .735(3)(c) (1979); *Prather v. Eisenmann*, 200 Neb.1, 261 N.W.2d 766 (1978).

80. UTAH CODE ANN. § 73-3-23 (1980). The statute embodied the decisions in *Salt Lake City v. Gardner*, 39 Utah 30, 114 P. 147 (1911), *Big Cottonwood Tanner Ditch Co. v. Shurtliff*, 56 Utah 196, 189 P. 587 (1919), and *U.S. v. Caldwell*, 64 Utah 490, 231 P. 434 (1924).

81. 9 Utah 2d 324, 344 P.2d 528 (1959).

82. 23 Utah 2d 97, 458 P.2d 861, 865 (1969).



waters in relation to others to the end that wastage of water is avoided and the greatest amount of available water is put to beneficial use." One commentator has noted that the Utah statute increased the burdens on the junior appropriator above the risk imposed by the prior appropriation doctrine—"that seniors will take all the available water, leaving none for him"—requiring payment of indemnity "in tribute" to the seniors.<sup>83</sup> The *Wayman* decision indicates that senior interests will be required to bear at least some of the increased costs of extraction.

After the Colorado Supreme Court announced the goal of "maximum utilization" in *Fellhauer v. People*,<sup>84</sup> the legislature incorporated the same objective in the 1969 Water Rights Determination and Administration Act.<sup>85</sup> The court's opinion recognized that maximum utilization of groundwater resources would collide with the "vested rights" of prior appropriators of hydraulically connected surface streams.<sup>86</sup> The legislature's solution was to approve junior groundwater diversions that had not in fact deprived senior rights of water and to authorize new appropriations under a "plan for augmentation."<sup>87</sup> Such a plan might propose retirement of irrigation rights or any expedient that prevents injury to senior rights.<sup>88</sup>

In 1980, Arizona adopted a dewatering statute that requires a permit for necessary mine dewatering, subject to providing the pumpage without charge to those adversely affected.<sup>89</sup> Presumably, all other costs must be borne by the affected senior interest. Wyoming<sup>90</sup> and Idaho<sup>91</sup> have also adopted statutory methods of allowing junior appropriations of groundwater.

Mine dewatering required to recover uranium deposits in the Westwater Canyon member of the Morrison formation in New Mexico's San Juan Basin presented a critical challenge to the impairment concept. Dewatering a major aquifer might deprive existing users of their supply and

83. Widman, *Groundwater-Hydrology and the Problem of Competing Well Owners*, 14 ROCKY MTN. MIN. L. INST. 523, 538 (1968).

84. 167 Colo. 320, 447 P.2d 986 (1968).

85. Codified at COLO. REV. STAT. § 37-92-102(1)(a) (Supp. 1980). Note, *A Survey of Colorado Water Law*, 47 DEN. L. J. 226, 296-308, 331-39 (1970).

86. 167 Colo. 320, 447 P.2d 986, 994.

87. COLO. REV. STAT. § 37-92-501(1) (1973); COLO. REV. STAT. § 37-92-301(2) (Supp. 1980).

88. *Kelly Ranch v. Southeastern Colo. Water Conserv. Dist.*, 191 Colo. 65, 550 P.2d 297, 299-301, 304 (1976); *Cache La Poudre Water Users' Ass'n v. Glacier View Meadows*, 191 Colo. 53, 550 P.2d 288, 289-91, 293 (1976); Hannay, *supra* note 73.

89. ARIZ. REV. STAT. ANN. § 45-513 (Supp. 1981-1982). Johnson, *The 1980 Arizona Groundwater Management Act and Trends In Western States Groundwater Administration and Management: A Mineral Industry Perspective*, 26 ROCKY MTN. MIN. L. INST. 1031, 1082 (1980); Goodman, *Current Groundwater Law in Arizona*, 1978 ARIZ. ST. L. J. 205; Higdon and Thompson, *The 1980 Arizona Groundwater Management Code*, 1980 ARIZ. ST. L. J. 621.

90. WYO. STAT. § 41-3-106(a) (Supp. 1981).

91. IDAHO CODE § 42-228 (Supp. 1980).

thus "impair" their rights; yet dewatering was wholly unregulated. The State Engineer's jurisdiction was limited to an "appropriation" based on beneficial use; displacement of water to obtain access to mineral ores involved no beneficial use and hence was not an appropriation.<sup>92</sup> The administrative apparatus, therefore, could not protect the affected uses, which included the full variety of industrial, municipal, agricultural, domestic, and livestock.

Instead of leaving the problem for the courts, which might have withheld any remedy under the precedents that mine dewatering is a privilege of ownership,<sup>93</sup> the legislature passed a Mine Dewatering Act in 1980 to place the entire problem in the State Engineer's hands.<sup>94</sup> A permit is prospectively required for mine dewatering, which is defined as the diversion and discharge of groundwater developed by mining activities, including both wells and mine shafts.<sup>95</sup>

To permit dewatering to occur despite impairment of existing rights the act created a "right of replacement," but it is applicable to any appropriation, not only to mine dewatering.<sup>96</sup> Senior rights affected by dewatering are deprived of their right to seek an injunction against such subduction of groundwater,<sup>97</sup> although the act disclaims any intent to change constitutionally established priorities or to take them by eminent domain.<sup>98</sup>

The New Mexico right of replacement is the most significant recent innovation in western water law.<sup>99</sup> Although similar to its antecedents in Utah and Colorado, the New Mexico statute applies more broadly, to surface as well as to groundwater appropriations. It thus amounts to the statutory abandonment of the strict non-impairment policy in the interest of fostering new water uses, if a "plan of replacement" (P/R) to avoid or prevent impairment of existing rights, regardless of priority, receives administrative approval. Although no P/R has yet been approved by the

---

92. In 1941 New Mexico enacted N.M. Stat. Ann. § 72-5-27 (1978), presumably to confirm the decision in *Hagerman Irrigation Co. v. East Grand Plains Drainage Dist.*, 25 N.M. 649, 187 P. 555 (1920), that artificial or developed water is private property, subject to beneficial use by the owner. See Clark, *Background and Trends in Water Salvage Law*, 15 ROCKY MTN. MIN. L. INST. 421, 434 (1969). That statute could divest the State Engineer of jurisdiction even where mine water was beneficially used, as in an ion exchange process to recover marketable uranium salts.

93. See cases cited *supra* note 41.

94. N.M. Stat. Ann. §§ 72-12A-1 to -13 (1978). Comment, *New Mexico's Mine Dewatering Act: The Search For Rehoboth*, 20 NAT. RES. J. 653 (1980).

95. N.M. Stat. Ann. § 72-12A-3(B), -6 (1978). N.M. Stat. Ann. § 72-5-25 (1978) was not repealed and may yet govern pre-enactment dewatering under N.M. Stat. Ann. § 72-12A-5B (1978).

96. N.M. Stat. Ann. § 72-12A-4 (1978).

97. N.M. Stat. Ann. § 72-12A-11(B) (1978). The State Engineer may seek an injunction under N.M. Stat. Ann. § 72-12A-11(A) (1978).

98. N.M. Stat. Ann. § 72-12A-13 (1978).

99. See Corker, *Inadequacy of the Present Law To Protect, Conserve and Develop Groundwater Use*, 25 ROCKY MTN. MIN. L. INST. 23-1 (1979).

State Engineer, the plans awaiting consideration provide various indemnities to alleviate the probable effects of mine dewatering. Mine dewatering may render existing extraction equipment ineffective within its normal useful life, thus demanding an extraordinary expenditure to maintain a water supply. The indemnity provisions of the typical P/R, following the damage awards for well interference and the "physical solution" cases, obligate the applicant to pay such costs as increased utility expense, deepening the well, replacing the pump, or enlarging its capacity, and, in extremity, constructing a new well. The period of such indemnities runs from a few years to almost indefinitely. The Act authorizes delivery of mine water as a substitute supply, but such a physical solution would rarely be practical.

Whether existing rights are protected against impairment by subduction of water in hydraulically connected aquifers (or streams) caused by mine dewatering is to be decided on an individual basis. Each affected well (or surface point of diversion) must be identified, and existing extraction equipment must be described and evaluated. Protection need not be provided for existing extraction facilities rendered ineffective by a decline in the groundwater level attributable to continued appropriations under existing vested or permitted rights, for wells formerly productive but now abandoned or out of service, for "Mendenhall" wells whose construction was begun before declaration of the groundwater basin but never perfected with due diligence,<sup>100</sup> or for wells that have failed to meet the conditions of a permit prescribed by the State Engineer. By use of a digital model, the effects of dewatering are projected across the basin and over the time in which the pumping stress will be physically present in its saturated materials. Each affected point of diversion can thus be separately identified, the expected decline in water level measured, and its economic effects calculated. The P/R's "replacement" provisions are typically a schedule of economic indemnities for which the applicant admits liability.

Initiation of a P/R rests with the new user. The statutory standard for the State Engineer's approval of a P/R is whether it "avoids"<sup>101</sup> or "prevents"<sup>102</sup> impairment of existing rights. A somewhat different standard must be applied on complaint of the senior interest that his rights are being impaired. The Engineer then determines whether this interest is "protected" by the plan.<sup>103</sup> The different standards seem to recognize that approval of the P/R must be based on theoretical factors,<sup>104</sup> while its

---

100. State ex rel. Reynolds v. Mendenhall, 68 N.M. 467, 362 P.2d 998 (1961).

101. N.M. Stat. Ann. § 72-12A-3(D), -8(A) (1978).

102. N.M. Stat. Ann. § 72-12A-3(E), -7(F) (1978).

103. N.M. Stat. Ann. § 72-12A-7(H), -9(B), -9(C) (1978).

104. N.M. Stat. Ann. § 72-12A-8(A) (1978).

enforcement is based on the actual operation of the plan in practice. If the P/R has not worked out as expected at the time of approval, the permit can be suspended or terminated,<sup>105</sup> and the parties thus forced to renegotiate an amended plan. Or, if a dewatering permit was granted without a plan, the Engineer may suspend or terminate the permit,<sup>106</sup> if a senior interest shows impairment, thus exposing the mining company to immediate termination of pumping and forcing the parties to bargain for a P/R. The Engineer has no direct authority to impose a plan or an amendment, but his power to suspend or terminate a permit and to withhold approval of a P/R is equivalent to compulsory arbitration.

The applicant's ability to file a P/R with the State Engineer and request approval despite a senior right's refusal to consent may be a powerful advantage in the bargaining process, notwithstanding the P/R's legal admission that the applicant's proposed activity will injure the scheduled existing uses. The liability phase of the potential plaintiff's case is thus proved by the defendant, the applicant. But he controls the schedule of affected rights and the indemnities, supported by the model's projections. Thereafter, negotiations about the proposed indemnities will be similar to negotiations of a settlement of an action for damages for well interference, but the senior right is deprived of his power to threaten an injunction to stop mine dewatering until a bargain is made.

If a substitute water supply is proposed by the P/R, the person furnishing the water obtains a water right in the amount and for the use specified in the P/R.<sup>107</sup> Where mine dewatering is involved, with no beneficial use of the water, a water right could not arise. But furnishing the mine discharge to the senior interest completes the appropriation and creates the water right through the recipient's beneficial use.<sup>108</sup> Since the recipient of the substitute water supply does not lose his senior rights,<sup>109</sup> he conceivably could sell his old rights for transfer elsewhere, substituting the contractual provisions of the P/R as the basis for his supply.

The State Engineer cannot directly enforce the indemnities. The mining company must fulfill the P/R "with all deliberate speed," which is probably equivalent to the "due diligence" requirement for completion of works under the doctrine of relation back. Enforcement of the P/R is left

---

105. N.M. Stat. Ann. § 72-12A-9(B) (1978).

106. N.M. Stat. Ann. § 72-12A-9(C) (1978).

107. N.M. Stat. Ann. § 72-12A-7(G) (1978). *Mathers v. Texaco, Inc.*, 77 N.M. 239, 421 P.2d 771 (1966).

108. An application for a dewatering permit with a P/R that proposes furnishing a substitute water supply should fall under N.M. Stat. Ann. § 72-12A-3 (1978) rather than N.M. Stat. Ann. § 72-12A-7(A) (1978). For simplicity, N.M. Stat. Ann. § 72-12A-7(G) (1978) expressly makes a separate application unnecessary.

109. N.M. Stat. Ann. § 72-12A-13 (1978).

principally in the hands of the indemnitee; if he does not complain, the Engineer cannot order payment of the indemnity.<sup>110</sup>

The "right of replacement" with compulsory indemnity for senior rights may eventually be adopted by other states and supersede the non-impairment concept as the basis of administrative control over western water resources. New uses prohibited by impairment predicated on vague and general hydrological analyses, without regard to actual deprivation of water, may be initiated under a P/R at the cost of an actual indemnity, payable at such time as a loss is imminently threatened or actually incurred, and limited to the cost of obviating the deprivation. Broad-scale purchase and retirement of irrigated lands will no longer be necessary, unless they would actually be forced out of production by subduction of their supply. No longer can state water administrators ignore the long periods between initiation of a new use and the manifestation of its effects. The statutory right of replacement coupled with administrative, rather than judicial, approval of the plan of replacement will probably allow new appropriations at minimum cost. The fixed indemnities of the P/R will certainly be less than the cost of purchasing outright the adversely affected senior rights, and the cost would probably be less than a damage award in a suit by aggrieved senior interests.<sup>111</sup>

It is not yet apparent whether the P/R procedures prescribed by the 1980 Dewatering Act will be adequate to handle messy situations like the widespread dewatering of the Westwater Canyon aquifer. Pumping will occur at many locations, cones of depression will intersect and overlap, the same senior interests will be affected by more than one dewaterer, and the multiple indemnities proposed by overlapping P/R's will require both sophisticated models to calculate each company's proper share and an administrative system to assure due payment of the proper indemnity by each company. Since the mining companies involved have had ex-

---

110. N.M. Stat. Ann. § 72-12A-9 (1978). The State Engineer's permit, under N.M. Stat. Ann. § 72-12A-7(F) (1978) is "contingent upon implementation and maintenance of the plan." If the plan were not in fact carried out, the State Engineer might *sua sponte* invoke the contingency and terminate the permit.

111. Such plaintiffs would find it difficult to sue for an injunction (in the case of preenactment dewatering or a non-dewatering withdrawal of groundwater) because proof of irreparable injury may not be available in advance of actual impairment, *Maestas v. Elephant Butte Irrigation Dist.*, No. 78-138B (D.N.M. May 11, 1979), and the statutory recognition that impairment could be obviated by approved P/R indemnities may lead a court to find that the plaintiff has an adequate remedy at law in an action for damages. A damage action would require proof of plaintiff's senior rights, the nature and extent of its uses, the reduction of his available supply proximately caused by the defendant's withdrawals, and the economic costs of reestablishing a reliable supply, or the direct and consequential losses resulting from loss of the supply. Such evidence could also be presented in the administrative proceeding to approve the P/R, and the scheduled indemnities could be the same as judicially awarded damages. But a local jury may well have different concerns from the State Engineer. To the extent P/R indemnities were less generous than a jury award, the administrative procedure favors new uses.

perience with complicated royalty interests, they should be equipped to handle multiple water indemnities.

A company's contribution to the necessary indemnity for a well should be proportionate to its contribution to the well's impairment during a specified period. For a calendar year (or other period) the projected impairment of an existing well will be so many feet, caused by so many pumpers. An adequate "replacement" for that period should then be provided at the expense of all such pumpers in proportion to their respective projected effects for that interval, determined by agreement or possibly by a governing model. If more pumpers appear over time, the increasing impairment should be borne by the increased number of pumpers, who should contribute to the indemnity in proportion to their respective incremental contributions to the impairment.

Since many pumpers will no doubt contribute to the impairment of particular wells in different amounts for different periods, each individual's contribution to the impairment during each period should be scheduled. With the State Engineer's support, all P/R applicants might be persuaded to sign an agreement with all adversely affected senior interests so as to apportion the necessary indemnity for each impaired well. The first permittee could be responsible for paying the indemnity for each well impaired by its pumping, and its responsibility could continue as long as its incremental projected pumping impaired the well. The responsible pumper would, under the agreement, collect the contributions of junior pumpers to the total indemnity and see that the required "replacement" was actually made. Whenever its pumping ceased to contribute to the impairment, its administrative chores as "responsible pumper" would be passed on the next senior indemnitor for as long as its pumping contributed to the impairment. If contractual administration of the indemnity system failed, the State Engineer might step in and enforce the indemnities.

The P/R mechanism is workable only because computer models of water basins have become feasible in the last several years. For complex, multiparty arrangements, all parties may need to agree on a single model, which will thus become the oracle of hydrological truth. The technical ability appears to exist. Within the modeled basin, existing uses can be displayed and the effects of proposed pumping projected, measurements of effects in specific nodes of the model surface are obtainable, and the incremental effects of overlapping cones of depression can be taken into account.

An accurate model would give the same answers as a direct physical measurement. Indeed, the model may provide information that could not, with present equipment and methods, be obtained directly; therefore, an accurate model can be substituted for the physical reality for all relevant

judicial and administrative purposes. However, an experienced model maker recently stated that "a model is only an approximate representation of the prototype system. . . . The state of the art of digital modeling does not permit a [scientific] statement on the confidence limits bounding the projections made by the model. . . . The confidence in the predicted response to these simulated withdrawals [must be] based on the subjective appraisal of the analogy between the [actual] aquifer system and the model."<sup>112</sup> For P/R purposes, the authority of a model may be based on a multiparty agreement or the State Engineer's discretion rather than judicial approval after consideration of the evidence.

Although scientific study of surface water began in the second half of the 17th century,<sup>113</sup> measurement of the movement of groundwater began with Darcy's Law in 1856.<sup>114</sup> The digital computer finally made reliable models practical within the last 15 years.<sup>115</sup> The basic requirements for a valid model are an accurate description of the physical system, mathematical equations that describe correctly the shape, distribution, and quantity of water in an aquifer and the flow of water both on and under the earth, and proper description of the "boundaries" of the model area.<sup>116</sup>

Physically, a model consists of a set of Fortran commands, in print or on cards or tape, which control a computer's calculations. The calculations produce a mathematical (numerical) description of the flow of water in the system according to equations which describe or measure the

---

112. Glenn A. Hearne, *Mathematical Model of the Tesuque Aquifer System Underlying Pojoaque River Basin and Vicinity*, *New Mexico* 4, U.S. GEOLOGICAL SERVICE OPEN FILE REP'T NO. 80-1023 (January, 1981).

113. Pierre Perrault (1608-1680) and Edme Mariotte (1620-1684) measured rainfall and subsequent runoff; Edmund Halley (1656-1742) measured evaporation rates. 6 *ENCYCLOPAEDIA BRITANNICA* 80(d) (1974).

114. Henri Darcy (1803-1858) measured the flow of water through sand and found that the volume of water was proportionate to pressure and inversely proportionate to the thickness of the bed. 8 *ENCYCLOPAEDIA BRITANNICA* 438(b) (1974). A useful introduction, with appropriate drawings, is Widman, *supra* note 83.

115. Dr. George F. Pinder's work was basic. Pinder & Bredehoeft, *Application of the Digital Computer for Aquifer Evaluation*, 4 U.S. GEOLOGICAL SERVICE, WATER RESOURCES RESEARCH NO. 4, at 1069-1093 (1968); Pinder, *A Digital Model for Aquifer Evaluation*, 7 U.S. GEOLOGICAL SERVICE, TECHNIQUES OF WATER-RESOURCES INVESTIGATIONS ch. CI (1970). The mathematical code was published in P. C. Trescott, *Documentation of Finite-Difference Model for Simulation of Three-Dimensional Ground-Water Flow*, U.S. GEOLOGICAL SERVICE OPEN FILE REPORT NO. 75-483 (1975), Supp. 76-591 (1976); Trescott, Pinder & Larson, *Finite Difference Model for Aquifer Simulation in Two Dimensions with Results of Numerical Experiments*, 7 U.S. GEOLOGICAL SERVICE, SURVEY TECHNIQUES & WATER-RESOURCES INVESTIGATIONS ch. CI (1976); and Posson, Hearne, Tracy & Frenzel, *Computer Program for Simulating Ground-Water Flow in Three Dimensions*, U.S. GEOLOGICAL SERVICE OPEN FILE REPORT NO. 80-421 (1980).

116. The following eight paragraphs have been derived from Exhibit US-126 in *State vs. Aamodt*, No. 6639-M Civil, D.N.M. (Pinder & Balleau, SIMULATION OF THE POJOAQUE GROUND-WATER BASIN (1980)).

interrelationships of significant parameters.<sup>117</sup> Values are assigned according to observed characteristics of the real system for the reservoir's ability to store ("specific storage" and "specific yield")<sup>118</sup> and to redistribute water among localities with differing water levels ("hydraulic conductivity")<sup>119</sup> and to accommodate different pumpage rates ("stress"). The governing equations are, by themselves, an incomplete description of the system. Further information is required to describe the model's

117. "The equation for three-dimensional flow of groundwater in a porous medium can be written similarly to Trescott (1975) as

$$\frac{d}{dx} \left( K_x \frac{dh}{dx} \right) + \frac{d}{dy} \left( K_y \frac{dh}{dy} \right) + \frac{d}{dz} \left( K_z \frac{dh}{dz} \right) = S_s \frac{dh}{dt} + W(x,y,z,t)$$

where,

$K_x$ ,  $K_y$ , and  $K_z$  are the hydraulic conductivities in the  $x$ ,  $y$ , and  $z$  directions ( $L/T$ );

$h$  is the hydraulic head ( $L$ );

$S_s$  is the specific storage ( $L^{-1}$ );

$W$  is the volume of water released from or taken into storage per unit volume of the porous medium per unit time, and represents a source-sink term ( $T^{-1}$ ); and

$t$  is time ( $T$ )." The equation is given in Hearne, *supra* note 112, at 9.

118. "Water is stored in the Tesuque aquifer system in both confined and unconfined conditions. Therefore, it was necessary to estimate both the specific storage and the specific yield. Under confined conditions, a decrease in hydraulic head is associated with expansion of the water and compression of the porous medium. Similarly, an increase in hydraulic head is associated with compression of the water and expansion of the porous medium. The specific storage is the volume of water released from or taken into storage per unit volume of the porous medium in response to a unit change in hydraulic head.

"The compaction of the porous medium associated with declines in hydraulic head is a combination of elastic and inelastic (plastic) deformation. Elastic deformation is fully reversible if the hydraulic head returns to the initial condition. Plastic deformation is irreversible. Available data only are adequate to estimate the specific storage due to elastic compaction. Compaction of sandy beds is typically elastic. Clay or silty beds typically contain more water per unit volume, release the water more slowly, and undergo more plastic deformation than sandy beds. The amount of plastic deformation to be expected from a clay or silty bed depends on the geologic history of the bed. Because of the permanence of the deformation, a bed will have very little plastic deformation until the stress exceeds the maximum stress to which the bed has been subjected. Because of this threshold effect and the slow release of water, the development of a ground-water reservoir (which generally produces a large change in hydraulic head after a long time) may produce plastic deformation that was not determined during aquifer tests (which generally produce a small change in hydraulic head after a short time)." Hearne, *supra* note 112, at 16.

"For unconfined conditions, the change of the volume of water in storage per unit area as the result of a unit change in hydraulic head is produced primarily by the draining or filling of pore space. This change is dependent upon pore size, rate of change of the water surface, and time. Only an approximate measure of the relationship between hydraulic head and storage is obtainable for unconfined conditions. This measure is the specific yield." Hearne, *supra* note 112, at 17.

119. "The ability of an aquifer to transmit water can be described by the hydraulic conductivity or by the transmissivity. Hydraulic conductivity is the volume of water that will flow in unit time through a unit area under a unit hydraulic gradient. Transmissivity is the product of the hydraulic conductivity and the saturated thickness. For an ideal aquifer, transmissivity may be determined by aquifer tests conducted using wells that are open to the total thickness of the aquifer. . . . Transmissivity also may be estimated from specific-capacity data. The specific capacity of a well is the ratio of the rate at which water is withdrawn to the drawdown of water level in the well." Hearne, *supra* note 112, at 9.



boundaries, which typically are connections between an aquifer and surface water or impermeable material ("boundary conditions"), and to describe the water levels in the model area at a specified time ("initial conditions"). The governing equations, augmented by the specified boundary and initial water-level conditions, constitute a complete mathematical description of the hydrologic system. To the degree that a mathematical model is an accurate realization of the physical system, it can be used to forecast the response of the system to current or proposed water uses or development programs.

The equations governing groundwater flow in a system are well established and can be found in the scientific literature.<sup>120</sup> The numerical procedure employed in the approximation of these equations is the well established method of finite differences. The specific finite-difference formulation (the program) and the computational scheme (the algorithm) used to solve the resulting set of algebraic equations are also readily available in the scientific literature.<sup>121</sup>

Boundary conditions consist of information specified *a priori* at the boundaries of the model. The boundaries include locations where groundwater is in contact with adjacent bodies of surface water, the atmosphere, impermeable rock units, or simply where the extent of the model area is arbitrarily delimited because conditions in the model area have no significant effects at greater distances. In groundwater-flow simulation, boundary conditions can have three forms: specified constant flow, specified hydraulic head with variable flow, and a "Cauchy condition" which specifies the relationships between the hydraulic head and the flow. Initial conditions consist of the specification of water levels everywhere within the model area at some initial reference time.

A complete hydrologic model for the study of water quantities consists of the governing equations with their terms, boundary conditions and initial hydraulic head specified. A valuable but somewhat less complete model may be based on steady-state conditions, in which the volume and schedule of flow does not change and water levels do not rise or fall so that storage properties can be ignored. In this "steady" case, calculations are based on fewer terms than in the comprehensive model. The steady water-level elevation and flow rate at any point in the three-dimensional region of flow can be described and compared to other observed data for steady conditions. Historical or future changes in the flow system are not considered. This steady-state modeling procedure is useful in preliminary model calibration.

---

120. See, for example, PINDER & GRAY, *FINITE ELEMENT SIMULATION IN SURFACE AND SUBSURFACE HYDROLOGY*, ch. 5 (Academic Press 1977).

121. See, for example, Trescott, *supra* note 115 (1975), and Trescott & Larson, *supra* note 115 (1976).

Sometimes, a steady-state solution is an appropriate initial condition for a more complete (non-steady or transient) simulation. The transient simulation then makes it possible to include information on aquifer storage properties and on the amount and schedule of flow changes, such as well pumpage or river diversions, as part of a water development program.

The model is displayed as a surface map subdivided into a number of rectangles ("nodes"). Within each rectangle the hydraulic head is assumed to behave linearly. Thus, the finite-difference model approximates the physics of the natural system with an accuracy related to the shape of the natural system and the size of the rectangles. The model area is chosen sufficiently large in the areal plan that behavior at the edges (or boundaries) does not significantly affect simulation within the area of interest; thus, larger rectangles are used near the model edges where a high degree of resolution, in the form of information per square mile, is neither required nor achieved.

The model requires values for the parameters that describe the aquifer material (for the governing equations), specification of the nature of the flow at boundaries, and knowledge of the initial water levels. Where the aquifer is composed of interbedded layers of gravel, sand, silt, and clay and dips below the horizontal in a certain direction, hydraulic conductivity may vary according to direction ("anisotropy"), and a correct simulation requires a three-dimensional anisotropic model. Anisotropy can be accommodated through a judicious choice of grid orientation; an orientation aligned with the major trend of field conditions requires the specification of only three of the possible nine hydraulic conductivity components of an arbitrarily oriented system. Each element of a three-dimensional model may be visualized as one of a series of bricks representing three-dimensional cells.<sup>122</sup> The aquifer's hydraulic properties are derived from aquifer tests and other field studies, published information, and laboratory anal-

---

122. Hearne, *supra* note 112, at 9 elaborates:

To simulate a three-dimensional flow system, the description of the aquifer system provided by the conceptual model is subdivided in a large number of cubical cells. The continuous physical properties of the porous medium (that is, the ability to store and transmit water) are represented as discrete functions of space by assuming them to be uniform within each cell. Heterogeneity is possible because the physical properties may vary from cell to cell. The hydraulic head associated with each cell is the hydraulic head at the center of the cell. At each cell, a finite-difference approximation for the derivatives in the three-dimensional flow equation yields an algebraic equation in seven unknowns (hydraulic head in the cell and hydraulic head in each of six adjacent cells). For a model with  $N$  cells, a set of  $N$  simultaneous equations in  $N$  unknowns is generated. The simulation program solves this set of simultaneous equations subject to prescribed initial and boundary conditions. Refer to Trescott (1975) and Trescott, Pinder, & Larson (1976) [see *supra* note 115] for details of the solution algorithm. The computer program used for this study (Posson and others, 1980) evolved from that of Trescott.

Hearne, *supra* note 112, at 9.

ysis. Nevertheless, parameter values cannot be precisely measured empirically. To validate the properties assigned to the model, a "calibration" procedure is essential: the model is asked to reproduce the general hydrologic characteristics of the actual area, as disclosed in pumping tests, known steady-state water levels, and a realistic actual water balance between streams and aquifer in the area.

Once the values of aquifer properties have been validated in that manner, the appropriate boundary conditions must be specified and again validated through calibration, by determining the model's ability to reproduce historical water levels within the basin. Impermeable boundaries represent the contact between the aquifer and the relatively impermeable rocks of mountain ranges, faults, or other structures. The base of the model is also an impermeable boundary at a depth specified according to known or estimated geologic measurements. Constant head values simulate contact between the aquifer and rivers in the nodes of the model where the head is maintained at the elevation of the stream bed as estimated from topographic maps. A limited source boundary is a Cauchy boundary condition in mathematical nomenclature, which allows water to enter the node according to the vertical head gradient at that node. Thus, the rate of infiltration cannot exceed the water available in the stream nor a designated maximum infiltration rate determined by the proportionality constant coupling the head gradient and the flow through the stream bed. Constant-flow boundary conditions may be specified to account for infiltration and seepage from adjacent mountains and to accommodate consumptive use by native vegetation. Incorrect boundary conditions, like erroneous hydrologic parameters, can drastically distort the model, making it affirmatively misleading. Therefore, calibration is essential to construction of a reliable model.

Since the values used for the hydrological parameters are only wise approximations in the best cases, and the actual depth of saturated sediments throughout a basin often has not been precisely measured, the forecasts derived from a digital model are not equivalent in scientific reliability to astronomical forecasts of solar eclipses. Nevertheless, a good model is far superior to the earlier administrative fortunetelling, which governed "resource management" for the last three-quarters of a century.

Basin models constructed as the basis for a P/R to support a new appropriation or necessary mine dewatering can finally form the foundations of an effective market to allocate water among those who need it. The model will organize the essential market information concerning the geohydrological reality (the supply) and the existing water uses (the demand); it will specify the interests that must be "purchased" (the incremental impairments) and provide a basis for establishing a price (the indemnity). The deals that result will not be free of coercion; the reluctant

senior interest, unable to stop the proposed pumping, may see his supply disappear because of permitted pumping and face a Hobson's choice of negotiations to improve a P/R indemnity or a suit for damages based on the same data but with the uncertainty of a jury verdict after a spirited defense. However, the procedure will permit "purchase" of less than entire senior interests. Both existing and additional water-users will continue to share the resource, and the cost of developing the new use should be substantially less than the costs of achieving a complete substitution of new for old users.

The "right of replacement" has superseded the non-impairment rule, just as the latter superseded open appropriation. Public resources will, at least in part, be redirected from water projects to the technical data required to create acceptable basin models. Administrative discretion will be structured by the models; they will become the key resource management tool. Lurking in every cranny are justiciable issues that eventually will be litigated. All things considered, the interplay among existing and new users, administrators, scientists and engineers, courts and lawyers, and structured markets is more promising than at the creation of the water bureaucracies 75 years ago.