Feeding the Tribe

The Role of Soft Infrastructure in Addressing the Root Problems of the Navajo Nation San Juan River Irrigation System

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Abstract: Small-scale Navajo farms in northwestern New Mexico have water rights to surface water from the San Juan River, which flows through two main canals to individual farms. The potential of this irrigation system to meet the food security needs of the nation's residents are undermined by fifty years of deferred maintenance that have left the system in disrepair and led to farm abandonment. Federal appropriations have been made and environmental approvals are nearing completion to address the physical infrastructure needs of the system. However, attention is also needed to rehabilitate the soft infrastructure to ensure timely delivery of irrigation water and allow future generations of farmers to move into farming. This article outlines the root problems of the irrigation system decline, provides a historical and institutional summary of the system, and makes suggestions for addressing the systemic problems, focusing on soft infrastructure issues. Specific soft infrastructure needs include an information system to map and track land-use permits, organization of a maintenance system, revision of governance mechanisms, and creation of academic programs targeted to meet the needs of small-scale Diné farmers.

Keywords: Navajo irrigation system history, small-scale Diné farming, soft infrastructure, irrigation system management and rehabilitation

Farmland and irrigation water are vital resources for the future of the Navajo Nation (NN). The primary irrigation system serving individual small-scale Navajo (Diné) farmers on the NN consists of two projects, the Hogback-Cudei Irrigation Project (HC) and the Fruitland-Cambridge Irrigation Project (FC), both located in San Juan County, New Mexico. Both projects are major diversions off the San Juan River. The two irrigation projects are locally referred to as the NN San Juan

River Irrigation System (NNSJRIS). The NNSJRIS is a separate system from the Navajo Indian Irrigation Project (NIIP), which is used by the Navajo Agricultural Products Industry (NAPI) to operate a large-scale commercial and industrial farm. Both the NIIP and the NNSJRIS water rights were finalized in the 2010 San Juan Basin in New Mexico Navajo Nation Water Rights Settlement Agreement (NM NN Water Settlement), which superseded the 2005 agreement between the state of New Mexico and the NN.[1]

The NNSJRIS is a system in decline that pending physical infrastructure rehabilitation efforts will partially improve. This article argues that the decline will likely continue even after physical rehabilitation takes place if soft infrastructure needs are not addressed. Repairing diversion structures and installing pipelines are a necessary but not sufficient intervention. Parallel and equally important is soft infrastructure, which includes institutional arrangements and operational strategies. Though critical, soft infrastructure is more complicated and difficult to fund. This article (1) explains the forces that have contributed to the system decline, (2) lays out the history, status, and governance mechanisms of the NNSJRIS and efforts under way to address physical system rehabilitation, (3) presents the arguments for investment in soft infrastructure or governance mechanisms, and (4) provides some recommendations on how to proceed.

FORCES AFFECTING THE NNSJRIS

The forces moving the NNSJRIS in the direction of decline are self-reinforcing; such forces are called "positive feedbacks." Positive feedbacks move systems in the direction of greater instability, as opposed to negative feedbacks, which stabilize a system. To illustrate a positive feedback, the well-known example from climate change is the rapid loss of sea ice in the Arctic. As air and water temperatures warm, the sea ice melts, expanding the area of blue water, which is darker than ice, and reducing the albedo, or reflectivity. Continued conversion of sea ice to water increases absorption of heat, hastening the melting of the sea ice. In the language of social-ecological systems analysis, positive feedbacks occur when changes in one variable cause secondary effects in other variables, thereby amplifying the original perturbation.[2] In the case of the NNSJRIS, the original perturbation in the system was inade-

quate funding to maintain and operate the system, which is explained in greater detail here. The secondary effects that amplify the original system shock are explained below.

Preventative and timely maintenance of the NNSJRIS has been insufficient, at least since the Bureau of Indian Affairs (BIA) turned over system maintenance to the NN in 1963 and possibly before that. Without crews and equipment cutting trees and shrubs on a regular basis, invasive species have encroached upon the canals, laterals, ditches, drainages, and riparian corridor. In addition, the drains facilitate the spread of seeds from invasive weeds, salt cedar, Russian olives, and Chinese elms. The trees impede water delivery and break up the concrete-lined canals. Since water delivery is not guaranteed, especially for those Diné farms that are located farthest from the irrigation head gates, many Diné farmers have abandoned farming. Head gates are wooden or metal plates that hold back water in the canals until farmers raise the gates to allow water onto individual farms. Abandoned farms provide habitat for Gunnison prairie dogs and allow the spread of pernicious weeds such as Russian knapweed and camelthorn. Prairie dogs build new colonies on untilled and unirrigated fields, dig up corn seed, and eat vegetable transplants and alfalfa on adjacent farms. Under these conditions, Diné farmers are discouraged and reluctant to make expensive investments in higher-value food crops, and farming appears to be a poor use of time. As Diné farming declines in this region, demand for canal maintenance follows, and more expensive repairs that seem less and less justified are needed, especially as Diné politicians decide priorities. The trust of Diné farmers in the Navajo Nation's institutional capacity to maintain the system is reduced, which undermines incentives to pay fees for maintenance. All these secondary effects of inadequate irrigation system maintenance are observable in the NNSJRIS. Versions of this dynamic have been noted by previous authors.[3]

As farmers age, Diné youth do not take up farming, in part because of challenging farming conditions but also because of problems in the Navajo farm permit system, which is explained in greater detail below. Diné farmers are also discouraged when, over time, farmland parcels are subdivided, reducing access to head gates, and no new head gates are installed. If a new head gate is not installed when a plot is subdivided, accessing water when it is needed may be difficult, especially if disputes arise.

An important and obvious step in reviving the NNSJRIS is improvements to the physical infrastructure. Invasive species need to be cleared, cement-lined canals and diversion structures repaired, and more head gates installed. Diversion structures shunt water from the river into main canals. Fortunately, funding has been allocated for some of this physical infrastructure work by the NM NN Water Settlement, which in 2016 was valued at about $30 million.[4] Some of the settlement money is also being used to establish rights-of-way along the canals. The physical rehabilitation is, in effect, a program to address more than five decades of deferred maintenance, which at the time of this writing was scheduled to begin in the fall of 2018.[5]

However, "soft" infrastructure investments are not addressed in the NM NN Water Settlement. Soft infrastructure consists of the institutional arrangements and operational strategies that ensure preventative maintenance and bring new Diné farmers into farming. Soft infrastructure is also referred to as "governance mechanisms."[6] These mechanisms are needed when networks of independent organizations have authority over and provide services within an irrigation system. These governance mechanisms are "understood to be the laws, rules, regulations, procedures, and common practices that influence and control the interaction between individuals or organizations in exchange relationships."[7]

Taken together, improvements in soft and physical infrastructure are also called "modernization" efforts, which ideally improve water delivery service. An important characteristic of improved water delivery service is improved flexibility, including flexibility in the frequency of delivery, water flow rate, and duration.[8] Improved frequency flexibility involves getting water when needed, with minimal advanced request requirements. Improved flow rate flexibility allows farmers the option to change flow rates throughout the growing season or even during a single irrigation event. Duration flexibility allows farmers the ability to tailor the duration of the irrigation to their needs with minimal to no advance request requirements.[9] On the NNSJRIS, Diné farmers do not request water but merely open their head gates and receive whatever water is flowing, and farmers close the head gates when they determine they have enough water. No formal coordination exists to manage on-farm water delivery frequency, flow rates, or duration. No ditch bosses are involved, in part because the NN Department of Water Resources (NNDWR) does not have adequate staff. Ditch bosses are common in

New Mexico irrigation systems. They manage the head gates to ensure that farmers along a particular canal get water when requested and no one steals water.

In the NNSJRIS, while efforts to address the physical infrastructure requirements are under way, attention to soft infrastructure or governance mechanisms is lacking. This article argues that the cycle of deterioration and abandonment will likely resume in the coming decades, if soft infrastructure is not addressed along with physical infrastructure needs.

INDIAN IRRIGATION SYSTEMS IN THE WEST

The deferred maintenance problems plaguing the NNSJRIS are not unique. Neglect of irrigation system maintenance has been the object of international research efforts, particularly in the wake of the rapid expansion in the transfer of irrigation systems from governmental organizations to water user organizations during the 1990s.[10] It is fairly common for irrigation maintenance to be prioritized on the basis of complaints rather than systematic monitoring or evaluation of performance indicators such as head discharges and tail-end water levels.[11]

Indian irrigation systems have fared no better. In 2015 the US General Accountability Office (GAO) provided testimony before the US Senate Committee on Indian Affairs regarding deferred maintenance and unresolved financial sustainability issues. The report focused on the deferred maintenance costs of sixteen selected Indian irrigation projects of the more than one hundred Indian irrigation projects in the West that irrigate more than 750,000 acres under the supervision and management of the Bureau of Indian Affairs (BIA).[12] The deferred maintenance costs of those sixteen projects was estimated to be $568 million in 2014, including $125 million on the NIIP.[13] The NIIP irrigates NAPI, the eighty-thousand-acre industrial center-pivot irrigated farm near the NNSJRIS.

The GAO report indicated that the BIA could not assess which of the one hundred irrigation projects were capable of being self-sustaining, and the BIA did not have funding to study the issue. The BIA also had no plan for how it would obtain funding to fix the deferred maintenance items. These challenges had been previously noted in the 2006 GAO report on the same topic.[14]

To illustrate the dangers of deferred maintenance, on May 13, 2016, during planting season, a 1970s era forty-foot-wide siphon broke on the NIIP, necessitating a $1.6 million emergency repair to prevent catastrophic loss of production, income, and jobs.[15] US Senate Bill S. 438 was placed on the Senate legislative calendar on April 27, 2016, to provide funding to the BIA to address deferred maintenance on Indian irrigation projects.[16]

While national legislative attention is being devoted to tackling deferred maintenance on Indian irrigation projects across the West, the problems at the NNSJRIS require primarily local efforts to address the soft infrastructure challenges. These local efforts are explained in the following sections.

HISTORY AND CURRENT STATUS OF THE NNSJRIS

The Diné signed the Treaty of 1868 with the US government and returned from Bosque Redondo to their homelands in the Four Corners. Components of the Treaty of 1868 stipulated that heads of Diné families could select 160 acres to farm, and those farmers would retain their farmland until they discontinued cultivation. Similarly, single Diné men could select eighty acres under the same conditions.[17] However, farms of this size have never been provided to Diné farm families. Today most Diné farms are ten acres or less, although occasionally more land accumulates in one family over time. Farm sizes on the FC canal were reduced from the promised twenty acres to just ten in 1936 after the canal was completed due to the then Indian Service superintendent's observation of low utilization of farms on the HC canal, which had been completed previously.[18]

The act of July 4, 1884, provided funding to the secretary of the interior to develop irrigation on Indian lands.[19] In the pivotal 1908 case *Winters v. United States*, the US Supreme Court established the doctrine of reserved water rights for Indian reservations based on an effort on behalf of residents of the Fort Belknap Reservation in Montana.[20] Initial work on what would become the NNSRIS began in the early 1900s.

The FC and the HC canals are the two main canals in the NNSJRIS. The FC canal starts in Upper Fruitland, New Mexico, and diverts water to serve Diné farmers in the Upper Fruitland, Nenahnezad, and San

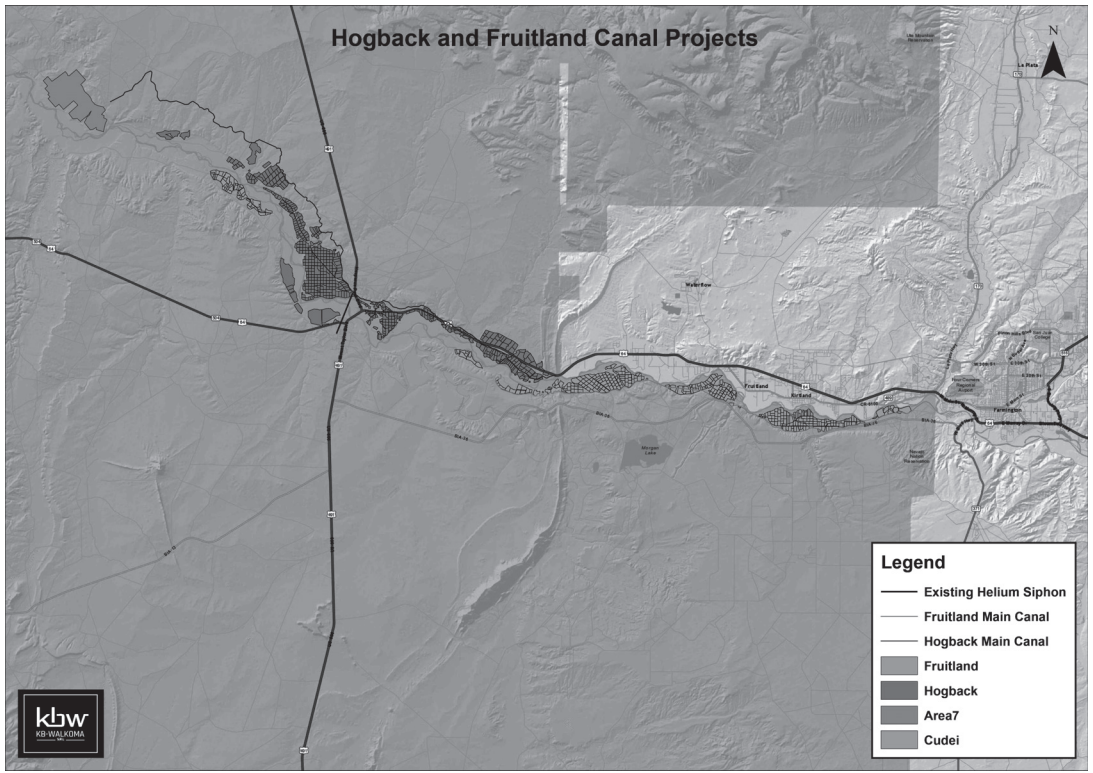

FIG. 1. The two main canals of the Navajo Nation San Juan River Irrigation System. Map by Michael Isaacson.

Table 1. Length, acreage of irrigable land, and settled tribal water rights available for diversion for small-scale Diné farmers for two canals on the NNSJRIS

Main canals	*Main canal length (miles)**	*Irrigable land (acres)**	*Diversion (acre-feet)***	*Depletion (acre-feet)***
Hogback-Cudei (HC)	26	8,830	48,550	21,280
Fruitland-Cambridge (FC)	22	3,335	18,180	7,970
Total	48	12,165	66,730	

**Source*: Keller-Bliesner Engineering, "San Juan River Irrigation Projects Planning Document, Rev 2," July 13, 2015. About 250 miles of secondary laterals are also part of the NNSJRIS.

***Source*: 2010 San Juan Basin in New Mexico Navajo Nation Water Rights Settlement Agreement.

Juan Chapters. The larger system is the HC canal, which diverts water to the Tse Daa K'aan (Hogback), Shiprock, and Cudei Chapters (figure 1).

Both diversion and depletion rates are specified in the NM NN Water Settlement. The diversion rate is monitored, and because the NN has senior water rights, users upstream of the NN must ensure that that rate arrives at the diversions, while the depletion or consumption rate is estimated (table 1).[21] The flow rates are monitored at the diversions using water-level sensors embedded in weirs and sent by satellite to the Bureau of Reclamation. Flow-measuring weirs are barriers that change the height of flowing water and allow for volumetric flow-rate estimates.

The Navajo Nation estimated the number of irrigable acres in production on the NNSJRIS in the fall of 2015 in response to the Gold King Mine spill. On August 5, 2015, the US Environmental Protection Agency (EPA) disturbed a soil barrier holding back a pond of acid mine drainage, located near the mine entrance of the abandoned Gold King Mine, releasing three million gallons of water containing heavy metal contaminants into the Cement Creek, a tributary of the Animas River, which then flowed into the San Juan River.[22] The spill triggered an inventory by the NN Department of Agriculture (NNDA) of Diné farms along the San Juan as a step in a legal process to sue the EPA. In November 2015 the NNDA estimated only 2,771 acres in production (table 2), which is 22.7 percent of the irrigable diversion settled in the NM NN Water Settlement.

Table 2. Farm survey estimates on the NNSJRIS, fall 2015

Chapter	*Acres surveyed*		*Acres not surveyed*	*Total acres*
	Active	Idle		
Upper Fruitland	762	212	364	1,338
Nenahnezad	465	363	37	865
San Juan	350	436	943	1,729
Tse Daa K'aan	346	212	347	905
Shiprock	848	208	1,721	2,777
Total	2,771	1,431	3,412	7,614

Source: NN Department of Agriculture. The Cudei Chapter was excluded from this analysis and accounts for about six hundred acres.

The estimate of 22.7 percent of land in production may be high, because it is likely that many of the farm plots measured included the entire farm permit area, regardless of whether how much of it was covered by buildings, corrals, or driveways. However, the low utilization of irrigated acreage potential on the NN is not a new phenomenon. A 1985 Soil Conservation Service survey of eighty-three "historic Navajo Indian Irrigation Projects" revealed that only 36 percent of the then available 46,219 acres across the NN were in production due to lack of maintenance and funding and institutional and personal conflicts.[23] The ratio of irrigated farmland in production to the "subjugated" farmland, where only one crop per season is possible due to environmental constraints, is defined as cropping "intensity."[24] Cropping intensity on small-scale Diné farms on the NNSJRIS was found to be correlated with availability and reliability of water supply.[25]

IRRIGATION ASSESSMENT AND INSTITUTIONAL ARRANGEMENTS

Irrigation assessments are typically instituted for the purpose of generating income that can be used to maintain and repair the irrigation system. Maintenance has been defined as any activity that "slows deterioration of a facility, whether caused by use or aging."[26] A civil engineering definition describes maintenance as "planned and auditable procedures to pick up problems before they become critical, and tight financial control to prevent waste."[27] According to Walter Svendsen and Mark Huppert, there are three "archetypal" approaches to

maintenance strategies.[28] The "gold-plated" strategy involves repair and replacements as soon as any equipment shows sign of wear, and canals are maintained at original design values.[29] A "pragmatic" approach involves routine maintenance procedures but allows for a certain level of weed infestation and rust.[30] In the "minimal" maintenance system, the only maintenance conducted is that which is absolutely necessary to enable water to flow through the main canals. Levels of reliability and diminished conveyance throughout the system are not a concern.[31]

THE BUREAU OF INDIAN AFFAIRS

The BIA issues farm permits, known as land use permits (LUPs), to provide Navajo farmers the opportunity to farm a specified number of acres. In February 2017 948 LUPs were active, and 11,678 acres were permitted.[32] According to the Code of Federal Regulations (CFR) 25 Section 162, LUPs have time limits up to ten years or up to twenty-five years in cases of significant financial investment in the farm.[33] The CFR regulations also require that the exact locations of these LUPs be specified by an appropriate method. However, these regulations regarding farm maps/locations and time limits have never been enforced.

The BIA operated an irrigation assessment program on the NNSJRIS prior to turning it over to the NN. The BIA assessment rate was $1.50/acre. That rate was increased in 2011 by the San Juan River Dineh Water Users, Inc., described below. Delinquent accounts have never been collected, and clear policies on managing delinquent accounts were never established.

In 1960 the transfer from the BIA to the NN of all Indian irrigation projects, including the NNSJRIS, was authorized by Public Law 86-636, and in the spring of 1963, the agreement between the NN and the BIA was finalized.[34] The number of laborers and ditch managers employed by the BIA at the time of transfer was estimated to be 135 for all of the NN irrigation projects. By the 1960s about thirty-five people were employed by the NN in canal operation, maintenance, and repair (OM&R).[35] As of this writing, only three maintenance workers are employed by the NN to maintain the NNSJRIS main canals. Five people total are employed, including a secretary and supervisor.[36]

The BIA continues to manage the LUP system, even though in May

2014 the assistant secretary of the BIA signed the Navajo Nation General Leasing Regulations of 2013 (GLA), which gives the authority to the NN to issue all leases except mineral leases while retaining the authority to approve any changes in regulations governing the issuance of leases. The GLA indicates that all lease rates, with a few exceptions, such as those needed for home sites or religious or governmental purposes, need to be based on fair market values as determined by appraisals that are conducted by licensed appraisers and that lessees must obtain performance bonds and insurance.[37] Agricultural leases, or LUPs, were not specifically exempted from these requirements (and others) in the GLA. There is no history of requiring NN farm leases, or LUPs, to be subject to such requirements, and it would seem that the failure to provide an agricultural exemption in the GLA is an oversight. At the 2017 Navajo Agricultural Elected Officials Summit, Elerina Yazzie, of the newly established NN General Leasing Department, indicated to the conference participants that instituting the GLA as a governance structure for business site leases is a priority for the NN. Farm site leases, or LUPs, were not mentioned.[38] A day earlier at the same meeting, Renelda Begay, a policy analyst and San Juan River Farm Board liaison from the NN Department of Agriculture, said that the BIA had indicated that it has no policies governing LUP management.[39]

For the NN to take over control of the LUP management, regardless of how management policy, appraisal, performance bond, and insurance issues are resolved, the NN will need to involve the BIA in any transfer of records. The historical lack of BIA attention to the LUP records would mean giving the NN a system in chaos. The transfer would be easier if, first, the BIA and NN records were compared and used as a baseline to map or survey all LUP farm plots and then entered into a modern GIS/database system. With such an information system, physical management of irrigation could be better facilitated. GIS mapping needs to be specifically authorized, however, since the General Leasing Act currently requires land to be surveyed by certified land surveyors.

THE SAN JUAN RIVER FARM BOARD

Farm boards were first established by the Navajo Nation in 1980, including the San Juan River Farm Board (the Farm Board).[40] In 2014 the NN Council passed an act (CD-76-14) to amend the plans of operation

for the farm boards. The act indicates that the farm boards are responsible for ensuring full utilization of idle farmlands, implementing and promoting "adequate research, education, and training" in agricultural "production, irrigation management, marketing, and financial management," and proper operation and maintenance of their local irrigation system. The farm boards are also charged with building local capacity for the economic use and development of local farmland.[41]

After the transfer of the NNSJRIS from the BIA to the NN, the NNDWR Shiprock office began collecting the NNSJRIS assessments and depositing them in the NN general fund, which meant those funds were unavailable to pay for OM&R. In the mid-1990s the Farm Board passed a resolution to request that the assessment income be retained locally, and the NNDWR Shiprock office began depositing the assessment funds in a local bank for transfer to the San Juan River Dineh Water Users, Inc.

THE SAN JUAN RIVER DINEH WATER USERS, INC.

The San Juan River Dineh Water Users, Inc. (the Water Users) organization was incorporated as a 501(c)(3) nonprofit entity on December 21, 1999, under the NN. The Farm Board provided the leadership to create the Water Users with the intention that the Water Users would operate and maintain the irrigation system and an effective assessment program. Local control over system OM&R was considered a high priority. Another argument used to justify forming the Water Users was the fact that the Farm Board did not really represent Diné farmers because Farm Board members are elected by chapter members, not all of whom are farmers.

The literature supports the need to organize water users to break the "cycle of deterioration" in irrigation systems.[42] This cycle exists in part because of conflicts between the objectives of irrigation system managers and farmers. Irrigation managers tend to be civil engineers who are rewarded for and see accomplishment in terms of physical rehabilitation. Farmers want water delivery flexibility.[43] However, given the history of the NNSJRIS, formation of a Water Users' organization was necessary but not sufficient to interrupt the cycle of deterioration.

In 2010 the Water Users amended their articles of incorporation to include these responsibilities:

1. operate, lease, construct, and maintain relevant irrigation system structures;
2. manage water delivery to irrigation users;
3. assess and collect water-use levies;
4. enter into appropriate contracts;
5. apply for appropriate funding to carry out irrigation system responsibilities; and
6. develop Navajo knowledge of farming.

The Water Users have primarily focused on activity 5, applying for grant money and bringing in almost $8 million in capital improvement projects with external financing, which have reduced OM&R requirements but have been inadequate to fully carry out their operation and maintenance responsibilities.[44]

In March 2011 the Water Users approved an increase in the per acre assessment to $3.00.[45] Whether the Water Users and Farm Board discussed the increase is not known. The validity of the increase is unknown because there were no meeting minutes kept from that 2011 decision, and the Farm Board never passed a resolution authorizing the increase.

Thus, a typical ten-acre LUP on the NNSJRIS would be assessed *$30* annually. If assessments were paid on all 11,678 LUP acres, the annual budget for OM&R would be $35,034, barely enough to cover one salary. The annual budget of the NNDWR Shiprock Irrigation Office is about $310,000, with a staff of five to manage all OM&R.[46] By way of comparison, the Arizona Salt River Project (ASRP) 2016 fees for irrigation were $66.25/year and $0.34/acre for account service, called the Annual Water Delivery Fee, and an additional Annual Assessment Fee of $31.80/acre to cover system operation and maintenance.[47] Thus someone with ten acres in the ASRP would pay annually a total of (10 × 32.14 + 66.25) = *$387.65*. In southern New Mexico in 2016, farmers in the Elephant Butte Irrigation District (EBID) paid $75 per water-righted acre for parcels greater than two acres; a ten-acre farm would be charged *$750* plus a $10 administrative fee.[48]

THE TRI-PARTY AGREEMENT

On June 6, 2010, the NNDWR, the Farm Board, and the Water Users signed a Memorandum of Agreement (the Tri-Party Agreement) to

specify roles and responsibilities for each entity regarding irrigation system management.[49] The responsibilities of the Water Users under the Tri-Party Agreement were to administer and implement an OM&R Fund and Program and, in collaboration with the Farm Board, determine the strategy and methods for the following tasks. The Water Users were authorized either to carry out or to delegate these tasks:

1. obtain a current Navajo Nation water-use permit;
2. collect assessment fees for OM&R as delegated by the Farm Board;
3. prepare an annual OM&R budget for approval by the Farm Board and review by the (NNDWR);
4. be responsible for the OM&R on system components from the "boundary control points" to the farmers' delivery gates, which excludes the main canals;
5. work with local farmers to permit operation of maintenance equipment and access of personnel maintenance;
6. make written recommendations to the NNDWR at the beginning and ending dates of the irrigation season;
7. measure water between boundary control points and farmers' delivery gates; and
8. report water deliveries at the end of the season to the NNDWR.

The responsibilities of the Farm Board in the Tri-Party Agreement were to assist the Water Users with the collection of OM&R assessments, recommend cancellations on delinquent permits per the OM&R Policies and Procedures, and account for and expend the assessments collected. While the Farm Board was supposed to assist the Water Users to determine strategies for collecting assessments and maintaining the system, the Farm Board never accomplished task number 5, to "develop a written strategy and method for completing these tasks and provide a copy to the Water Users within three months" of the effective date of the Tri-Party Agreement.[50] The agreement did not specify consequences or alternative scenarios for any failures on the part of any of the agreement signatories.

The primary responsibility of the NNDWR, according to the Tri-Party Agreement, was to maintain the main canals subject to the availability of funds. The NNDWR has taken responsibility for the water users' assessment records since the BIA relinquished control. The Water

Users were instructed by the Farm Board to take over management of these assessment records, but they have not yet done so. Meanwhile, the BIA continues to maintain control over transfer of LUPs, and it is unknown how their LUP records differ from NNDWR records.

The assessment records for each farm plot from the NNDWR include the farm plot number, the permittee name and address, acreage, assessment paid in a given year, and balance due. The assessment records do not indicate when a plot was permitted or any subsequent transfers to heirs or other parties. No geophysical identification is provided either, such as latitude and longitude or GPS points.

ARGUMENTS FOR REFORM

While the $30 million NM NN Water Settlement physical infrastructure rehabilitation projects are gearing up, attention is needed to plan for long-term system OM&R and other soft infrastructure issues. As an example of the consequences of lax system maintenance on the NNSJRIS, in the summer of 2015 a $150,000 repair was needed on a siphon that traversed an arroyo after the pipe broke as it crossed out of the arroyo. The reason it broke was because the water could not flow out of the pipe and into an earthen canal due to excessive vegetation obstructing the water flow. The water backed up and the pipe broke. Preventative maintenance would obviate such expensive repairs.

In addition to excessive out-of-pocket costs for preventable maintenance repairs, the opportunity cost to the NN of not farming irrigable and idle farmland is significant. An opportunity cost is the cost of an option not taken. If only 23 percent of the land is farmed that could be farmed, then 77 percent is not farmed and represents an opportunity cost. What is the value of that unfarmed land?

Assuming the land was planted in alfalfa, the opportunity cost of not farming the remainder of the land that is available to be irrigated is worth an estimated $14 million in annual gross revenues. This estimate was based on San Juan County 2013 average yields of 5.95 tons/acre and 2013 statewide average price of $250/ton.[51] The estimated per acre gross income opportunity cost was $1,487.50. Financial multipliers would result in even larger economic impacts, as would the assumption of higher-value crop production. In Doña Ana County, in southern New Mexico, high-value crops such as chiles, onions, and pecans, as well as

dairy and floral production, are grown using water from EBID. According to the 2012 US Census of Agriculture, the market value of all crop production in that county was a little less than $167 million from 76,172 harvested acres, which amounts to $2,190.48/acre. If similar per acre gross returns on the NNSJRIS were achieved, the gross income would be about $26.6 million annually. Southern New Mexico has a much longer growing season than does San Juan County, so $26.6 million can be considered the very high upper end of what might be possible on the NNSJRIS.[52] Maximizing income from farming in an irrigation system and maximizing acreage in production, however, do not always lead to the same cropping patterns.[53] In addition to the economic opportunity costs associated with farm abandonment on the NNSJRIS, the loss of traditional crops and Navajo farming culture is incalculable.

Beyond the Shiprock Chapter, located in the northwest corner of San Juan County, New Mexico, is a section of irrigable farmland called Area 7 that contains an estimated 2,200 acres that were once farmed back in the 1970s. This farmland could be reopened to production to help increase the number of acres to the 12,165 maximum acres of farmland that can be irrigated. The portion of LUP farm plots that is under structures needs to be estimated to help determine how much of the current LUPs could actually be farmed, which will help determine how much of Area 7 could be opened up for farming.

The issue of whether there are enough Diné farmers to farm all of the possible acres may be a consideration whether to spend money to improve the irrigation system. However, while no systematic survey of potential new farmers has been conducted, the economic, cultural, and social needs to increase food production are great. Finding a way to make land available to interested new farmers is important. Documentation of how much new land could be opened up to new Diné farmers, potentially in Area 7 or in existing chapters, depends on documenting existing farm plots with legal surveys and GIS mapping.

Thus, four soft infrastructure efforts have been identified that will help ensure the long-term viability of small irrigated farms on the NNSJRIS. These soft infrastructure efforts include (1) creation of a state-of-the-art management information system to map and track LUPs, (2) organization of a self-sustaining OM&R system to keep the water flowing, (3) revision of the existing governance mechanisms in the Tri-Party Agreement to ensure effective functioning of the relationships, rules,

policies, and procedures in the system, and (4) hiring agricultural staff at Diné College in the Shiprock office to provide research, demonstration, and outreach to small-scale Navajo farmers.

A plan is needed that will detail the cost of establishing and maintaining an information system to identify and map LUP farm plots. A second plan is needed that will estimate the costs of establishing a self-sustaining system of irrigation management and maintenance. In addition, a dedicated teaching and research station focusing on the needs of small-scale Diné farmers would help farmers diversify their crops, care for their land better, and increase their incomes. Diné College will again have access to irrigation water after the completion of the infrastructure rehabilitation projects funded by the NM NN Water Settlement and could potentially launch an integrated research and education station with a local staff. The land-grant program at Diné College is currently housed in Tsaile, Arizona, sixty miles from Shiprock, New Mexico, and the demonstration farm. No full-time agricultural staff are currently located in Shiprock.

RECOMMENDATIONS

In order to create a vibrant and productive irrigated Diné farm sector that uses all of its NM NN water rights and land allocation, the OM&R system needs to be adequately funded and staffed. Funding sources include water assessments and tribal allocations. In addition, water regulations are needed so that each farm plot will get adequate water. More head gates and a system of ditch bosses may be needed to improve water delivery frequency, flow rate, and duration flexibility.[54] Investments in Shiprock-based Diné College research and demonstration farm staff and infrastructure are needed to provide targeted and practical information for local small-scale Diné farmers. Improvements are needed in the management of the LUP process, including an improved electronic database, GIS mapping, and staff to facilitate LUP transfers in a timely manner.

To institute these changes, a master plan is needed based on an effort involving all of the stakeholders. A master plan task force should represent farmers, the BIA, the Farm Board, Diné College, the Water Users, and the NN (Land Department, Agriculture Department, Water Resources Department, Water Development Department, and Jus-

tice Department). The task force should prepare a vision document that guides a work plan. The work plan should specify research activities and a timeline for all stakeholder representatives, determine costs of work plan activities, and provide options for funding the work plan research.

The work plan could include these tasks:

1. analyze irrigation districts in other places, especially Native American systems on trust land (this analysis should investigate irrigation system roles, responsibilities, costs, policies, maintenance, software, management, assessment fees, and staffing);
2. examine integrated and sustainable agricultural teaching, research, and outreach centers in the region and around the country to study best practices;
3. discuss future roles of all stakeholders in irrigation system management; and
4. compile research findings, make recommendations, and prepare a preliminary budget.

Following completion of the work plan, the stakeholders would reconvene to evaluate research results, create a memorandum of understanding to authorize and implement the vision, and create an implementation team. The implementation team would then create an implementation plan (master plan and master budget).

In summary, the proposed steps, listed in sequential order, to make the necessary changes that will support long-term sustainable irrigated agriculture region on the Navajo Nation include the following:

1. The stakeholder group forms a master plan task force and prepares a vision document.
2. The task force creates a work plan and a work plan budget and obtains funding.
3. The task force undertakes research, compiles findings, and reports back to the stakeholder group.
4. The stakeholders create a memorandum of understanding to implement organizational changes in the irrigation system, including OM&R, LUP management, and research and education infrastructure.
5. An implementation team is then selected.
6. A budget is prepared.
7. Implementation begins.

SUMMARY AND POSTSCRIPT

Taking the steps outlined in this article may help address the soft infrastructure needs of the NNSJRIS that are critical to reviving the small farm sector on the Navajo Nation along the San Juan River. The soft infrastructure needed includes development of a GIS-based LUP database, revision of the Tri-Party Agreement responsibilities, institution of an effective and adequately funded OM&R system, and creation of a demonstration farm at the Shiprock Diné College office with full-time staff.

The EBID irrigation system in southern New Mexico is an example of a well-maintained system serving the needs of commercial farmers. In the spring of 2016, Gary Esslinger, the manager of EBID in southern New Mexico, visited the NNSJRIS. He explained that the high assessment fees paid in EBID were needed to keep the canals and drains completely free of vegetation, maintenance that the farmers demand. He also shared information on equipment that can be used to clear canals and ditches of Russian olives and that would reduce labor requirements. In addition, he explained the great potential for using low-head hydro turbines in the irrigation system to produce electricity.[55] He identified several locations on the NNSJRIS where vertical drops of at least four feet could house low-head hydro.

Software has also been identified that could be used to map farms and upload photographs, GIS information, and farm production data right in the field while interviewers talk to farmers.[56] The web-based GIS mapping system, FIELD (Farm Information and Environmental Land Data), can be adapted for use on the NN. The software can be installed on tablets for field use. The database can be accessed by various agencies, and their access can be customized depending on their data needs.

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