NATURAL RESOURCES JOURNAL

Volume 40
Issue 4 *Water Issues in the U.S.-Mexico Borderlands*

Fall 2000

Implications of Sustained Drought for Transboundary Water Management in Nogales, Arizona, and Nogales, Sonora

Barbara J. Morehouse

Rebecca H. Carter

Terry W. Sprouse

BARBARA J. MOREHOUSE,* REBECCA H. CARTER,**
AND TERRY W. SPROUSE***

The Implications of Sustained Drought for Transboundary Water Management in Nogales, Arizona, and Nogales, Sonora

ABSTRACT

An analysis of the potential impacts of severe drought on long-range water resource management in Nogales, Arizona, reveals that insufficient attention is paid to the potential combined impacts of such a drought on the water systems of Nogales, Arizona, and Nogales, Sonora. Most notably, effluent is an increasingly important renewable water resource for meeting demand in both communities. Today, most of the effluent is produced in Nogales, Sonora, and flows across the border to Nogales, Arizona. Effluent from both cities is treated on the Arizona side of the border at the Nogales International Wastewater Treatment Plant (NIWWTP). The treated water flows northward, recharging the aquifer and supporting a lush stretch of riparian vegetation and habitat along the Santa Cruz River. Should Mexico choose to retain its portion of the effluent currently treated at the NIWWTP, then Nogales, Arizona, could experience significant declines in water availability. Under extended drought conditions, this water source would likely become even more important and could generate negotiations for retaining the effluent in Sonora, or receiving compensation from Arizona. A parallel sensitivity analysis of the urban water system in Nogales, Sonora, an in-depth analysis of the implications of climate variability for water policy on both sides of the border, and greater availability and use of climate information are needed to address such potential stresses on transboundary water resources.

I. INTRODUCTION

Rapid population growth and development in portions of the U.S.–Mexico borderlands are generating increasing demands for water and

* Barbara J. Morehouse is Program Manager at the Institute for the Study of Planet Earth, The University of Arizona, Tucson, Arizona; Ph.D., 1993, The University of Arizona.

** Rebecca H. Carter is a Ph.D. student in the Department of Anthropology at The University of Arizona.

*** Terry W. Sprouse is a Ph.D. student in Arid Lands Resource Sciences at The University of Arizona, and Border Coordinator for the Santa Cruz Active Management Area (SCAMA), Nogales, Arizona.

pressure to develop additional sources of supply. Ambos Nogales, encompassing Nogales, Arizona, and Nogales, Sonora, is one such area. The two cities, named for the walnut trees (*nogales*) that used to grow in the vicinity, share serious challenges associated with managing scarce water supplies in a context of rising demand.[1]

Both cities rely on groundwater for their supplies, and both have come to view effluent as a significant component of their water resource base.[2] Even under average precipitation conditions,[3] the increasing value of effluent to the two communities poses challenges to binational cooperation in water resource management. Extended drought conditions would only increase these challenges.

We review the importance of effluent as a source of water supply for Ambos Nogales and consider the implications of severe drought for binational sharing of this resource. We base our work on the thesis that severe drought could pose significant threats to the water budgets of both urban areas, and place a strain on existing institutional arrangements. We argue that this issue should be addressed binationally before a major drought occurs.

II. AMBOS NOGALES IN CONTEXT

The twin cities of Nogales, Sonora, and Nogales, Arizona, share a landscape of low, steep hills, semiarid vegetation, and, today, virtually no surface water flow. The Santa Cruz River, the dominant stream in the area, no longer features perennial flow except downstream of the Nogales International Wastewater Treatment Plant (NIWWTP). The river originates in Arizona, northeast of Nogales, Arizona, then loops some 25 miles through Sonora and flows back across the border into Arizona. Nogales Wash, a major tributary of the Santa Cruz River, flows directly through both cities before converging with the river near the NIWWTP. The river

---

1. The 1999 projected population of Nogales, Arizona, was 21,360; neighboring Nogales, Sonora, with a 1999 projected population of 206,554, is almost ten times as large. Projections for the year 2018 place the population of Nogales, Arizona, at 27,000 and Nogales, Sonora, at 344,988. *See* CAMP DRESSER & MCKEE, INC., INTERNATIONAL BOUNDARY AND WATER COMMISSION PROGRESS REPORT: ELEMENT 4 SOCIO-ECONOMIC EVALUATION AMBOS NOGALES FACILITY PLAN (DRAFT) 4-97 (1997).

2. *See* HELEN INGRAM ET AL., DIVIDED WATERS: BRIDGING THE U.S.–MEXICO BORDER 67, 69-70 (1995).

3. Average annual precipitation for the period 1953 to 1995 in the Santa Cruz Active Management Area, within which Nogales, Arizona, lies, was 18.4 inches. *See* ARIZ. DEP'T OF WATER RESOURCES, THIRD MANAGEMENT PLAN FOR SANTA CRUZ ACTIVE MANAGEMENT AREA: 2000-2010 at 2-3 (1999), *available at* <http://water.az.gov/documents/TMP/tmp_final/pre-toc.htm#Santa> [hereinafter ADWR].

and the wash were historically the primary sources of water supply for residents of the watershed.[4]

To address the explosive growth in demand for potable water generated by a huge influx of residents drawn by employment opportunities in, or associated with, local *maquiladora* plants, Nogales, Sonora, has reached southward into the Los Alisos Basin for its municipal water supplies.[5] At the same time, Nogales, Arizona, has extended its reach northward to obtain supplies needed to support its lower, but still substantial, growth rate.[6] If Sonora were to develop more groundwater wells along its portion of the Santa Cruz River, concern would arise on the Arizona side of the border about the decreased availability of groundwater subflow. This subflow constitutes a significant input to the water supply in the water budget for Nogales, Arizona.[7]

The development of new water supplies, in turn, generates additional effluent flows that must be collected and treated. Much of this water returns to the system as surface flow and recharge to groundwater supplies downstream.[8] With proper infrastructure, this water can be returned to the source area upstream for recharge/reuse. Along this portion of the border, elevation generally decreases from south to north, placing Nogales, Arizona, in the downstream position with regard to surface water, subflows, and effluent flows.[9] The topography thus results in a loss to Sonora of this water as a potential (recycled) supply. Indeed, the topography of the area was a key factor in the decision to construct a wastewater treatment plant, the NIWWTP, in Nogales, Arizona, to process effluent from both sides of the border.[10] Outflows from the NIWWTP currently recharge groundwater and support a lush and highly valued riparian habitat north of Nogales, Arizona.[11]

The availability of this effluent is crucial to balancing the local water supply/demand budget in Nogales, Arizona.[12] This water is also viewed by Nogales, Sonora, as a potential source of supply augmentation to balance its own water budget.[13] By contrast, U.S. entities have resisted the

---

4. *See* INGRAM ET AL., *supra* note 2, at 59-61.

5. *See Issues*, AMBOS NOGALES WASTE WATER FACILITIES PROJECT UPDATE (Camp Dresser & McKee, Inc., Tucson, Az.), Winter 1997, at 3.

6. *See id.*

7. Water managers on the Mexican side of the border have indicated that they do not plan to drill new wells along the Santa Cruz River. Telephone interview with Terry Sprouse, Border Coordinator, Santa Cruz Active Management Area (Dec. 30, 1999).

8. *See* ADWR, *supra* note 3, at 2-15.

9. *See id.* at 2-8 to 2-10, 2-23 to 2-24.

10. *See* INGRAM ET AL., *supra* note 2, at 61.

11. *See* ADWR, *supra* note 3, at 3-19. *See also* INGRAM ET AL., *supra* note 2, at 191.

12. *See generally* ADWR, *supra* note 3, at 2-22 to 2-24.

13. *See* INGRAM ET AL., *supra* note 2, at 191-92; ADWR, *supra* note 3, at 2-24.

notion, arguing that retaining and treating the water in Sonora could pose a public health threat to Nogales, Arizona, due largely to concerns that Mexico would not enforce treatment standards at a sufficient level.[14]

A. Nogales, Sonora

1. *Water Supply/Demand*

Water resource management for Nogales, Sonora, lies within the purview of COAPAES.[15] The agency supplies water to 64 percent of the residents of Nogales, Sonora, and 85 percent of the residents of the surrounding region.[16] Local water consumption is estimated to be approximately 150 liters per capita per day (an austere 39.6 gallons per capita per day, compared to approximately 200 gallons per capita per day used in Nogales, Arizona).[17]

Water supplies for the city come from three sources: the Santa Cruz River (the actual river and proximate wells), the Los Alisos groundwater basin, and groundwater wells within the city. A total of 45 percent of the supply comes from an aquifer along the Santa Cruz River, 40 percent comes from wells in the Los Alisos groundwater basin, and 15 percent comes from the Nogales Wash aquifer.[18]

Of these three sources, the Santa Cruz River groundwater wells are the most sensitive to drought conditions. Here, the aquifer is shallow and the alluvium soil has a high level of transmissivity, meaning that surface water moves quickly into and out of the deposit.[19] There are currently two well fields in this area, the Paredes–Santa Barbara and the Mascareñas.[20] If Sonora were to develop more wells along this portion of the Santa Cruz River, there could be negative effects downstream, in Nogales, Arizona, for

---

14. *See* INGRAM ET AL., *supra* note 2, at 191.

15. Comisión de Agua Potable y Alcantarillado del Estado de Sonora (COAPAES) (Commission for Potable Water and Sewerage of Sonora) is a state agency headquartered in the state capital of Hermosillo.

16. *See* COMISIÓN NACIONAL DE AGUA, ACTUALIZACIÓN DEL PLAN MAESTRO DE LOS SERVICIOS DE AGUA POTABLE, ALCANTARILLADO Y SANEAMEIENTO DE LA CIUDAD DE NOGALES, SONORA 40 (1996) [hereinafter CNA].

17. *See* CAMP DRESSER & MCKEE, INC., *supra* note 1, at 4-97, 4-25, 4-37. *See also* INGRAM ET AL., *supra* note 2, at 58-59.

18. Interview with José Arreola, COAPAES Director, in Nogales, Sonora, Mex. (Sept. 29, 1998).

19. *See* INGRAM ET AL., *supra* note 2, at 55. *See also* ADWR, *supra* note 3, at 2-1.

20. The Paredes–Santa Barbara wells produce an average of 6,315 acre-feet a year; the Mascareñas well field produces an average of 2,684 acre-feet a year. However, yields in this area of the Santa Cruz River can decrease by more than 30 percent during dry seasons. *See* Juan Manuel Rodriguez Esteves & Luis Ernesto Cervera Gómez, *Aspectos de la Relación Sociedad-Ambiente Natural en la Cuenca Binacional del Río Santa Cruz, Sonora*, FRONTERA NORTE, Julio-Diciembre 1999, at 81, 99, 107-08 tbl.8.

the possibility exists that increased pumping could decrease availability of subflow north of the border.[21]

The Los Alisos well field, located some ten miles south of the border, taps waters from the Rio Magdalena watershed. Six wells currently pump water from the well field for use by the city of Nogales, Sonora.[22] This aquifer is considered to be the most important future source of water for the city.[23] Water from this well field may be largely non-renewable, for it is believed that precipitation may not be recharging the aquifer to any appreciable extent.[24]

Eighteen urban wells near Nogales Wash constitute a third source of water for Nogales, Sonora.[25] Today, water in the wash primarily comes from fugitive flows resulting from breaks in sewerage pipes and potable water pipes.[26] This well field constitutes the smallest source of drinking water for the city.[27] Due in part to persistent water contamination problems, it is considered a reserve supply.[28]

The national water resource agency, *Comisión Nacional de Agua* (CNA) predicts that by the year 2015, Nogales, Sonora, will need an additional 11,700 acre-feet of water per year.[29] The agency anticipates that this water will be supplied from new wells drilled between Agua Zarca and Cibuta, located respectively 16 and 30 km south of the city.[30] The Agua

---

21. Telephone interview with Terry Sprouse, *supra* note 7.

22. Currently, this well field pumps an average of 7,670 acre-feet a year for municipal use. *See* Rodriguez Esteves & Cervera Gómez, *supra* note 20, at 108 tbl.8.

23. *See* Luis Ernesto Cervera, *Planeación de la Demanda de Agua en Nogales, Sonora: La Sustenabilidad de su Utilización en una Región*, *in* DESARROLLO FRONTERIZO Y GLOBALIZACIÓN 185, 197 (Alejandro Mungaray & Ma. Guadaluepe García de León eds., 1997).

24. Soil borings suggest that there are actually two aquifers here—one shallow and alluvial, the other deeper. The two aquifers are separated by a confining layer. Radio isotope dating suggests that no significant amounts of new water are being recharged from the Los Alisos River. *See* CAMP DRESSER & MCKEE, INC., HYDROGEOLOGICAL ASSESSMENT FOR THE CANDIDATE DISCHARGE SITE AT RIO LOS ALISOS, SONORA, 4-1 (1998). Most of the water presently in the aquifer was deposited before 1952; dating of one well indicates that its water is at least 1700 years old. *See* generally R. ALLEN FREEZE & JOHN A. CHERRY, GROUNDWATER 134-36 (1979) (discussing carbon dating of groundwater).

25. *See* Rodriguez Esteves & Cervera Gómez, *supra* note 20, at 107 tbl.8.

26. *See* ADWR, *supra* note 3, at 2-18. *See also* INGRAM ET AL., supra note 2, at 73.

27. *See* Rodriguez Esteves & Cervera Gómez, *supra* note 20, at 107 tbl.8.

28. Interview with José Arreola, *supra* note 20. Two monitor wells on Nogales Wash in Mexico were found to have elevated levels of PCE. *See* INTERNATIONAL BOUNDARY AND WATER COMM'N, BINATIONAL NOGALES WASH UNITED STATES/MEXICO GROUNDWATER MONITORING PROGRAM, INTERIM REPORT 42 tbl.19 (1998).

29. *See* Cervera, *supra* note 23, at 197.

30. *See* CAMP DRESSER & MCKEE, INC., *supra* note 1, at 4-32, 4-37.

Caliente area, 44 km from Nogales, is viewed as a long-term future source as well.[31]

Construction and maintenance of water and sewerage infrastructure in Nogales, Sonora, remain problematical in part due to the fact that some service areas lie in steep, hilly terrain.[32] Currently, only 39 percent of the total population receives water 24 hours per day; 36 percent of the population is not connected to the system at all.[33] Those receiving piped water less than 24 hours per day, and those outside the system, must rely either on illegal connections or on delivery by large tank trucks (*pipas*) to supply their needs.[34] Estimates of the number of people using one or the other of these options range from 74,400 to 128,000.[35]

Aging infrastructure constitutes one of the largest water management problems in the city. Broken and leaky pipes result in supply losses estimated at 51.2 percent.[36] Much of this water ends up in the wastewater collection system, or in Nogales Wash, and flows northward into Arizona.[37] Similar infrastructure problems in the sewerage system contribute additional wastewater flows crossing the border.

2. *Regulatory and Institutional Factors for Nogales, Sonora*

Water management in Mexico is governed at the national level through the CNA. At the *municipio* level in Nogales, Sonora,[38] water management is under the authority of COAPAES.[39] This agency is responsible for building and maintaining infrastructure, as well as delivering water to customers. Binational water issues in the border area are handled by the International Boundary and Water Commission (IBWC), which is made up of separate American and Mexican sections.[40] The IBWC is discussed more fully below.

---

31. *See id.* at 4-37.

32. *See* INGRAM ET AL., *supra* note 2, at 69.

33. *See* CAMP DRESSER & MCKEE, INC., *supra* note 1, at 4-25.

34. Those who cannot receive water delivery legally often make illegal connections to the public water system. The *Colegio de la Frontera Norte* (COLEF) estimated that 3,000 such connections existed. *See* INGRAM ET AL., supra note 2, at 74.

35. This number was calculated using CNA data for COAPAES water coverage. The 74,400 figure is arrived at by multiplying the percentage of persons not connected to the system (36 percent) by the total population in 1999 (206,554). The 128,000 figure is based on multiplication of the percentage of persons who receive service only part of the day (62 percent) by the same total population figure. *See* CAMP, DRESSER & MCKEE, *supra* note 1, at 4-25, 4-97.

36. The CNA estimates 7,000 leaks occur a year. *See id.* at 4-25.

37. *See* ADWR, *supra* note 3, at 2-18.

38. *Municipios* are roughly commensurate with counties in the United States.

39. *See supra* note 15.

40. *See* INGRAM ET AL., *supra* note 2, at 180-82. The Mexican section is known by the acronym CILA (*Comision Internacional de Limites y Agua*).

B. Nogales, Arizona

1. *Water Supply/Demand*

The portion of the Santa Cruz River upon which Nogales, Arizona, and the surrounding area depends drains approximately 1,680 square miles of watershed;[41] its major tributaries are Nogales Wash, Sonoita Creek, and Sopori Wash. Unlike the Sonoran portion of the river, the stretch just across the border in Arizona features areas of intermittent flows, including perennial flows that support a lush riparian area immediately downstream from the NIWWTP.[42]

Renewable water supplies in the area are quite limited, although the area is generally in safe-yield condition (that is, demand is in balance with renewable supply). Indeed, the 1999 water management plan for the area explicitly recognized that large spatial, seasonal and interannual variations in local hydrology must be taken into account in efforts to maintain the sustainability of its water resources as required by law.[43] Key to renewable supplies in the area are precipitation falling on the Upper Santa Cruz River watershed and effluent flows from both Nogales, Sonora, and Nogales, Arizona.[44] Table 1[45] indicates the distribution of water supply by source, and water demand by sector.

The city of Nogales, Arizona, depends on several groundwater well fields for its water supply. The primary source of water is located in four shallow aquifer units along the Santa Cruz River.[46] The well field is located between the international boundary and the NIWWTP, with the wells being drilled in shallow alluvial deposits.[47] Due to the shallowness of the aquifer and the nature of the alluvium, the water table is very sensitive to meteorologic changes, rising quickly in response to precipitation events and falling rapidly in dry periods as pumpage depletes supplies.[48] The second well field is located northwest of the city of Nogales, along Potrero Creek. The wells here are deeper and are less sensitive to changes in precipitation

---

41. *See* ADWR, *supra* note 3, at 2-1.
42. *See id.*
43. *See id.* at 1-4.
44. *See id.* at 2-24.
45. *See* REBECCA H. CARTER ET AL., INSTITUTE FOR THE STUDY OF PLANET EARTH, ASSESSING THE SENSITIVITY OF THE SOUTHWEST'S URBAN WATER SECTOR TO CLIMATE VARIABILITY: CASE STUDIES IN ARIZONA 110 app.3 (CLIMAS Report No. CL1-00, 2000) (data derived from ADWR, *supra* note 3, at 11-13, 11-14).
46. *See* ADWR, *supra* note 3, at 2-12.
47. *See id.* at 2-5.
48. *See id.* at 2-13.

TABLE 1: 1995 AND 2025 WATER BUDGETS FOR THE SANTA CRUZ AMA

Water Resource	1992-1995 Average	2025 Baseline
SUPPLY		
Recharge:		
Main channel & major tributary	14,283	14,283
Main channel effluent	16,188	19,549
Mountain front and minor tributary	11,400	11,400
Underflow:		
Santa Cruz River at international boundary	300	300
West of Nogales, Mexico & the international boundary	700	700
Total inflows	42,871	46,232
Minus underflow leaving SCAMA	-8,700	-8,700
Total available renewable supply	34,171	37,532
DEMAND		
Municipal	6,300	11,400
Agricultural	11,300	10,300
(minus 36% incidental recharge)	-4,068	-3,708
Industrial	1,300	2,400
(minus 5% incidental recharge)	-65	-120
Exempt wells	500	1,000
Riparian use	25,800	25,800
Total Demand	**41,067**	**47,072**
WATER BALANCE	**-6,896**	**-9,540**
EFFLUENT		
Received at NIWWTP from Mexico	11,169	13,600
Produced in SCAMA and processed by NIWWTP*	5,019	5,949
Total Effluent	**16,188**	**20,577**

All figures are provided in acre feet.
Main channel recharge includes precipitation; effluent recharge refers only to effluent produced through water demand and that is recharged; this latter figure is assumed to increase by 2025 based on assumptions regarding increases in demand.
*The figure for 2025 is based on the "current use rate" demand scenarios (*See* ADWR, *supra* note 3. at 11-5, *see also* CARTER, ET AL., *supra* note 45 at 33-34.

patterns.[49] However, a cone of depression has formed around these wells, indicating that withdrawals are exceeding recharge.[50] It is anticipated that increases in demand for water will result in greater pumping from this well field.[51] Alternation between the two well fields during times of limited capacity has been identified as a way of coping with limitations on supply.[52]

2. *Effluent As A Supply Source*

Based on figures obtained from the NIWWTP for the period 1990-1998, effluent flows from Mexico have ranged from a low of 6,089 acre-feet in 1990 to a high of 11,208 acre-feet in 1995.[53] Projections for the future show wastewater flows from Sonora increasing to 19,800 acre-feet in 2020, 23,000 acre-feet in 2035, and 28,600 acre-feet in 2050.[54] However, climatic events may affect the amount in any given year, with higher flows probable in years of high precipitation (or when precipitation occurs in one or more very intense events) and lower flows occurring during drought years.

At current levels of demand and assuming average precipitation,[55] water supply and demand in the Nogales, Arizona, area are generally in balance. One of the most critical factors in sustaining this balance is receiving sufficient precipitation to maintain water levels in the wellfields. At the climate division level,[56] average annual precipitation amounts to 14.33 inches.[57] However, the range of precipitation is high, varying from a low of 7.94 inches in 1948 to a high of more than 24 inches in 1984.[58] Arizona Department of Water Resources (ADWR) has identified a cycle of approximately 30-year periods of alternately wet and dry conditions,[59] although annual variability even within these periods can be substantial.

---

49. *See id.* at 2-15.

50. *See id.*

51. *See id.*

52. *See id.*

53. This data was provided by Steve Tenza, Plant Manager, Nogales International Wastewater Treatment in Nogales, Arizona (Nov. 1999).

54. *See Work Completed*, AMBOS NOGALES WASTE WATER FACILITIES PROJECT UPDATE, (Camp Dresser & McKee, Inc., Tucson, Az.), Winter 1997, at 5.

55. *See supra* note 3.

56. The U.S. National Weather Service divides each of the states into climate regions, usually based on physiographic features. Arizona is divided into seven climate divisions. Data is aggregated and reported at the climate division level.

57. This figure was obtained from the web site of the Western Regional Climate Center, <http://www.wrcc.dri.edu>. The average annual precipitation noted in the SCAMA Third Management Plan specifically for Nogales, Arizona, is somewhat higher: 18.4 inches; however, the averaging period was much shorter: 1953-1995. *See* ADWR, *supra* note 3, at 2-1.

58. Data obtained from Western Regional Climate Center web site at <http://www.wrcc.dri.edu>.

59. *See* ADWR, *supra* note 3, at 2-1.

Maintaining safe yield with the current mix of municipal, industrial, agricultural, and riparian uses depends in no small part on the continued availability of the effluent flows from Mexico through the NIWWTP, as well as on the rate of growth in the area. Given that the Mexican portion of effluent flowing through the NIWWTP constitutes on average two-thirds of all water treated there, this water is a significant source of supply (see table 1).[60] Much of this water infiltrates the alluvium beneath the Santa Cruz River and then moves underground in a generally northerly direction.[61] Thus, while effluent is not directly piped to customers for potable uses,[62] the recharged effluent constitutes an important source of renewable groundwater downstream. Under drought conditions, this supply could become even more important, for the only other potential sources of water readily available are surface water in Pena Blanca Lake and Patagonia Lake.[63] Barriers exist to using these sources, as discussed later in this article.[64]

3. *Riparian Water Demand*

Of all current uses, riparian demand would likely be most immediately threatened by prolonged imbalances between water supply and demand in the SCAMA.[65] The riparian area expanded from about 6,200 acres in 1954 to some 8,600 acres in 1995, much of this along the Santa Cruz River and supported by increased effluent flows from the NIWWTP.[66] Over the same time period, evapotranspiration increased from 17,500 acre-feet per year to 25,800 acre-feet per year. Water losses to evapotranspiration also occur along Nogales Wash, Sonoita Creek, and Sopori Wash.[67]

Today, the riparian area on the Santa Cruz River extends 12 miles north of the NIWWTP. It provides habitat for myriad species of birds as well as other fauna, and offers appealing recreational opportunities including hiking, birding, and horseback riding. The riparian area constitutes the largest demand sector in the SCAMA.[68]

---

60. *See id.* at 11-1, 11-10.

61. *See id.* at 8-1.

62. Effluent may eventually be piped directly to several golf courses in the SCAMA. *See id.* at 2-24.

63. The city of Nogales, Arizona, owns surface water rights to 4200 acre-feet of water from Patagonia Lake; use of this water by the City of Nogales, Arizona is currently restricted by law to emergencies. *See* ARIZ. REV. STAT. ANN.§ 41-511.20 (West 1994). Even in an emergency this water would not be readily available due to lack of infrastructure to pipe the water to the city. *See* ADWR, *supra* note 3, at 2-24.

64. *See* ADWR, *supra* note 3, at 2-24.

65. *See id.* at 3-19.

66. *See id.*

67. *See id.* at 3-18.

68. *See id.* at 3-19.

Diversion of effluent flows from the area downstream of the NIWWTP would cause a serious reduction in water available to vegetation and wildlife in the area, for the only other water source is precipitation, which even in average years would today be insufficient to support the flora and fauna currently thriving there.[69] Significant attention has been brought to bear on this riparian area, with the intent of mobilizing the public to support its protection. A very active group, organized as the Friends of the Santa Cruz River, has as its primary mission protection of the riparian corridor along the river. Any attempts to divert significant quantities of water from the streambed below the NIWWTP could expect to meet strong resistance from this group.

Currently, several populations of the Gila topminnow living in the Santa Cruz River are under consideration by the U.S. Fish and Wildlife Service for possible designation as endangered species under the Endangered Species Act (ESA).[70] In addition, the U.S. Fish and Wildlife Service is currently working to determine the status of the yellow-billed cuckoo, which occupies riparian habitat along the upper reaches of the river.[71] Resistance to destruction of the riparian area could be mounted based on listing as endangered under the ESA. Such resistance, in turn, could be expected to generate tensions between those wanting to divert the water for purposes such as agriculture and those wanting to preserve the ecosystem. It is not possible at this point to foretell the outcome of such a contest.[72]

4. Regulatory/Institutional Considerations

Water resource management on the Arizona side of the international boundary is primarily under the jurisdiction of the ADWR through its Santa Cruz Active Management Area.[73] The Santa Cruz Active Management Area (SCAMA) office has responsibility for ensuring that groundwater on the Arizona side of the border is managed in accordance with the state's Groundwater Code.[74] The Code is designed to eliminate

---

69. *See id.*

70. *See id.* at 8-25.

71. *See id.*

72. However, if either the topminnow or the cuckoo is listed as endangered, federal requirements to support habitat for these species under the Endangered Species Act will likely supersede other uses of the water, including municipal and agricultural. Market-driven pressures will then focus on those non-protected demand sectors.

73. The SCAMA incorporates the Santa Cruz watershed, within which Nogales, Arizona, lies, from the international boundary on the south to just above the Pima-Santa Cruz County boundary on the north. *See* ADWR, *supra* note 3, at 1-7. Water quality is managed by the Arizona Department of Environmental Quality.

74. ARIZ. REV. STAT. ANN. §§ 45-401 to 45-704 (West 1994 & Supp. 1999). *See also* ADWR, supra note 3, at 1-2 to 1-4 (describing the ADWR and the Groundwater Code).

severe groundwater overdraft in areas of the state where groundwater supplies have been identified as rapidly diminishing, and to ensure that groundwater is allocated in the most effective manner to meet the state's water needs."[75] The Code includes provisions aimed at attaining and sustaining safe yield and preventing long-term water table decline. Safe yield, a cornerstone of the Code, is defined as achieving "and thereafter maintaining a long-term balance between the annual amount of groundwater withdrawn in an active management area and the amount of natural and artificial groundwater recharge in the active management area."[76]

The mission of the ADWR, and thus of the SCAMA, is "[t]o ensure a long-term, sufficient and secure water supply for the state; to develop public policy which promotes efficient use and equitable distribution of water in an environmentally and economically sound manner; and to promote the management of floodplains and dams to reduce loss of life and damage to property."[77]

According to the SCAMA Third Management Plan, "The volume of water that can be withdrawn while maintaining a safe-yield condition in the AMA will not be a fixed amount; it will change due to annual variations in incidental recharge, natural recharge, and safe-yield recharge."[78] Further, "The goal of preventing long-term declines in local water table levels is defined in the Santa Cruz AMA as maintaining a target water level, consistent with state surface water and groundwater laws which could vary by hydrologic segments, that on average must be maintained subject to natural fluctuations."[79] In order to attain the specified goals, the Groundwater Code gives ADWR regulatory authority over providers and well operators.[80]

The SCAMA office, an administrative and regulatory arm of the state ADWR agency, is located in Nogales, Arizona. The boundaries of the SCAMA encompass 716 square miles of the Upper Santa Cruz Valley River Basin.[81] The axis of the SCAMA is defined by the 45-mile stretch of the Santa Cruz River beginning at the international boundary and ending a few miles north of the Santa Cruz County–Pima County line. As stated in its Third Management Plan, the SCAMA has two primary goals: "to maintain a safe-yield condition and prevent local water tables from experiencing long-term

75. § 45-401 (West 1994).
76. § 45-561(12) (West 1994 & Supp.1999). *See also* ADWR, *supra* note 3, at 1-3.
77. ADWR, supra note 3, at 1-1.
78. ADWR, *supra* note 3, at 1-3.
79. *Id.*
80. *See* ARIZ. REV. STAT. ANN. § 45-411.04 (West Supp. 1999).
81. *See* ADWR, *supra* note 3, at 2-1.

declines."[82] In effect, by designating this area as a separate AMA in 1994,[83] the state legislature recognized the need to coordinate groundwater and surface water management, and the desire of water users to engage in transboundary water management coordination with Mexico.

The SCAMA office must take into account an array of institutional factors in its management of water supply and demand. Some of the key elements of the Arizona Groundwater Code that facilitate this effort are the authority to prohibit new irrigated agricultural activities,[84] license wells and govern spacing of wells,[85] establish mandatory conservation requirements (including enforcement authority)[86] aimed at achieving and maintaining safe yield, and monitor AMA's water budget.[87] AMAs, among other authorities, are also authorized to enforce assured water supply rules that require providers and new developments to demonstrate availability of a 100-year supply of water of satisfactory quality and quantity for human use.[88] A unique challenge facing SCAMA is interaction with Mexico regarding development and management of wastewater treatment facilities, as well as disposition of the treated water.[89]

Among the most significant provisions of the Groundwater Act are the assured water supply (AWS) and safe yield requirements. The AWS provision requires subdivision developers to demonstrate the availability of water of drinking water quality for 100 years.[90] The rule is intended to direct urban growth toward areas of the AMAs where large supplies of water are available.[91] The safe yield requirement, which calls for a balance

---

82. *Id.* at 1-3.

83. *See* ARIZ. REV. STAT. ANN. § 45-411.03 (West Supp. 1999). From 1980 to 1994, the SCAMA was part of the Tucson AMA. *See* § 45-411(A)(1) (West 1994).

84. ARIZ. REV. STAT. ANN.§§ 45-416, 45-431 to 45-452 (West 1994 & Supp. 1999).

85. §§ 45-559, 45-598 (West 1994 & Supp. 1999).

86. §§ 45-562(C), 45-565.01, 45-566 (A)(2) (West 1994 & Supp. 1999).

87. §§ 45-632, 45-633 (West 1994 & Supp. 1999).

88. § 45-576 (West 1994 & Supp. 1999).

89. *See* ADWR, *supra* note 3, at 1-15.

90. ARIZ. REV. STAT. ANN. § 45-576 (West 1994 & Supp. 1999).

91. Instituted in 1980 and strengthened in 1995, the Assured Water Supply Program, *see* ARIZ. REV. STAT. ANN. § 45-576 (West 1994 & Supp. 1999), is designed to ensure that purchasers of property within developments of a designated size or larger know what the status of their water supply is. The law allows developers in the AMAs to choose between two options. The first, and preferred option, is to provide proof that there is sufficient water of adequate quantity and quality to meet proposed uses for 100 years, and that use of the water be consistent with AMA goals. The second option is to forego demonstration of an assured water supply. In this case, the developer is required to formally advise buyers of the lack of an assured supply. A recent audit of ADWR raised the concern that, although the law requires the first purchaser of a property lacking an assured water supply be apprised of this fact, the law does not explicitly require that subsequent buyers be so notified. *See* DOUGLAS R. NORTON, ARIZ. OFFICE OF THE AUDITOR GEN., REPORT NO. 99-8, PERFORMANCE AUDIT: ARIZONA DEPARTMENT OF WATER RESOURCES 21-22 (1999).

between renewable supply and demand by the year 2025 in the AMAs, is designed to ensure that demand for water in the AMAs achieves balance with available renewable supplies.[92] The intent of the requirement is to bring a halt to groundwater mining or other unsustainable water consumption within the AMAs.

The SCAMA Third Management Plan indicates that the AMA is currently at safe yield,[93] and the assured water supply requirement has not posed significant issues to date. However, anticipated growth in demand and uncertainty about the volume of renewable water that will be available cast doubt on whether safe yield will be achieved by the year 2025.[94] Such doubts would likely be magnified in a severe extended drought producing a serious imbalance between supply and demand.[95] The AMA has developed a water budget that includes a range of supply conditions extending out to the tenth percentile of the distribution. Droughts even at the SCAMA-determined levels of probability would strain the area's capacity to meet demand.[96]

Conjunctive management of surface and groundwater resources is essential when managing for the kind of high variability in water supply and demand experienced in the SCAMA.[97] Yet Arizona law continues to impede such efforts.[98] Notably, as Glennon and Maddock[99] observed,

---

92. Attainment of safe yield is one of the key provisions of the Groundwater Code. *See* ARIZ. REV. STAT. ANN. § 45-561(12) (West 1994 & Supp. 1999). As written, the goal of this provision is "to achieve and thereafter maintain a long-term balance between the annual amount of groundwater withdrawn in an active management area and the annual amount of natural and artificial groundwater recharge in the active management area." *Id.* The volume of groundwater that can be withdrawn will change over time, depending on "annual variations in incidental recharge, natural recharge, and safe-yield recharge." ADWR, *supra* note 3, at 1-3. Whether safe yield can in fact be attained and maintained in the AMAs over the long term remains open to question, however. *See generally* NORTON, *supra* note 91.

93. *See* ADWR, *supra* note 3, at 11-9. Note, however, that calculations done for the CLIMAS Urban Water Sensitivity Analysis show the SCAMA as having a 17 percent deficit between supply and demand. *See* CARTER ET AL., *supra* note 45, at 110 app.3. Given the high level of responsiveness of the alluvial aquifers to meteorological variations, supply and demand in the AMA may move quickly into and out of safe yield status.

94. *See* ADWR, *supra* note 3, at 11-9, 11-11.

95. *See* CARTER ET AL., *supra* note 45, at 95-97.

96. *See* ADWR, *supra* note 3, at 11-9.

97. *See id.* at 1-2.

98. *Compare generally In re* General Adjudication of All Rights to Use Water in the Gila River Sys. & Source, 857 P.2d 1236 (Ariz. 1993), *and* Maricopa County Municipal Water Conservation Dist. Number One v. Southwest Cotton Co., 4 P. 2d 369 (Ariz. 1931), *with* ADWR, *supra* note 3, at 1-2.

99. Robert J. Glennon & Thomas Maddock III, *In Search of Subflow: Arizona's Futile Effort to Separate Groundwater from Surface Water*, 36 ARIZ. L. REV. 567, 571, 609-10 (1994). *See also In re* General Adjudication of All Rights to Use Water in the Gila River Sys. & Source, 857 P.2d at 1236 *Southwest Cotton Co.*, 4 P.2d 369.

fundamental principles of hydrogeology have not yet been taken into account effectively by the state of Arizona's Supreme Court when adjudicating water rights. Thus, conjunctive management of water resources in the SCAMA, as elsewhere in Arizona, remains problematical. Specifically, in parts of the Santa Cruz basin, surface water and groundwater are highly interactive.[100] Added to this is the problem of incomplete understanding of the degree of interaction between surface water and groundwater in the basin.[101] These factors, plus the patterns of ownership of surface and groundwater rights, make rational management of water resources in the SCAMA problematical at best, and even more challenging under conditions of water scarcity.

a. Relevant State-Level Authorities

Several state-level authorities, beyond the Groundwater Management Act, are associated with water management in the SCAMA. Perhaps the most important is the Arizona Department of Environmental Quality (ADEQ), which formulates and enforces water quality regulations.[102] ADEQ is responsible for issuing Aquifer Protection Permits, which are needed by any "new or...existing facility that disposes of pollutants to the land surface, the underlying soil, or to groundwater in order to prevent the groundwater contamination that would otherwise result, if there is a reasonable probability that the pollutants would reach the aquifer."[103] ADEQ is also responsible for issuing Wastewater Reuse Permits, which are required if direct use of treated wastewater, including effluent and industrial wastewater, is planned.[104]

Also important is the Arizona Corporation Commission (ACC), which regulates private water companies, particularly with regard to rate setting. The Arizona Department of Real Estate works with ADWR to assure that sufficient water is available for development of new subdivisions.[105] The 1991 Groundwater Transportation Act[106] restricts the ability of municipal providers to move groundwater from rural basins into the AMAs, as well as groundwater transfers between rural basins.[107] This legislation also, however, provides a legal framework for establishment of

---

100. *See* ADWR, *supra* note 3, at 1-2.

101. *See id.* at 11-11.

102. *See* ARIZ. REV. STAT. ANN. § 49-221 (West 1994 & Supp. 1999). Authority is also derived under the 1997 Water Quality Assurance Revolving Fund. *See* ARIZ. REV. STAT. ANN. §§ 49-282 to 49-298 (West 1994 & Supp. 1999). *See also* ADWR, *supra* note 3, at 7-1.

103. ADWR, *supra* note 3, at 8-24.

104. *See* ARIZ. REV. STAT. ANN. § 49-245.02(A) (West 1994).

105. *See* ADWR, *supra* note 3, at 1-9.

106. ARIZ. REV. STAT. ANN. §§ 45-551 to 558 (West 1994 & Supp. 1999).

107. § 45-551 (West 1994).

interbasin transfers of groundwater where the goal is to demonstrate an assured water supply.[108] The 1992 Water Exchange Act[109] allows for water to be traded between water users, with trades allowed as long as each water user has the legal right to use the water it gives in trade.[110]

Legislation providing for establishment of a Santa Cruz Valley Water District exists, although the district itself is not functioning.[111] The SCAMA Third Management Plan recognizes, however, that the creation of such an entity in the SCAMA could be useful in pursuing water augmentation activities through efficient distribution of existing supplies, acquisition of additional supplies, doing studies to identify potential water recharge sites, and assisting in negotiations associated with water rights marketing. The plan notes, "If a water district is created, there would be an opportunity in the future for Mexico to participate in the district and perhaps take part in some type of water exchange involving effluent recharged upstream from Nogales, Sonora's Santa Cruz River wellfield."[112]

b. Federal Authorities

The SCAMA Third Management Plan recognizes several relevant federal authorities.[113] The Environmental Protection Agency, Region IX, is responsible for enforcing federal environmental regulations in the Nogales, Arizona, area, including the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA),[114] and the Resource Conservation and Recovery Act of 1976 (RCRA).[115] The Endangered Species Act,[116] likewise, provides an important legal framework for preserving the riparian area along the Santa Cruz River. Also identified as an important federal authority was the Clean Water Act,[117] which, by enforcing designated levels of water quality, may operate to limit the quantity of water, especially potable water, available.[118]

108. § 45-557 (West 1994 & Supp. 1999).

109. Arizona Laws 1992, Ch. 225 § 2 (codified in scattered sections of Title 45 ARIZ. REV. STAT. ANN.).

110. § 45-1001(6)(West 1994).

111. *See* ARIZ. REV. STAT. ANN. §§ 48-4801 to 48-4984 (West 1994). *See also* ADWR, *supra* note 3, at 8-12.

112. *See* ADWR, *supra* note 5, at 8-12.

113. *See id.* at 8-25, 8-26.

114. Pub. L. No. 96-510, 94 Stat. 2767 (codified as amended in scattered sections of 42 U.S.C.).

115. Pub. L. No. 94-580, 90 Stat. 2795 (codified as amended in scattered sections of 42 U.S.C.).

116. 16 U.S.C. §§ 1531-1544 (1994).

117. 33 U.S.C. §§ 1251-1387 (1994).

118. *See* ADWR, *supra* note 3, at 8-25.

C. International Agreements

The primary international agreement relevant to the issues discussed in this article is the 1944 treaty entitled "Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande."[119] The treaty established the International Boundary and Water Commission (IBWC) to replace the International Boundary Commission (IBC).[120] This prior organization, consisting of U.S. and Mexican sections, had been created under the Convention of March 1, 1889.[121] The U.S. section of the IBWC receives guidance from the U.S. State Department; the Mexican section, *Comisión Internacional de Límites y Agua* (CILA), is under the authority of Mexico's Secretary of Foreign Relations.[122]

The two sections collaborate routinely on addressing water issues in the border area. Among other responsibilities, the IBWC jointly owns, with the city of Nogales, Arizona, the Nogales International Wastewater Treatment Plant (NIWWTP).[123] The two sections also facilitate exchange of information related to transboundary water basins, including the Santa Cruz River and Nogales Wash.[124]

In Ambos Nogales, one of the most important institutional factors associated with managing water supplies in the SCAMA is the language of IBWC/CILA Minute 227, which allocates to Mexico ownership of its share of the wastewater treated by the NIWWTP.[125] Minute 227 is one of a series of Minutes that have been issued over the years by the IBWC and CILA and approved by the respective governments, as authorized under the 1944

119. Treaty on the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, Feb. 3, 1944, U.S.-Mex., 59 Stat. 1219.

120. *See id.*

121. Convention between the United States of America and the United States of Mexico to Facilitate the Carrying Out of the Principles Contained in the Treaty of November 12, 1884, and to Avoid the Difficulties Occasioned by Reason of the Changes which Take Place in the Beds of the Rio Grande and the Colorado Rivers, U.S.-Mex., Mar. 1, 1889, 26 Stat. 1512.

122. For a discussion of the IBWC and CILA, see Stephen P. Mumme, *Regional Power in National Diplomacy: The Case of the U.S. Section of the International Boundary and Water Commission*, PUBLIUS: J. FEDERALISM, Fall 1984, at 115, 115-21.

123. *See* ADWR, *supra* note 3, at 1-9. "The facility is operated by personnel from the city of Nogales, Ariz., with support from the IBWC. The operating costs are split between Nogales, Ariz., and Nogales, Son., based on their respective shares of the influent." INGRAM ET AL., supra note 2, at 89.

124. *See* INGRAM ET AL., *supra* note 2, at 180.

125. *Enlargement of the International Facilities for the Treatment of Nogales, Arizona and Nogales, Sonora Sewage*, IBWC Minute 227 (Sept. 5, 1967) (on file with the IWBC, <www.iwbc.state.gov>) [hereinafter Minute 227].

treaty.[126] The arrangement poses yet another—and considerable—challenge to SCAMA's efforts to maintain water supply and demand at sustainable levels. The challenge becomes even greater if local water resources are stressed by extended drought.

III. IMPLICATIONS OF SEVERE DROUGHT FOR NOGALES, ARIZONA

A. Urban Water Sensitivity Analysis

The Climate Assessment Project for the Southwest (CLIMAS)[127] recently completed the first phase of a study of the impacts of climate on urban water resources in selected Arizona cities. This first phase entailed an analysis of the sensitivity of urban water systems to extreme drought.[128] The analysis focused on the Phoenix, Tucson, and Santa Cruz AMAs, as well as the city of Sierra Vista and the Middle San Pedro River Valley. The results of the sensitivity analysis performed for the SCAMA provide valuable insights for examining the importance of transboundary wastewater flows in balancing water supply and demand in Ambos Nogales under conditions of climatic variability.

The sensitivity analysis for the SCAMA was based on the most severe one-, five-, and ten-year droughts on record. These droughts were

126. "Decisions of the Commission shall be recorded in the force of Minutes done in duplicate in the English and Spanish languages, signed by each Commissioner and attested by the Secretaries, and copies thereof forwarded to each Government within three days after being signed. Except where the specific approval of the two Governments is required by any provision of this Treaty, if one of the Governments fails to communicate to the Commission its approval or disapproval of a decision of the Commission within thirty days reckoned from the date of the Minute in which it shall have been pronounced, the Minute in question and the decisions which it contains shall be considered to be approved by that Government. The Commissioners, within the limits of their respective jurisdictions, shall execute the decisions of the Commission that were approved by both Governments." Treaty on the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, *supra* note 119, at art. 25. Minute 227 states, "Mexico may dispose of a part or of all the Nogales, Sonora sewage in its own territory when it may so consider it advisable." Minute 227, *supra* note 125.

127. CLIMAS is currently funded by a grant from the U.S. National Oceanic and Atmospheric Administration. The project seeks to identify climate impacts on human and natural systems in the Southwest, facilitate transmission of climate and hydrologic information and forecasts to citizens of the region, and identify areas where further climate and hydrologic research could improve forecasting skill and enhance general knowledge of climatic processes affecting the region. *See* CLIMAS, *About CLIMAS* (last modified July 12, 2000) <http://www.ispe.arizona.edu/climas/about.html>.

128. Sensitivity analysis involves determining the extent to which an entity or system, such as an urban water system, responds readily (either positively or negatively) to externalities such as climate impacts.

identified based on annual[129] precipitation data reported at the climate division level for Climate Division 7.[130] Using water budget data developed by ADWR,[131] the 1995 and 2025 baseline figures for water supply and demand were reduced proportionally, based on the percentage of normal precipitation produced during that drought period. Separate calculations were made for each scenario to reflect the impact of the drought with and without agriculture, and with/without the two-thirds portion of effluent owned by Mexico.[132] Data for the year 2025 were used because this is the year that the Groundwater Code specifies when the AMAs are expected to have achieved safe yield.[133] The results of the scenarios are summarized below.

1. Summary Of Methodology

The methodology for the CLIMAS Urban Water Study involved computer spreadsheet calculation of supply and demand for each of the study areas. For the SCAMA, the analysis used the figures in the water budget calculated by ADWR for the years 1995 and 2025 as the baseline for supply and demand (see table 1 for water budget categories). For each of the drought scenarios, the baseline supply figures were adjusted downward in the same proportion as the decrease in total average precipitation that fell during the winter for that time period (one year, five years, ten years) in that climate division.[134] For supply calculations, a "worst-case" scenario was included, assuming that none of the effluent flow from Mexico would be available. On the demand side of the budget, adjustments proportional to the decrease in precipitation were made to account for assumed increase in water use by crops and riparian vegetation. These adjustments reflected the fact that summer precipitation over the three drought periods was also low, relative to the long-term average for the summer half year. Separate calculations were made based on an assumption of complete elimination of agriculture. These calculations allowed estimation of the maximum amount of water that could conceivably be shifted from agricultural to urban uses under severe drought conditions, as well as quantification of the contribution such a shift would make to alleviating groundwater overdraft.

129. For the other locations included in the study, winter-season precipitation data were used. The decision to analyze the SCAMA using annual data was based on recognition of the unique and highly variable nature of local water resources.

130. The records for this climate division extend from the late 1800s to the present. *See supra* note 56.

131. *See* ADWR, *supra* note 3, at 11-1 to 11-11.

132. *See* Minute 227, *supra* note 125.

133. *See* ADWR, *supra* note 3, at 1-2.

134. *See supra* note 56.

2. *Baseline Climate Data*

Climate data for Nogales, Arizona, are available at the local scale and at the climate division scale.[135] Local data are available from three reporting stations, which together provide a record spanning the years 1892 through the present. Aggregate data at the local level indicate that mean annual precipitation is 14.33 inches.[136] However, precipitation is highly variable from season to season, year to year, and over longer time scales. Thus, according to these records, the driest one year in the historical record occurred in 1948, when only 7.94 inches of precipitation were received (55.4 percent of normal). The driest ten-year period occurred between 1915 and 1924, when rainfall averaged 11.58 inches (80.8 percent of normal).[137] By contrast, the wettest one-year period, based on available data, was 1983, when 31.84 inches of rain were recorded (181 percent of normal). The wettest ten-year period, 1983 to 1992, produced 127 percent of normal rainfall.[138]

Climate Division 7[139] provides data for an area stretching across all of Santa Cruz County eastward to the Arizona–New Mexico boundary. The aggregated data capture, in addition to local measurements, precipitation for higher elevations, which are an important source of groundwater and surface water recharge.[140] For this reason, data for Climate Division 7, rather than local data, were used in the analysis of the sensitivity of SCAMA water resources to drought.[141] These data indicate a mean annual precipitation of 14.33 inches across the division for the period spanning roughly 1890 to 1999,[142] somewhat lower than the mean reported for Nogales itself, of 18.4 inches on average per year for the period 1953 to 1995.[143]

Using calculations based on data for Climate Division 7,[144] the driest year in the historical record occurred in 1948, when precipitation amounted to 7.44 inches (57 percent of average). The driest five-year historical drought, 1900–1904, produced an average of 9.98 inches per year (71 percent of average), and the driest ten-year historical drought, 1947–1956, averaged 11.58 inches per year (80 percent of average). These proportions were used

---

135. Data were obtained from *Western Regional Climate Center Website* (visited Sept. 24, 2000) <http://www.wrcc.dri.edu>.

136. *See id.*

137. *See id.*

138. *See id.*

139. *See supra* note 56.

140. *See* ADWR, *supra* note 3, at 2-15.

141. *See generally* CARTER ET AL., *supra* note 45 (regarding methodological assumptions).

142. *See id.* at 10. *See also Western Regional Climate Center Website*, *supra* note 135.

143. *See* ADWR, *supra* note 3, at 2-1.

144. Such data are available through the *Western Regional Climate Center Website*, *supra* note 135.

to calculate the sensitivity of the SCAMA's water budget to various drought scenarios.

It should be noted that the Southwest experienced a more severe drought in the late 1500s.[145] This drought, which lasted from 1579 to 1598, has been identified as having a return period of between 400 and 700 years.[146] However, the decision was made in this study to use historical data to develop scenarios for many reasons, one of which being that the historical record spans the period of urban growth and development in the region. This era represents a recognizable period of record for the water managers and regulators to whom the results of the study were directed.

3. SCAMA Water Budget

The 1995 water budget for the SCAMA (table 1) represents supply and demand data for the Nogales, Arizona, area only.[147] No similar water budget has yet been developed for Nogales, Sonora, although development of such a budget would be very useful in improving management of water supplies on both sides of the border.

Analysis of the SCAMA water budget indicates an average potentially available renewable water supply of 34,171 acre-feet, and total demand of 41,067 acre-feet, producing a 17 percent deficit between renewable supply and demand.[148] Baseline projections for the year 2025 show an increase in effluent to 19,549 acre-feet, resulting in a renewable supply total of 37,532 acre-feet, a total demand of 47,072, and a deficit of 20 percent.[149] These figures must be viewed with caution, however, for, as the SCAMA itself recognizes, natural variability of water supply is high. In fact, the SCAMA typically reports its water supply in terms of a range, with the low and high volumes representing the tenth and ninetieth percentiles of variability, respectively.[150] Also, the amount of effluent received from Mexico may vary as an input to the SCAMA water budget. Thus, the SCAMA defines its water supply for management purposes as varying from a low of 39,600 acre-feet to a high of 142,900 acre-feet.[151]

4. Sensitivity Analysis Procedures

The sensitivity of the SCAMA to severe drought was assessed based on the numbers lying on the extreme dry end of the distribution. Thus, the

---

145. Robert A. Young, *Coping with a Severe Sustained Drought on the Colorado River: Introduction and Overview*, 31 WATER RESOURCES BULL. 779, 783 (1995).

146. *See id.*

147. *See* CARTER ET AL., *supra* note 45, at 110 app.3.

148. *See id.*

149. *See id.*

150. *See, e.g.*, ADWR, *supra* note 3, at 11-6 to 11-7.

151. *See id.*

analysis reflects conditions outside the parameters normally considered in the SCAMA water budget. The rationale for using extreme conditions in the analysis was to provide a sense of how severely droughts as deep as the worst ones in the historical record would affect water supply and demand in the urbanized area, particularly under conditions of growth in demand stimulated by population growth. The most basic case under each scenario reflects a reduction in precipitation and an increase in demand generated by population growth projected for the year 2025. Other cases reflect a combination of reduced precipitation and increased demand (urban, agricultural, and riparian), loss of the two-thirds of effluent flow that belongs to Mexico, and shift of agricultural water to urban uses. No additional sources of water were assumed to be available to water managers during any of the drought scenarios.[152]

These scenarios provide a framework for drought planning and decision making in Nogales, Arizona, and furnish a template for carrying out the same type of analysis for Nogales, Sonora. The analysis also highlights the considerable extent to which the water resources of the two cities are interlinked, and suggests the degree to which impacts from drought could influence relations between the two cities with regard to sharing limited water resources.

Most importantly, the analysis reveals that, in the absence of other renewable supplies, achieving safe yield would likely be impossible if the effluent from Mexico was not included. However, the SCAMA acknowledges that "[b]ecause the effluent generated by the NIWWTP is owned in part by Mexico, water management strategies will need to be developed which address the interrelated nature of supplies and demands on both sides of the international border."[153] Interactions between the CLIMAS researchers and SCAMA analysts over the course of several months in fall 1999 indicate that the SCAMA does not consider it likely that Sonora will reclaim all of the effluent flows already entering Arizona due primarily to the costs involved.[154] Future increases in effluent production on the Sonoran side of the border may or may not be retained in Mexico; active negotiations on this issue are in progress.

152. The SCAMA Third Management Plan identifies Peña Blanca Lake and Patagonia Lake as potential emergency sources; however, access to these sources, amount of water potentially available, and water quality issues associated with Peña Blanca Lake, render these options less than satisfactory. *See* ADWR *supra* note 3, at 2-23.

153. *Id.* at 2-24, 11-10.

154. Interview with Pam Nagel, Water Resources Specialist III, Santa Cruz Active Management Area, in Nogales, Ariz. (Oct. 6, 1999).

B. Potential Drought Impacts on SCAMA

Assessment of the SCAMA water budget reveals that severe drought conditions would produce a considerable imbalance between renewable supply and demand. In fact, as indicated in table 1, based on ADWR calculations of supply and demand for the 1992–1995 time period, the SCAMA shows, on average, modest deficit of renewable water supply relative to demand even though the AMA deems itself to currently be at safe yield.[155] Assuming average climate and a "business as usual" scenario for the year 2025 (i.e., no conservation measures introduced to reduce water demand), the SCAMA water budget shows a water supply deficit, even when including both the Arizona and Sonora shares of effluent.[156] The impacts of the maximum one-, five-, and ten-year droughts of record, calculated against the baseline budget, produce even more pronounced deficits (see table 2[157]).

1. One-Year Drought of Record

Mean annual precipitation in Climate Division 7 amounts to 14.33 inches per year, based on the years 1896 to 1999.[158] The most severe one-year drought produced 7.96 inches, or only 55.4 percent of the mean amount.[159] Assuming the "business as usual" level of demand projected for 2025 in the SCAMA and only 55.4 percent of mean precipitation, renewable water supplies in the SCAMA were calculated to be reduced to 19,936 acre-feet, a 40 percent deficit between renewable supply and demand (see table 2).[160] Loss of the two-thirds portion of Mexican effluent would result in only 32 percent of renewable water supplies being available to meet demand.[161]

Factoring in the demand side of the budget, assuming full availability of Mexican effluent and no change in riparian demand, but reduction of agricultural demand to zero during the drought year, the deficit between renewable supply and demand would drop to 30 percent.[162]

155. *See* ADWR supra note 3, at 11-9.

156. *See id.* at 11-5, 11-7. Given that effluent is not likely to be directly delivered for municipal uses, this water constitutes a potential renewable supply largely in terms of aquifer recharge, for agricultural and riparian uses, or for certain industrial uses such as golf course irrigation.

157. *See* CARTER ET AL., *supra* note 45, at 110 app.3.

158. *See Western Regional Climate Center Website, supra* note 135.

159. *See id. See also* CARTER ET AL., *supra* note 45, at 110 app.3.

160. *See* CARTER ET AL., *supra* note 45, at 110 app.3.

161. *See id.*

162. *See id.*

TABLE 2: IMPACTS OF DROUGHT ON SCAMA WATER BUDGET

Scenario	Basic Supply	Water Budget Balance			
		Business as usual	1/3 of effluent	Zero agriculture	Zero agriculture 1/3 of effluent
1995 baseline	34,171	-6,896			
2025 baseline	37,532	-9,540			
2025 1-yr. drought	29,688	-19,936	-33,536	-12,922	-26,522
2025 5-yr. drought	161,585	-86,536	-154,536	-51,466	-119,466
2025 10-yr. drought	339,354	-156,887	-292,887	-86,748	-222,748

All figures given in acre-feet; figures for five- and ten-year droughts are for the full drought period.

Loss of Mexican effluent would result in an imbalance between renewable supply and demand of 62 percent.[163]

The research team deemed it unlikely that alternative supply sources could—or would—be developed within the time span of a one-year drought. The team also believed it unlikely that agricultural demand would be reduced all the way to zero. Therefore, it was concluded that, unlike earlier one-year droughts when population size and water demand were low, under a drought with potential deficits ranging from 30 to 62 percent and the 2025 population levels determined by ADWR, careful monitoring of water supplies would be required to assure that basic needs continued to be met. Further, assurance of continued availability of effluent from Sonora and stringent water conservation measures within the SCAMA would likely be required to maintain sufficient flows to the riparian area along the Santa Cruz River.[164]

163. *See id.*
164. *See id.* at 97.

2. Five-Year Drought of Record

During the worst five-year drought of historical record, 1900 to 1904, annual precipitation averaged 9.98 inches per year, or 70 percent of mean.[165] If this proportional decrease in precipitation occurred under "business as usual" demand conditions in the year 2025, the impacts on the SCAMA's urban water system would be considerable. The imbalance between supply and demand, even with full access to Mexican effluent, could be as much as 86,536 acre-feet over the five-year period (see table 2).[166] This would amount to a 35 percent imbalance between renewable supply and demand over the period. Eliminating the Mexican portion of effluent flows would raise the deficit to 62 percent.[167] Eliminating all agricultural activity while maintaining full riparian demand would produce a deficit of 51,446 acre-feet, and a deficit of 24 percent.[168] Eliminating Mexican effluent would raise the imbalance to 56 percent.[169]

As these figures illustrate, the impact of a five-year drought of this magnitude would be quite substantial. Indeed, the "business as usual" scenario (including maintenance of the riparian area) could only be maintained if stringent, multi-year conservation measures were invoked. Reallocation of effluent to direct use would not be likely to occur, for at the current level of treatment, this type of water is only appropriate for certain uses. Further, lack of infrastructure poses a barrier to direct delivery even for some potentially appropriate uses, such as agricultural irrigation. Construction of such a system would be unlikely to occur within the time span of a five-year drought. Likewise, institutional arrangements and lack of infrastructure pose considerable barriers to use of alternative sources such as Peña Blanca or Patagonia Lakes.[170]

Potential impacts of a severe five-year drought on the city remain conjectural at this time. However, it is not unreasonable to suggest that concerns about reduction in economic growth and development would prompt serious discussions about the relative merits of allocating water to certain sectors, including riparian preservation, low-value agricultural crops, and water-intensive municipal and/or industrial uses (e.g., golf courses). The focus of such discussions would likely be on these sectors, for minimal potential exists for conservation in domestic consumption: existing consumption rates are already low in this sector.

165. *See Western Regional Climate Center Website*, *supra* note 135.
166. *See* CARTER ET AL., *supra* note 45, at 110 app.3.
167. *See id.*
168. *See id.*
169. *See id.*
170. *See* ADWR, *supra* note 3, at 2-23.

3. *Ten-Year Drought of Record*

The most severe ten-year drought period occurred between 1948 and 1957, producing an average of 11.58 inches per year over the period.[171] Although some wet periods occurred during the ten-year drought, the average precipitation for this period was calculated to be only 81 percent of normal. If this extended drought period were to occur under the "business as usual" demand conditions projected for the year 2025 (including riparian demand), it could be expected that demand would exceed renewable supply by as much as 156,887 acre-feet over the ten-year period (see table 2).[172] Demand would exceed renewable supply by 32 percent. Elimination of the Mexican portion of effluent flows over the ten-year period would increase the deficit to 292,887 acre-feet, resulting in a 59 percent deficit between demand and renewable supplies.[173]

Assuming complete elimination of agricultural demand over the entire ten-year period (but continuation of sufficient supplies to meet riparian demand), the imbalance between supply and demand would decrease to 86,748 acre-feet, still a significant shortage.[174] Elimination of the Mexican portion of effluent flows under the no-agriculture case would result in a 52 percent deficit between renewable supply and demand.[175]

Deficits of these magnitudes could exceed the estimated total water storage capacity in the most actively used well fields in the AMA.[176] Thus, the existing water sources could be tapped out prior to the end of the ten-year period. Effectively coping with impacts of these magnitudes would require aggressive water management strategies, including prioritization of water allocations. Under these conditions, protection of the Santa Cruz River riparian area would certainly come under considerable pressure. Conservation measures, such as limiting water use on golf courses and in other water-intensive areas, would be unlikely to produce sufficient savings to cover the deficit. Therefore, to avert severe economic dislocation or human hardship, a drought of this magnitude would be likely to stimulate a search for and development of additional water sources, primarily groundwater resources. Further, because drought would not end at the international boundary, drought stress would likely prompt intensive interactions between Nogales, Arizona, and Nogales, Sonora, regarding how the available water resources should be allocated and managed.

---

171. *See Western Regional Climate Center Website, supra* note 135.
172. *See* CARTER ET AL., *supra* note 45, at 110 app.3.
173. *See id.*
174. *See id.*
175. *See id.*
176. *See* ADWR, *supra* note 3, at 2-19.

It is not expected that either city would be likely to founder under a ten-year drought, although climate impacts would be keenly felt. Further, the impacts would be unevenly distributed across demographic, environmental, and economic sectors of the two cities, with potential for some areas or groups to be significantly affected. The pattern and nature of these potential impacts requires carefully targeted climate impacts research.

4. Potential Additional Water Resource Alternatives

Two nearby lakes have been identified as a partial drought buffer for the community.[177] One, however, Peña Blanca Lake, is not considered to be a viable alternative source for human uses due to mercury contamination. The other, Patagonia Lake, could only be tapped under special legal arrangements with the primary rights holders, the U.S. Forest Service and the Arizona Game and Fish Department. Also making this transfer problematical is the fact that interbasin transfers are allowed under the Arizona Groundwater Management Act only when necessary to achieve safe yield.[178] Whether a ten-year drought would qualify as a threat to safe-yield remains to be legally tested.

Another potential source involves drilling wells into the Older Alluvium of the regional aquifer that stretches northward from the city of Nogales, Arizona. Although the costs of drilling and pumping water could be substantial due to the greater depth to groundwater in this formation and to the lower transmissivity of the formation, this is viewed the most likely new source for augmenting the city's water supplies.[179]

In terms of existing water, expansion of effluent use remains the best alternative for the community.[180] Nevertheless, establishing a framework for assuring availability of sufficient supplies poses considerable challenges to water resource managers and urban developers on both sides of the border, due to the legal arrangements that recognize Mexican ownership of two-thirds of the existing effluent passing through the NIWWTP. Thus, the one-third of effluent generated within the SCAMA constitutes the most readily available water resource to be tapped in the event of a drought. Intensive use of this water, particularly in the absence of effluent flows from Mexico, would likely destroy the riparian area along the Santa Cruz River.

---

177. *See id.* at 2-23.

178. Safe yield is defined in the Groundwater Management Act as achieving a long-term balance between renewable supply and demand. *See* ARIZ. REV. STAT. ANN. § 45-561(12) (West 1994).

179. *See* ADWR supra note 3, at 8-10.

180. *See id.* at 8-20.

C. Transboundary Wastewater Management

Retention of the Mexican portion of the effluent treated at the NIWWTP is essential for achieving safe yield in the SCAMA—that is, achieving a balance between renewable supplies and demand.[181] Further, the Santa Cruz River riparian area is highly valued by environmental groups and others.[182] Loss of the Mexican two-thirds of the effluent flows would seriously threaten the viability of this ecosystem.

In recognition of the important role played by wastewater in Ambos Nogales, an EPA-funded binational planning process was begun in 1996 to find an integrated solution to wastewater management in the area. The NIWWTP presently has a capacity of 17.2 million gallons per day (mgd), of which 9.9 mgd is deemed to belong, under IBWC Minute No. 227, to Nogales, Sonora, and 7.3 mgd to Nogales, Arizona.[183] Components of the proposed plan include upgrading and expanding the present NIWWTP, rehabilitation and expansion of the wastewater pipe that brings wastewater from the border to the NIWWTP, rehabilitation of the wastewater collection systems in Nogales, Sonora, and Nogales, Arizona, and construction of a small (5 mgd) treatment plant in Mexico along with interceptor lines and pumps to take the wastewater to Los Alisos.

A recent announcement by the North American Development Bank (NADBank) indicates that, through its EPA-funded Border Environment Infrastructure Fund (BEIF), $46 million will be available for Ambos Nogales to pursue rehabilitation and expansion of the shared sanitation system.[184] Of this, $38.6 million will be devoted to construction costs; an additional $683,492 will be provided to Nogales, Arizona, to mitigate the effects on residents of resultant increases in water and wastewater rates.[185] Up to $250,000 will be available for construction maintenance assistance.[186] Under the funding, the NIWWTP will be upgraded to a treatment capacity of 17.2 mgd, and the plant's technology will be improved to meet appropriate environmental standards.[187]

---

181. *See id.* at 8-4, 8-8. *See also* Arizona Pub. Serv. Co. v. Long, 773 P.2d 988 (Ariz. 1989).

182. *See* INGRAM ET AL., *supra* note 2, at 56-58, 142.

183. *See Issues*, AMBOS NOGALES WASTE WATER FACILITIES PROJECT UPDATE, (Camp Dresser & McKee, Inc., Tucson, Az.), Winter 1997, at 3-1.

184. *See Press Release*, NADBANK NEWS (N. Am. Dev. Bank, San Antonio, Tx.), June 27, 2000 (sent via email to subscribers from news@nadb.org, on file with author).

185. *See id.*

186. *See id.*

187. It is notable that the announcement recognizes the importance of the downstream riparian habitat: "This effluent also serves as a valuable source of water for the preservation of an important riparian habitat within the aquatic ecosystem." *Id.*

This announcement supports the assumption that Mexico will continue to allow the present 9.9 mgd of effluent to continue to flow to the NIWWTP (see tables 3[188] and 4[189]). It remains to be seen whether Mexico will later pursue efforts to recharge subsequent increases in effluent into the Los Alisos basin. In any case, Mexico still has the legal right through IBWC Minute 227[190] to retain its portion of the effluent to the Nogales, Sonora, area for use or recharge, which continues to leave the long-term future of the effluent in doubt.

In response to this uncertainty, some preliminary efforts are being made by water right holders in southern Arizona to establish a water district to more closely manage water in the area.[191] Organizers view formation of the district as, among other things, a structure for seeking an accord with Mexico, perhaps through modification of Minute 227, to maintain the Mexican effluent in Arizona. It may be speculated that such an agreement could be designed to include financial remuneration to Mexico for transfer of ownership of the effluent to Arizona.

Efforts such as these need to take into account the relative value of water used for different purposes within the context of the transboundary watershed. These uses range from supplying basic (and already unmet needs) in the *colonias* of Nogales, Sonora, to demands generated by industrial, commercial, and residential development on both sides of the border as well as the needs generated by golf courses and riparian habitat. The specific decisions that are made, and the trade-offs that these decisions might entail, depend on the specific priorities identified by the leaders of both communities, as well as on external influences affecting the two communities. Whatever decisions are made regarding growth and development, careful consideration must be given to potential drought impacts on the populations, environment, and economic sectors of both communities.

Even though the Arizona Groundwater Management Act and related SCAMA policies focus entirely on Arizona, the SCAMA Third Management Plan recognizes the value of maintaining interactions with water management entities in Mexico. In the case of serious extended drought, it is probable that assistance would be requested from the IBWC/CILA. It is not improbable that assistance would be requested from

---

188. *See supra* note 53.

189. *See Work Completed*, AMBOS NOGALES WASTE WATER FACILITIES PROJECT UPDATE (Camp Dresser & McKee, Inc., Tucson, Az.), Winter 1997, at 5.

190. *See* Minute 227, *supra* note 125.

191. *See* ADWR supra note 3, at 12-4, 12-5.

the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADBank) as well.[192]

TABLE 3: ANNUAL SEWAGE INFLUENT AT THE NIWWTP: 1990-1998

Source of Effluent	1990	1991	1992	1993	1994	1995	1996	1997	1998
U.S.A.	4,448	5,335	5,194	5,442	5,170	5,514	4,494	4,677	5,617
Mexico	6,089	8,092	9,545	10,023	9,890	11,208	9,806	9,529	10,648
Total	10,537	13,447	14,740	15,465	15,060	16,721	14,301	14,206	16,265

Numbers are given in acre-feet.
Note that the numbers shown in this table are only for the past decade; the effluent average indicated in Table 1 is based on a longer-term average.

TABLE 4: PROJECTED WASTEWATER FLOWS
NOGALES, SONORA AND NOGALES, ARIZONA

Year	1996	2020	2035	2050
Nogales, Arizona	3.8	4.1	5.0	6.2
Nogales, Sonora	9.2	19.8	23	28.6
Totals	13.0	23.9	28	34.8

Numbers are given in acre-feet.

IV. IMPLICATIONS OF SEVERE DROUGHT FOR NOGALES, SONORA

Severe droughts of the magnitude calculated for Nogales, Arizona, would likely affect Nogales, Sonora, strongly as well. Although empirical research has not yet been done, among the impacts that may be expected are a decrease in the volume of water that can be delivered, a decrease in the number of hours water is available, decreases in water pressure, and a scarcity of water to serve those who are not connected to the city system.

192. The Border Environment Cooperation Commission (BECC) was established via binational executive agreements executed by the U.S. and Mexico to work in coordination with the NADBank to improve environmental infrastructure in the U.S.-Mexico border area. Both entities were outgrowths of the North American Free Trade Agreement (NAFTA) and the Border XXI program. BECC is charged with identifying environmentally sustainable projects within the 100-kilometer border zone delineated on each side of the international boundary; NADBank has responsibility for assisting in finding and obtaining loan funding for these projects. *See* Diana M. Liverman et al., *Environmental Issues along the United States-Mexico Border: Drivers of Change and Responses of Citizens and Institutions*, 24 ENERGY & ENV'T 607, 624-25 (1999).

Reliance on non-renewable sources of water in Los Alisos, even under normal climate conditions, may reasonably be expected to result in substantial draw-down of the aquifer; as the aquifer level drops, lower quality water may be encountered near the bottom. It is not unreasonable to expect that acceleration of depletion under conditions of a prolonged drought and continued rapid growth in demand would hasten this outcome.

Economic disparities and associated social inequities with regard to access to sufficient quantities of potable water are also matters of serious concern in the area, even under normal climate conditions.[193] Residents in poor neighborhoods of Nogales, Sonora, must rely on *pipa* deliveries and storage of delivered water in (typically) 50-gallon barrels.[194] This places significant limits on the amount of water each household can store—and thus the amount of water that a household has available for use at any given time. If deliveries are interrupted because of drought, it may be hypothesized that residents could be deprived of receiving and storing sufficient quantities to cover even the minimum daily amount necessary for basic health benefits. Such stresses could conceivably result in disease outbreaks. Insufficient sewerage infrastructure could exacerbate public health problems, if greater reliance were to be placed on pumping water from wells (such as those along Nogales Wash) lying down-gradient from these residences.[195]

Also a serious consideration, the Santa Cruz River aquifer experiences greatly reduced groundwater levels during periods of drought.[196] Since Nogales, Arizona, wellfields are downstream from Nogales, Sonora, pumping in Sonora affects the quantity of water reaching Arizona.[197] Yet, addressing potential shortages downstream by reducing reliance on Santa Cruz River wells in favor of using wells within the city of Nogales, Sonora, could be expected to result in distribution of lower quality water, with the consequences noted above.

Although water pricing is not strongly influenced by market conditions in Nogales, Sonora,[198] sustained drought could increase pressures to develop additional water supplies. The costs of such development, especially under the devolution of responsibilities from the federal to the state level in Mexico, could conceivably be reflected in considerable increases in consumer cost. Finally, drought-stimulated decreases in supplies would result in a reduction of Mexican effluent

---

193. *See* INGRAM ET AL., *supra* note 2, at 81-84.
194. *See id.* at 76-79.
195. *See id.* at 75.
196. *See* ADWR *supra* note 3, at 2-12.
197. *See id.*
198. *See* INGRAM ET AL., *supra* note 2, at 71.

flowing into Arizona, and, if treatment facilities were to be constructed in Sonora, less effluent as a supply for Nogales, Sonora, as well.

Concern in Arizona about the implications of construction of facilities in Sonora to capture the effluent flows dates back to the 1950s, when construction of municipal water infrastructure was undertaken in Nogales, Sonora. At that time, the IBWC was asked by local interests to "investigate the possibility of negotiating an allocation agreement for the waters of the Santa Cruz River that would be similar to agreements dividing the flows of other transboundary rivers."[199] The IBWC Commissioner expressed the Commission's reluctance to initiate the negotiations in a letter to Arizona's U.S. Senator Carl Hayden. Observing that the United States was already using more than half of the water from the portion of the Santa Cruz River watershed shared by the two countries, but that the U.S. portion of that contributing watershed amounted to only 34 percent, the commissioner advised that Arizona should be very careful about initiating such negotiations.[200] The stronger legal arguments for raising allocations were on Mexico's side.

Nothing has changed in the decades since, with regard to the legal context, to change this evaluation. Sonorans see treated effluent as a potential supply for irrigation and industrial processing.[201] In Arizona, the effluent is recognized as being the sole support for the Santa Cruz River riparian area, with its wildlife habitat and recreational opportunities.[202] Further, while the Mexican section of the IBWC sees constructing treatment facilities in Mexico as increasing the opportunities for reusing the water, the U.S. section opposes plants in Mexico on grounds of health concerns.[203] This opposition arises from the agency's belief that retaining the treatment function on the U.S. side of the border would provide greater assurance that treatment would be in compliance with the standards required by the state of Arizona.[204] The topographic impracticalities associated with pumping the sewage uphill to a Sonoran treatment plant also underlie the agency's preference for maintaining treatment facilities in Arizona.[205]

V. CONCLUSIONS AND RECOMMENDATIONS

As the above discussion indicates, the availability of some or all of Sonora's effluent is essential to maintaining a balance between renewable

199. *Id.* at 189.
200. *See id.* at 190.
201. *See id.* at 191
202. *See id.*
203. *See id.*
204. *See id.*
205. *See id.*

supply and demand (i.e., safe yield) within the SCAMA; at the same time, this effluent constitutes a potentially valuable source of supply for Nogales, Sonora. For Nogales, Arizona, and its environs, maintenance of the riparian area on the Santa Cruz River downstream of the NIWWTP and of agriculture at today's levels could not be sustained without access to this source.

In Nogales, Sonora, simply meeting basic urban demand remains a challenge. While alternative sources of groundwater have been identified as demand has increased, relative scarcity of potable water resources limits future options. Wastewater flowing across the international boundary from Mexico constitutes a substantial "untapped" source of renewable supplies for Nogales, Sonora. This water belongs to Mexico under IBWC Minute 227, although costs of retaining it, relative to the costs of developing other sources, have to date been a key factor in its continued flow into Arizona.

A deep, sustained drought would surely exacerbate existing water management problems in the transboundary setting of the two communities. Whether water providers and consumers in the SCAMA would agree to pay Mexico for the effluent crossing the border remains open to conjecture. However, such a possibility might become more attractive if proposals were to seriously materialize with regard to compensation for Nogales, Sonora's effluent flows.

In light of these conditions, we propose the following recommendations. First, there needs to be a coordinated, binational analysis of the potential impacts of deep drought in the transboundary context of Ambos Nogales. This analysis should be undertaken at the spatial resolution of the watershed of the Upper Santa Cruz River and should build upon the sensitivity analysis done for the SCAMA. In line with this recommendation, agreements should be achieved between Nogales, Arizona, and Nogales, Sonora, with regard to how water will be cooperatively managed in times of drought.

Further, Mexico should speed up its plans to develop water supplies to the south of the city, and encourage new growth in planned communities rather than in hard-to-reach hilly areas. Mexico is already moving in this direction by developing infrastructure in an area south of Nogales called Ciudad Ecological; more efforts of this kind are needed.

Finally, there is a need for transboundary mechanisms that provide water management agencies and others with the authority and capability to operate proactively rather than reactively. Precedent for transboundary mechanisms possessing legal authority to act binationally may be found in the IBWC/CILA example. There is also a strong need for agency mandates within jurisdictional units that allow for anticipation of problems and

identification of solutions before the problems occur.[206] The mandates of these agencies should include the collection and monitoring of climate and hydrologic data, as well as related socioeconomic and demographic data. The ultimate goal of these activities should be establishment and use of a binational set of indicators that could be used to trigger proactive drought-response activities. Local, transboundary response options should be developed for a range of situations, from simple advisories to enforcement of water use restrictions and development of critical infrastructure. As a corollary to this recommendation, climate and hydrologic forecasts should be developed specifically for this section of the U.S.–Mexico border; these forecasts should be transboundary in focus and content, and should regularly be made available to key decision makers and managers on both sides of the border.

These activities could be encouraged through changes in the legal and regulatory structures governing water management. For example, at the state and local levels, water management rules could be instituted requiring regular collection and use of climate and hydrologic data. Rules could also be established requiring consultation with counterpart(s) across the border whenever water resource decisions and activities affecting the other side arise. This would include decisions taken in the face of stresses associated with impending or actual drought. At the national level, agreements could be established that mandate harmonization of methodologies for gathering and reporting climate, hydrologic, and water resource management information and for regular sharing of that information. Establishment of a border climate/hydrology research and outreach center, operated cooperatively by U.S. and Mexican universities, should also be considered. Further, it may be appropriate to address the legal issues of sharing water and establishing compensation by Arizona for use of Mexican effluent. This process should be tied to developing binational contingency plans addressing reasonable scenarios for severe extended drought affecting the two cities.

In summary, strong reasons exist on both sides of the border to build upon existing cooperation between water managers and planners in the two cities in order to establish a coordinated approach to averting/mitigating climate-related stresses on their water systems. Such efforts could provide an important foundation for moving toward collaborative decision making at the basin or even watershed level, a development that could generate considerable benefits for the residents of Ambos Nogales

---

206. *See* Stephen P. Mumme & Terry Sprouse, *Beyond BECC: Envisioning Needed Institutional Reforms for Environmental Protection on the U.S.–Mexico Border*, *in* HANDBOOK OF GLOBAL ENVIRONMENTAL POLICY AND ADMINISTRATION 759, 775 (Dennis L. Soden & Brent S. Steel eds., 1999).

and its environs. Among the benefits are better management of shared water resources and improved capacity to anticipate and cope with systemic stresses, such as drought, that affect both communities. These advantages would generate secondary benefits in the form of greater assurance of continued availability of water supplies, better information for use in residential, industrial, and commercial development plans and decision making, and improved capability to address environmental issues ranging from protection of riparian areas to coping with water quality issues.