Saving Wild Rice:
The Rise and Fall of the Nett Lake Dam

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ABSTRACT

This paper examines the interrelations of technology, environment and people by exploring the origin, design and implementation of a dam-building project intended to control water-level fluctuations and enhance the Nett Lake wild rice ecosystem at Bois Forte Indian Reservation in northern Minnesota. Informed by the interdisciplinary field of science and technology studies (STS), it is argued that technologies, such as the dam, do not fail or succeed because they are ill or well conceived. Rather, they acquire these properties depending on whether the boundaries of the technology, user and ecosystem become stable. This implies that even if we can point to the separate entities involved, their boundaries cannot be determined *a priori*. Instead, they emerge constantly, renegotiated by a complex interplay of heterogeneous elements, including scientific, economic, political, cultural, legal and natural factors.

KEY WORDS

Dams, STS, Native Americans, wild rice, technology

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At midmorning on 1 October 1987, members of the Bois Forte Band, a state senator, the commissioner of the Minnesota Department of Natural Resources (MNDNR) and engineers from the various consulting and construction companies gathered to dedicate the newly reconstructed Nett Lake dam on the Bois Forte Indian Reservation in northern Minnesota. For the Bois Forte community, the day marked a triumphant conclusion to their half-century struggle to rebuild the original 1936 dam and control water-level fluctuations that affected their wild rice productivity. An Ojibwe ceremonial song highlighted the significance and festive nature of the occasion. The spiritual leader of the Band offered tobacco to the Creator for bringing the dam to help the rice beds upon which the community's cultural and economic well being depended. After a lunch prepared in the Bois Forte traditional manner, the dignitaries, guests and spectators left, confident that the dam would protect the rice.

By 2000, however, such optimism had virtually disappeared. Although the dam successfully regulated water levels, wild rice productivity continued to fluctuate just as it had before dam reconstruction. More importantly, many blamed the dam for increases in invasive weeds in areas once abundant with wild rice. Concerned, the Bois Forte Band again sought funding: this time to remove or modify the dam.

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How can students of human–environment relations understand the dam's rise and fall? The answer may depend on how the story is told. Do we present a story of the environmental, social, economic and cultural consequences of science and technology?[1] Do we isolate the dam, as a historian of technology might, to investigate its evolution and the ways in which its design was shaped by – and mirrored – complex social, economic, professional and political tradeoffs?[2] Or, considering critiques that the above approaches entail technological and social reductionism, respectively, do we adopt an interactive view of how the dam influenced – and was simultaneously influenced by – the Bois Forte and the wild rice ecosystem?[3]

All these approaches share a similar problem: they assume a categorical distinction between human and nonhuman worlds. Once such an assumption is made, we can view nonhumans only in two contradictory ways. The first approach views technologies as the cause of everything, leaving the social groups brought together to build the artefact unexamined. By the second approach, only humans have the status of actors, and technologies count for nothing. In the interactive view, technologies serve as an intermediary linking the social and the natural. However, the technology itself does not add or subtract from, but merely shuttles between, the 'pure' ontological qualities of nature and society.[4] The upshot of these approaches is the equally contradictory roles technologies play when things go wrong: as either the perpetrators (when viewed as powerful agents of change) or as simply hiding the real perpetrators (when viewed as mere receptacles of cultural values).

In this paper, I argue that to understand the role technologies play in social and environmental problems we cannot simply blame the hardware when things go wrong. Neither can we attach blame to those who design or use the technologies, the economic system, or abstractions such as 'culture', 'politics', 'ideology' and 'power'. To understand how people, technologies and the natural environment work together, shape one another, and hold one another in place, we need to explore what Tracy Kidder[5] called the 'soul' of technologies by looking at their genesis, design, emergence and stabilisation without blame and without *a priori* assumptions about the existence of an ontological chasm between human and nonhuman worlds. However, such an approach has received little attention in the study of human–environment relations, especially in interdisciplinary fields such as environmental history, which takes as one of its starting points the need to bridge human and nonhuman worlds.

The approach has mainly emerged from the empirically grounded, interdisciplinary field of science and technology studies (STS)[6] and rests on two principles. The first principle enjoins the researcher to use the same kind of social explanation for artefacts that work and those that fail. Treating successful and unsuccessful technologies in the same terms extends a principle introduced by Bloor[7] to counter an older sociology of science that explained the success of a scientific theory by its conformity to the 'Truth' (i.e., nature) and the failure of another theory to values, interests, ideology or power (i.e., society). Callon[8] introduced the second principle as a corrective to the first, urging researchers to not only treat success and failure symmetrically, but also to treat the social, natural and technical equally, without privileging one over the other and without assuming a categorical distinction between humans and nonhumans.

I use these two principles to examine the rise and fall of the Nett Lake dam. I begin with a brief historical account of water-level management leading to the dam-reconstruction project and the process of defining the dam's scope. Next, I examine some of the heterogeneous factors (e.g., political, economic, natural, cultural) that entered into the design, suggesting that the final design choice lay not so much in its intrinsic technical superiority or economic efficiency as in the interplay of various local circumstances. In addition, I stress the simultaneous emergence of the dam and the wild rice ecosystem, thereby questioning the conventional dichotomy between dams and the environments they inhabit. Following this, I analyse the failure of the dam by discussing what happened after its completion and arguing that its success or failure must not be treated as something determined at 'birth' but as an emergent effect produced by the confrontation between the projected behaviour of the entities inscribed in the dam and the behaviour of these entities in the real world. Finally, I discuss some of the implications of this case study for understanding the interrelations of technology, environment and society.

THE BOIS FORTE AND WILD RICE

The Bois Forte Indian Reservation (BFIR), established in 1866 and located in north-eastern Minnesota (Figure 1),[9] includes Nett Lake and its expansive wild rice beds. As an economic, cultural and spiritual mainstay for the Bois Forte Chippewa Band for hundreds of years,[10] wild rice cultivation is a designated use of the lake, and traditional access and harvest control mechanisms are still the

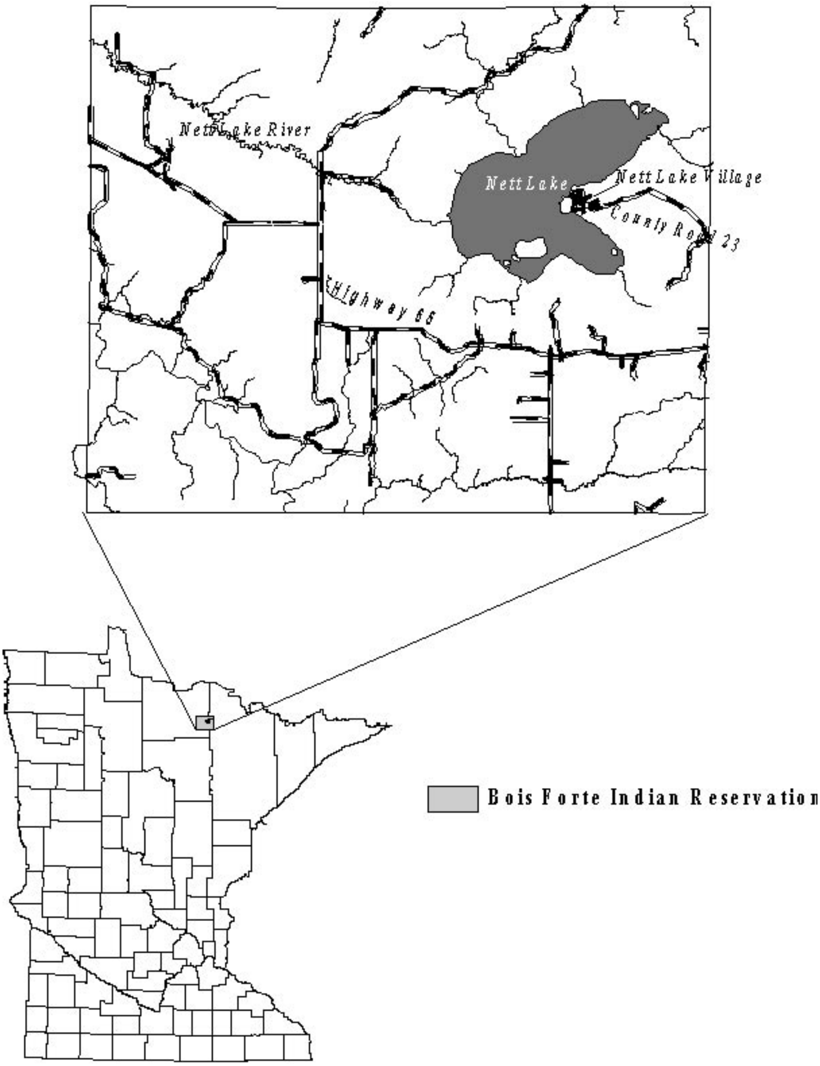

FIGURE 1. Map showing the state of Minnesota and the Bois Forte Indian Reservation.

principal means of Nett Lake management. However, securing a good harvest had always been challenging, partly due to high levels of water fluctuation.[11] During wet years, high water levels at any growth stage could result in near or total crop failure. Though dry years usually produced good crops, low water levels would render many beds inaccessible for canoe-based harvesting. Wind, hail, frost, heavy rain, or even a dry spell at a critical growth stage of the plant could also lead to meagre yields. Only occasionally – some Bois Forte say every four years – did optimal conditions turn Nett Lake into a 'vast wheat field'.[12]

Despite the strong influence of water level on wild rice productivity, the Bois Forte Band did not attempt to manage water levels until the late 1920s. Perhaps the first earnest official effort to regulate Nett Lake began in 1929 with a letter sent by the then Superintendent of the Minnesota Chippewa Tribe (Edgar A. Allen) to the Commissioner of Indian Affairs. Allen wrote, 'the wild rice crop in Nett Lake means much to the Nett Lake Indians, and, if such action is possible, it is believed that a dam and control gates should be placed in the mouth of the Nett River, so that the level of the lake might be controlled, thereby ensuring the proper growth and the easy harvest of this crop'. However, the Commissioner replied, 'no money is now available which could be used for the purpose. The matter will be given attention when Congress meets next December'.[13]

THE BOIS FORTE AND WILD RICE: POST-CCC DAYS

The requested assistance did not arrive until President Franklin Roosevelt began the Civilian Conservation Corps (CCC) in 1933. In 1936 the CCC Indian Division built a stop-log dam to control water levels during dry years. The approximately 125-feet-long dam consisted of eight bays six feet in width, eight feet high, and including about 75 feet of fill material (Figure 2).

FIGURE 2. The stop-log dam in 1936. Adding or removing stop-logs between the walls or buttresses raised or lowered the water level. Photo courtesy of the National Archives, Kansas City, Missouri.

However, the stop-log dam did not end the Bois Forte Band's struggle to secure good and consistent annual wild rice harvests. Indeed, from 1937–1939 meagre yields prompted an engineering study to determine the reason. The study blamed high water levels, noting that 'there is no way of lowering this high water level unless the river channel was dredged from the mouth of Nett Lake to falls on the west side of the reservation. … the [stop-log] dam is constructed solely to raise the lake level during dry years when there is subnormal rainfall'.[14] In 1942, frustrated by continuing failures of wild rice, the Minnesota Chippewa Tribe executive committee requested urgent assistance from the CCC Indian Division (ID) to 'cut a channel through the bog at the outlet of Nett Lake sufficient to permit the water to flow through and to restore [normal flowing] condition … if no help is possible from the CCC ID then the matter be submitted to the State Conservation Department for help in conserving this natural resource of the Indians'. Their plea was in vain. The CCC dissolved in 1943 before it could address the problem. An appeal to the State Conservation Department also brought no help, only the response that 'Indians rice this lake and maintenance should be taken care of by them'.[15]

Undeterred, the Bois Forte Band continued to seek assistance from the State Conservation Department. In 1945 the Bois Forte asked well-known wild rice biologist John B. Moyle for advice on removing the sandbar upstream of the stop-log dam to improve the hydraulic capacity of the channel. Although Moyle recommended channel improvement work, the Conservation Department did nothing, and the situation at Nett Lake deteriorated. Between 1950 and 1957, for example, only three years provided a wild rice crop. In the remaining years, high water levels destroyed the crop. Desperate, the Bois Forte Band invited John Moyle to visit Nett Lake again. Moyle visited in May 1957 and reported that channel improvement work was absolutely essential to alleviate the situation at Nett Lake.[16] But, once again, no one came forward to address the problem.

In 1975, the dam deteriorated to the point that Bois Forte leaders perceived it as part of the problem for wild rice beds, (Figure 3) which had declined by almost 50 per cent compared to their historical distribution. The Bois Forte Reservation Business Committee (BFRBC) once again requested assistance from the Commissioner of the Minnesota Department of Natural Resources (MNDNR) to perform a hydrological study and topographic survey of the Nett Lake inlet and outlet system. Two years later, the MNDNR conducted both studies and concluded that the stop-log dam indeed constricted flow and that if the goal was to increase wild rice production, a new dam with a spillway capacity was necessary.

In May 1978, the Bureau of Indian Affairs (BIA) commissioned a study (at the request of the BFIR) to assess the feasibility of implementing the recommendations of the 1977 MNDNR study. The study found the project to be economically feasible at an estimated construction cost of $1,039,000. Armed with

FIGURE 3. The stop-log dam in 1985. Notice the erosion on both embankments. Photo courtesy of the Minnesota Department of Natural Resources (MNDNR).

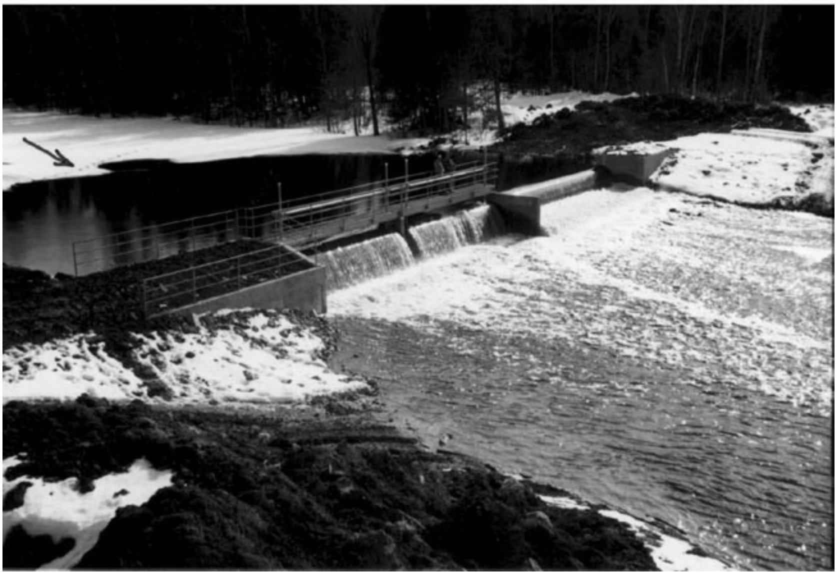

FIGURE 4. The new dam, completed in February 1987. Photo courtesy of the Minnesota Department of Natural Resources (MNDNR).

these studies, the BFIR lobbied the Minnesota legislature to provide funding. In 1985 the legislature appropriated $1.2 million for the dam construction,[17] and by December 1987, the new dam (figure 4) and reconfigured wild rice ecosystem and management system were in place. However, by 2000 many community members considered the dam not a solution but a contributor to the continuing decline of wild rice.

Let us now retrace the story of the simultaneous emergence of the new dam and the new wild rice ecosystem and management scheme so that we can then examine their fates.[18]

THE NETT LAKE DAM RECONSTRUCTION PROJECT

The Nett Lake dam reconstruction project began with the unexpected appropriation of $1.2 million from the Minnesota legislature to the MNDNR Water Division on 9 April 1985.[19] The bill surprised the MNDNR Water Division as they had neither requested the money nor known it was coming.[20] The following day, the Division received a phone call from the office of the legislators who had introduced the bill, explaining that they had backed it based on the 1977 and 1978 studies and as a development project for an economically depressed region. Although the Division had serious reservations regarding both studies, the MNDNR accepted responsibility for overseeing the project.[21] The immediate problem was how to work with the Bois Forte Band who, along with other Chippewa bands in Minnesota, had hostile relations with the state.[22] The head of the Division immediately assigned one of his staff hydrologists to lead and coordinate the project. Why he was selected among the many staff hydrologists and why he acts is of little importance here; he is, however the prime mover of the story analysed. Let us accompany him as he mobilised and juxtaposed an array of heterogeneous elements – for instance, skilled labour, scientific theory, machinery, organisations, legal and other experts – that was necessary for the successful completion of the project.

As one of his first steps, the hydrologist crafted a contractual agreement between the state of Minnesota and the Bois Forte Band. The agreement defined the project's scope and development phases, specified who would manage the project and own the new dam, described the payment schedule and finally, in case the project failed, addressed how each party would bow out without trials and litigation. Thus, the agreement required consideration of a series of issues and the ability of the Bois Forte to enter a legally binding agreement with the state of Minnesota. On 23 December 1985, the Bois Forte signed the contract.

The next step was to hire an engineering firm to prepare construction plans and specifications, select a contractor, estimate the cost involved and develop a timetable. Six engineering firms submitted proposals. Screeners quickly dismissed three proposals that based their dam designs on the 1977 MNDNR study, which the MNDNR itself considered inadequate and unreliable. The remaining three firms submitted very similar proposals, with the lowest bidder winning the contract.

The winning firm proposed four phases: preliminary hydrology and dam design, water management planning, final design, and construction phases. The first phase included an extensive field survey of the river and detailed description of the existing stop-log dam. Field data were to be used for evaluating 1) the major event hydrology of the Nett Lake watershed; 2) the hydraulics of the existing outlet channel; and 3) the hydraulics of the existing stop-log dam. In the second phase, the firm proposed to hire a local company to conduct a field survey for developing a bathymetric (contour) map of Nett Lake. The firm also planned to conduct a field survey of the lake and identify the types and general locations of competing vegetation, using a university scientist hired as a wild rice consultant. Based on the field data, the bathymetric map and current and historical lake conditions, the firm argued, the scientist would develop a water management plan that would maximise wild rice production and also help control competing vegetation. Then, the firm proposed to determine long-term flows into and out of Nett Lake to develop a dam outlet control program that would meet the monthly water requirements of wild rice. In the third phase, the firm would submit the final dam design with construction plans and specifications. Construction would occur in the fourth and final phase. The firm proposed to provide the following services: 1) handling contract bidding and awards for actual construction, 2) providing construction engineering services, 3) preparing as-built construction plans, and 4) preparing an operation and maintenance plan for the dam. The firm agreed to provide its services for 10 consecutive months for a lump sum amount of $75,000 for all phases of the project, excluding monthly payments for reimbursing direct expenses incurred in connection with the project.[23]

With a possible dam design, a consulting firm, and a definite work schedule at hand, the hydrologist had no problem getting the funds released. On 19 March 1986, the MNDNR transferred the first advance of $52,000 to the BFRBC's account.[24] To ensure an uninterrupted flow of funds and completion within the time and budget, the next step involved the difficult task of transforming the mute and heterogeneous river and stop-log dam into something more understandable.

UNDERSTANDING NETT LAKE RIVER

Who could speak on behalf of the river, the lake and the dam? All the social actors mobilised (Bois Forte Indians, MNDNR, elected officials) in the support of the project spoke and acted via their representatives. They were the end products of relatively stable networks that were already in place. But there was no one in a position to speak on behalf of the river, the lake and the dam. Members of the Bois Forte Band had lived near the lake for hundreds of years, and some elders remembered past lake and channel conditions as well as the building and deterioration of the stop-log dam. However, although representatives of the Bois Forte seemed to be the best spokespeople for the river, dam and lake, and sometime spoke on their behalf, they often could not answer specific questions posed by the engineers.[25] Previous studies of the river and the stop-log dam also proved either inadequate or unreliable.[26] In reality, very little was known about the characteristics of the river and any impediments to water movement. For example, it was unclear whether the stop-log dam was responsible for constricting water flow, what sources and volumes of water fed into the river, the hydraulic capacities of the channel and the stop-log dam, and how climatic conditions affected water flow. Most importantly, it was unknown how all these factors interacted with wild rice and affected its growth and productivity.[27]

The heterogeneous and unpredictable existences of the river and dam complicated the problem of answering these questions. For instance, the river had complex interactions with the soil and climate elements, making prediction of its rise and fall uncertain. Its long and winding channel had no identical points and underwent constant flux. Just as no one could understand the river in its totality, so too could no one understand the existing dam in its entirety. For more than five decades, the dam had constantly interacted with humans and natural elements. Was it doing what it was intended to do, namely control water to benefit wild rice? Or was it doing exactly the opposite? No one could tell whether it was working with the humans who constructed it, the river in whose channel it resided, or the sediments that it allowed to accumulate. The firm's problem, then, was to form a simplified but a workable representation of the river and the dam with the aim of understanding their obscure existences.

To gain this understanding, the firm first subcontracted a local surveying company to produce representations of the river and dam. For two weeks in March 1986, the surveying team collected detailed data about the existing dam, the Indian Service Road, and the hydraulic carrying capacity of the Nett Lake River from the lake three miles downstream to the bridge on the Indian Service Road (Figure 5).[28] The firm also prepared a description of the old stop-log dam and the bridge.

The next step was to apply this information in the laboratory. Contrary to conventional belief, scientific laboratories are not simply physical spaces in which 'nature' is observed. Nor are they spaces where one works with objects as they occur in 'nature'. Rather, laboratory researchers work with components, extractions and transformed versions of natural objects that are prepared and examined by what Latour and Woolgar[29] call 'inscription devices' to produce malleable images of the objects – visual images, auditory representations, mathematical expressions, electrical traces, and so on. In other words, by taking simplified but workable representations of natural objects and bringing them inside the walls of a laboratory, one can reproduce a small-scale version of outside events

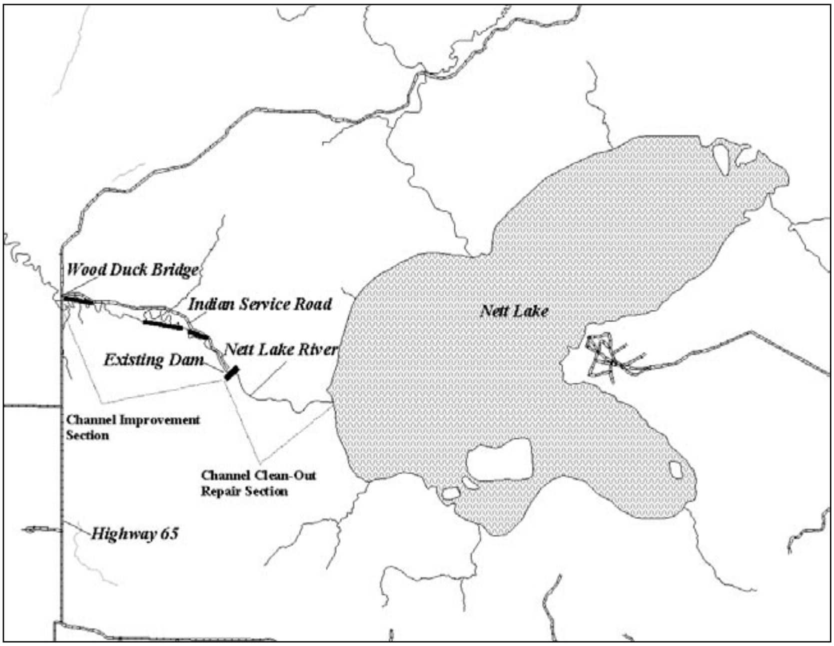

FIGURE 5. Project location showing the proposed channel improvement work both upstream and downstream from the dam. Notice the large meanders in the channel downstream from the existing dam.

and examine them at leisure. Laboratories can also scale-up events. Thus, in a laboratory, one can examine the effects of tons of water a hundred times more quickly than the Nett Lake River could create such circumstances in the real world.[30] Instead of a separate laboratory, TKDA used the TR-20, HEC-2 and DAMS-2 computer simulation models [31] to reproduce selected components of the Nett Lake watershed. These models allowed the firm to reduce the watershed, which encompassed over 138 square miles (88,510 square acres) to the size of a standard computer screen. From air-conditioned offices in St. Paul, the engineers could thus test theories about the river, its watershed and the stop-log dam.

The firm conducted two assessments.[32] First, they used the TR-20 model to investigate rainfall events over 10, 25, 50 and 100 years to determine watershed responses and any restrictions to water flow. Results for peak discharge were then input to the HEC-2 model to analyse restrictions in the river channel. These simulations revealed a number of factors causing flow restrictions,[33] particularly the high degree of meandering. From the old dam to the Wood Duck Road Bridge (Figure 5) river flow travelled four miles over a straight-line distance of approximately two miles. The flatness of the channel, its irregular cross-sectional shape and fallen trees also constricted water flow. These combined factors and their effect on water flow, the firm concluded, explained the decline in wild rice in Nett Lake. Under these conditions, the firm argued, Nett Lake would maintain high water levels even in dry years.

The second assessment, using the DAMS-2 model to examine whether the stop-log dam controlled lake levels, suggested that the stop-log dam was not working as intended. As the firm put it, 'in this [restricted] condition, no matter how many stop logs are removed or how long the dam spillway is, the dam has almost no effect on lake levels. We removed the dam from our mathematical model of the existing river and found almost no change in predicted lake elevations'.[34] The firm then recommended going ahead with its original plan of immediate channel improvements followed by dam repair in the fall.

DESIGNING THE NETT LAKE RIVER CHANNEL

In early April 1986, the firm decided to remove excess water through channel straightening, widening and grading. First priority was given to straightening the

FIGURE 6. Channel straightening by cutting a meander. Photo courtesy of the Minnesota Department of Natural Resources (MNDNR).

river from the dam to Wood Duck Bridge. Eliminating nine meanders (Figure 6) reduced the flow length from 4.0 miles to 2.3 miles and increased the channel slope by 75 per cent. To further reduce flow elevation at the dam, TKDA suggested cutting a channel to create uniform depth and increased slope. The firm analysed four alternatives (80 feet wide and 0.05 per cent slope, 80 feet wide and 0.066 per cent slope, 60 feet wide and 0.05 per cent slope, and 60 feet wide and 0.066 per cent slope), concluding that any would lower the water surface at the dam, allowing it to control lake levels. TKDA recommended, and the MNDNR accepted, the first alternative. If all the alternatives would have been effective, what explains their choice?

We cannot explain this choice by maintaining that technology is applied science. Such a view not only implies that technical development provides uniquely efficient solutions to clearly defined problems, but also that social factors intervene in the technical sphere only marginally, deciding, for example, the pace of development or the priority assigned to problems. Once priority is established and problems are clearly defined, the particular configuration of a technological object is entirely determined by technical matters whose content and inner workings require no enquiry since, by this view, they embody a universal scientific 'truth'. But as we have seen, this was not the case. In the firm's own words, technically (i.e., hydrologically), the various design alternatives were equally effective. Thus, technical principles alone are insufficient to determine technical choices.

Nor can we explain this choice by appealing to another common view – that economic efficiency determines the choice among alternative designs. Although this explanation is more complex than the above view, close examination reveals its tautological character. Before one can measure the efficiency of a technology, one has to know both the type and quality of the output. In other words, economic choices are necessarily secondary to clear definitions of both the problem to which the technology is applied and the solution it provides. But in matters of technological innovation, clarity is often the outcome, rather than the presupposition of technical development. It is only in hindsight, once a particular technology has become stabilised, that one can use economic efficiency to explain the trajectory of technical development. Recall, for example, that the rationale for excavating the channel was based first on the assumption of a direct correlation between water-level fluctuation and wild rice productivity. As illustrated by the end of this story, the relationship was not that direct. Second, it was assumed that the Bois Forte Band could access a market to sell the increased amounts of wild rice expected to be produced. This presumption was also untenable, for the wild rice market was already flooded by wild rice produced in paddies.[35] Indeed, even before channel improvement work began, Bois Forte Band members could not market their entire harvest. TKDA's chief engineer for the project recalled, 'at the time the project started, the [The Bois Forte] had wild rice stored all over the place. [Apparently] they were unable to sell it'.[36] What then explains the choice among the alternative designs? The engineers' assumptions about the entities comprising the world into which they planned to insert the new river channel? The behaviours of the natural environment and the Bois Forte people? Let us examine each in turn.

In the 1980s, except for the immediate area of the Bois Forte community, most of the Bois Forte Reservation was covered either with wetlands encompassing 30 per cent of the Nett Lake watershed and completely surrounding the lake or second- and third-growth forests. These natural characteristics concerned TKDA engineers. Their first study had linked fallen trees to water-flow restrictions. Further, dams built by the large population of beavers in the area had occasionally flooded roads and forestland and choked tributaries of the lake. How could the firm prevent these flow restrictions? To answer this question, TKDA's chief engineer and project leader examined the channel improvement alternatives, eventually choosing the plan with the widest bottom width (Figs. 7 and 8). As the chief engineer explained,

> the channel downstream is much larger than it needs to be hydraulically. I calculated flood flows and said we need a 40-foot wide channel. I talked that over with MNDNR [the hydrologist] and we decided to make the channel twice as big knowing over time the trees are going to come in and fill it and what not. By making it twice bigger, we also thought that we will discourage beavers from constructing their dams. So that forty years from now it will still work. That was our concern. Over time mother nature is going to reclaim that channel but there will be this large flood plain that will still carry the water for us. I talked this over with MNDNR and they basically said that, you know, your marching orders are make this thing work and do it within budget and if we have some budget leftover let's do this. So that was over constructed for that reason. In fact, that is one of the reasons you go out there and you see this huge thing and trickling water.[37]

The two engineers gave similar consideration to channel slope, knowing that over time sediment would accumulate in the channel and reduce the functioning of the dam. To avoid this problem, they inscribed in the channel design plan their assumptions about the origin of the lake and the channel and their prediction of future sediment movement. As TKDA's chief engineer put it:

> We dug a fairly deep channel. The thinking we had was that over time it [sediment] is going to fill. You can't stop that. But [we] over dug it both upstream and downstream of the dam so that it will take a long time [to fill the channel]. Also, in a lake like that most of the sediment is going to drop out in the lake. I don't think the channel was ever dredged into the lake like we did. And so our thinking was [because] we have made a flow path for the water, the velocity will be higher in there and it will kind of clean itself up a little bit. And that cleaning happens in the spring flood and it won't happen in any other time of the year. So, how fast it will come back, I don't know, you can make some educated guesses. But

FIGURE 7. Nett Lake River channel before improvement, the width ranged from 20–40 feet. Photo courtesy of the MNDNR.

FIGURE 8. Nett Lake River channel after improvement, the width is 80 feet. Photo courtesy of the MNDNR.

> I think they have got several years before that becomes an issue. But inevitably it will. We cut something deep, I think, it was maybe 8 feet deep out into the lake to the point where the channel we cut met the bottom of the lake. And so I think that will help with that issue [sediment accumulation].[38]

If the aim was to minimise channel obstruction by natural entities, over-constructing was not the only choice. For instance, regular channel maintenance could have kept the channel free from sediment, fallen trees and beaver dams, an alternative that would have met project objectives, cost less and had less environmental impact. However, the prevailing thinking was that the Bois Forte lacked the organisational, material and financial resources to undertake maintenance work. As TKDA s chief engineer recalls,

> [over-constructing] was one of the things we had to do. I talked this over with MNDNR and they said that this is one-shot money; we will never be able to fix it again. They [Bois Forte] wouldn t have the resources necessary to do a maintenance work on it. So, they agreed that the outlet issue is so important that to keep this [channel] going for a long time we needed to have that ability.[39]

The hydrologist made a similar comment:

> We knew that it would be virtually impossible for the state [MNDNR] to go in and spend new money in the future maintaining it. There has been little or any maintenance on the stop-log dam since it was constructed. It is kind of what we expected would happen to the new dam. So, I allowed the over-construction of the channel.[40]

Thus, the final channel design was not selected because of its technical or economic superiority. Rather it was based on the relations the engineers assumed between the life of the channel and the future behaviours of natural entities and the Bois Forte.

UNDERSTANDING WILD RICE: THE DESIGN OF THE DAM

The decisions on channel shape and size drove decisions regarding other structural elements of the dam such as spillway dimensions, height and weir length. But the engineers faced other design difficulties, particularly those related to wild rice. How much water did wild rice need at its germination, leaf floating, flowering and maturity stages? What was the historical coverage of wild rice? How many acres of the lake could be brought into wild rice production? Without such knowledge, it was impossible to set the minimum wall size and sills for the new dam. Moreover, historically, frequent flooding of the lake had helped control competing vegetation. This meant that the engineers had to design a dam that satisfied at least three requirements. It had to regulate water level throughout the lifecycle of wild rice, restore wild rice acreage to historical levels, and control competing vegetation by mimicking historical flooding. In short, the dam had to act like the natural environment but in a more predictable fashion.

To determine the water level requirements of wild rice, TKDA had hired a wild rice expert from the University of Minnesota. The Bois Forte leaders, however, blocked the scientist,[41] insisting that their elders had knowledge accumulated over hundreds of years and could provide any information that the project engineers might need.[42] Although the project manager did not doubt the elders' expertise, he knew that they could not provide the type of information the engineers needed to design the dam. They could not, for instance, answer questions about the water requirements of wild rice in feet or metres, data absolutely necessary to determine the appropriate dam crest elevations.[43] However, the hydrologist also did not want to aggravate hostility between the state and the band, potentially halting the project. Accordingly, he dismissed the scientist and authorised the TKDA to work with the Bois Forte Band to determine the crest elevations.[44]

Several meetings with various members of the Bois Forte resulted in quick consensus on two points: the historical wild rice distribution and the desired rate of water level increase during rice growth. All agreed that, except for a few places, the lake was once covered with rice. They also agreed that the water level should be raised slowly during rice growth. On other points, specific information and agreement were unobtainable. No one, for instance, could say with any certainty the minimum water level depth necessary for wild rice and controlling competing vegetation or the maximum depth the rice would tolerate.

The rate and timing of water level draw-down during the dormant season (i.e., winter) also created disagreement. Some Bois Forte members contended that very low levels in winter would allow the lake bottom to freeze, guaranteeing an appropriate dormancy temperature for rice seeds and enhancing germination. Under this condition, they insisted, spring ice break-up would uproot and remove weeds and, in doing so, stir the muddy alluvial bottom, thereby cultivating the rice beds. Others disagreed, arguing for high water levels during winter that would be released during spring break-up. This, they claimed, would increase water movement prior to and during germination, which is crucial for the germinating wild rice seed. The engineers, unable to take sides on the controversy, endeavoured to design crest elevations that could test both theories. As TKDA's chief engineer recalls:

> The Band had divided ideas of how we should operate. We had a number of meetings talking about different approaches…much of this design was [an outcome of] discussions on how to improve the quality [of wild rice and so on]. It was pretty clear early on that no one has the answer [as to] what will make this lake better. So, what we try to do is to give them the broadest possible range – 2.5 to 3.00 feet of swing in the elevation of the lake.[45]

Minimum crest elevations could have ranged between 1274.7 and 1277 feet above sea level, but the engineers chose 1276 feet. Having lost the services of the university scientist and unable to obtain specific information from the Bois Forte, the engineers turned to the scientific literature for help in setting the minimum crest elevation. They found a study indicating that wild rice yields and plant numbers drastically decrease if the bed water falls below ten inches. Taking this measure and the bathymetric map of the lake as a starting point, the engineers approximated the minimum crest elevation as 1275 feet. While this lower crest elevation would allow them to test the hypothesis of lower winter lake levels, it would have left more than 3000 acres of the lake surface with no water (Figure 9), a situation that was not acceptable as everyone agreed that

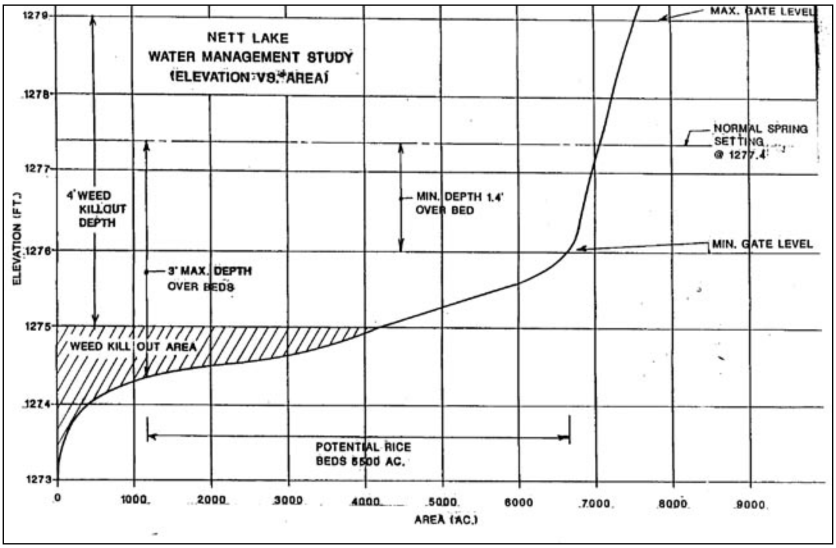

FIGURE 9. Effect of the new dam on wild rice coverage. Source: Proposed Nett Lake River channel improvement (TKDA, 1986).

rice had once covered the entire lake. Raising the water elevation to 1276 feet would potentially increase wild rice acreage to 6700 acres.

However, would 1276 feet be too high, preventing sunlight from reaching wild rice seedlings? The engineers again looked to the old engineering report on Nett Lake, which stated that for perfect wild rice propagation water depth should not exceed 3 feet ,[46] but that good wild rice stands have been observed in water depths of 7 inches . This suggests that setting the minimum crest elevations anywhere between 1274.7 and 1277 would have made no difference in wild rice growth. In fact, the earlier engineering report strongly suggested setting the elevation at higher values. However, the engineers chose 1276 feet, which they believed would both increase rice acreage and allow them to test the water-level hypotheses.

Deciding the upper crest level involved similar negotiations. The upper crest elevation could have been anywhere above 1277.4 feet, but the engineers chose 1279 feet. Assuming that three feet was the best water depth for wild rice production, the engineers needed to raise the water level by 16 inches, resulting in water elevation of 1277.4 feet. But this raised four problems. First, while some band members insisted on the importance of high water levels during spring break-up, an upper crest elevation of 1277.4 feet would not allow for testing of this hypothesis. Second, although three feet may be the 'perfect' water level for wild rice, the plant grows four or five feet above water level. Three feet of water would not support tall rice plants. Third, that upper crest elevation would not provide enough water to kill competing vegetation in most of the rice beds (Figure 9). The engineers decided (for reasons that are unclear) that at least four feet of water needed to cover the rice beds to control weeds. Finally, harvesting wild rice by canoe in areas of shallow water would have been impossible. A slightly higher crest, 1279 feet, met many of the constraints, providing water within wild rice requirements, controlling competing vegetation, and providing sufficient depth for harvesting in shallower beds.

The designers also had to decide whether to use stop-logs or controllable weirs for the dam gate. Technically, both were equally effective. A stop-log gate would have been far cheaper to construct, but it also would have been difficult to operate. As the Bois Forte Band member responsible for operating the stop-log dam recalls, 'operating the dam requires many people to remove or add stop-logs. Moreover, during the spring ice break-up, when water level control is crucial, it is sometimes necessary to remove all stop-logs, particularly if it has rained, to lower the water. This required getting into the river, which is very cold during that time'.[47] TKDA's chief engineer had similar concerns: 'stop-log dams are cumbersome to use and difficult and what you end up doing is not operating them. At a critical time when a log needs to be pulled out in the spring to start letting the flood go it is cold, it is miserable and it is nice and warm in your house and you won't do it. I wouldn't do it. My experience is human nature doesn't like to go out there in the middle of the cold and wet and drag these logs that are crusted with ice and all that. The logs leak typically. So, what we tried to do again was to come up with the system that would work. It was simple and would provide them the control they wanted and that meant getting rid of the stop-log system'.[48]

Another problem was how to raise and lower the controllable weir. The issue was whether to operate the gates remotely (by either portable hydraulic or electric operators) or manually and mechanically. The latter, although expensive ($20,000), was decided to be the best alternative because it saved time and allowed for quick gate operation in the case of an emergency.

STABILISING THE NETT LAKE RIVER: CONSTRUCTING THE DAM

The engineering firm, having first materialised, controlled and tested the Nett Lake river inside its computer models, was now ready to 'tame' the real river by converting the design specifications from paper into concrete and metal. To do that, the engineers had to assemble new groups of people and materials, arranging permits for disposing of more than 245,000 cubic yards of dredged materials, hundreds of workers, various equipment, and an organisational structure for coordinating this massive earth-moving undertaking.

In May 1986 the TKDA submitted an application to the Army Corps of Engineers for disposing of the dredged material.[49] On 2 June the Corps of Engineers issued the public notice.[50] Within the 20 days allowed for filing a complaint, two new actors appeared to seriously challenge the project: the United States Fish and Wildlife Service (FWS) and the Minnesota Pollution Control Agency (MPCA). The FWS conducted a field review of the site and identified several wetland habitats, including palustrine emergent, scrub–shrub and forested wetlands, that could be affected by the project,[51] and which provided valuable breeding and migratory habitats for various wildlife such as mallard duck, wood duck, ring-necked duck, great-blue heron, kingfisher, spotted sandpiper and numerous songbirds. The Service argued that the permit be given only if mitigating measures were taken to minimise the adverse impact on wildlife.

The MPCA, on the other hand, waived certification of the project provided that it was conducted in accordance with applicable requirements of the MNDNR.[52] Not withstanding, the MPCA expressed concern about the project's potential impact on ecologically significant peatlands and rare plant species. Accordingly, the agency requested an extensive environmental review, in accordance with section 404 of the Clean Water Act, to determine if there were alternatives to the proposed project. If the alternatives could not address, mitigate or avoid the potential impact of the project, the MPCA insisted, the permit should be denied. Although both objections posed serious challenges, neither went anywhere. The Band's recognition as a federally recognised sovereign state helped neutralise the objections and forced the Corps of Engineers to issue the permit without requiring even minor modifications to the project design.[53] As the project hydrologist explained,

> If you were to propose that [kind of project] anywhere else in the state either then or now, it wouldn't have happened. I mean, environmentally my own agency would have lined up council meetings and what not, you couldn't do a project like that. But nobody voiced any concern about that. They [Bois Forte] didn't need to

> apply for Federal Corps of Engineers permit, section 404 permit; everybody let that one go through without a lot of concern. I suppose they were worried about the same thing – if they put their head up they would become a target. You know, that is the way things work. That is the way that one worked. [54]

TKDA's engineer similarly commented,

> We had some issues with the Corps of Engineers, but they understood. Technically, this [the project] had to have the Corps of Engineers permit but they also told me this is just a formality. In fact, the Band legally could have done all this work without any permit. Later on, when things all look like this some guy from FWS flew over and I got a call the next day from this guy, I have never been cursed at so much in my whole life – what are you doing, you don't have permits, you don't have this; you don't have that, we [FWS] certainly never heard of anything about this project, you are just raping the wild out there. And I said, well, I am sorry but [advised him to] talk to my contact with the Corps of Engineers who I had work with. This guy was finally told, look you can sue the Band saying that they shouldn't be doing this and so on. You will go to court, you will lose, [so] just let it go.[55]

TKDA faced other problems as well, including numerous changes in the channel and dam designs, as well as legal, technical, organisational and economic issues that in the interests of space cannot be presented here. However, by October 1986 all of these problems had been resolved and the construction went ahead smoothly.

THE BIRTH OF THE DAM

On 1 October 1987, the newly completed dam was handed over to the Bois Forte Band. The newly reconstructed dam modified, once again, the relationship chain between the Bois Forte and the wild rice ecosystem. Thanks to the dam, the Bois Forte no longer had to depend solely on the weather to continue their age-old tradition of harvesting wild rice. They no longer had to worry about fallen trees, beaver dams and sediment accumulation in the river channel or perform the arduous task of operating stop logs. The dam replaced the backbreaking work of many people with an easy job requiring only a single person.

The dam altered the Bois Forte community, the wild rice beds, the lake and the river. For the Bois Forte, regulating the water level became a new practice in their cultural repertoire of wild rice cultivation. Wild rice yields changed from erratic to dependent on careful monitoring of the water level. Nett Lake River no longer flowed free. The lake did not rise and fall according to natural patterns, nor did it produce as it had in the past. It became, a 'pond' for selectively growing wild rice and suppressing other life such as macro-invertebrates and fish.

Whereas we have followed a long chain of people, natural entities, products, machines, tools and money so far in our story, only three elements now remain: the dam, its users, and the reconfigured Nett Lake wild rice ecosystem. That is, what began as an imbroglio of politics, nature, culture, economics, science and technology became clearly demarcated as the reconfigured wild rice ecosystem, the user (Bois Forte Indians), and the new dam mediating the relationship between the first two. The relation between the three appeared to have stabilised. But if this were the case the controversy regarding its benefit that emerged later on would not have happened. The dam would have worked as designed. How then do we account for its failure?

As described above, much of the engineers' work involved making assumptions about the world the dam would be inserted into and inscribing these assumptions into the dam design. Accordingly, when confronting the dam, the Bois Forte Indians did not leave their world of meaningful social relations and enter a world of mute objects. Rather they confronted meaningful social relations articulated in different materials – steel, concrete and gravel. In other words, the dam served as a lieutenant of the engineers' wills, passions and assumptions of the behaviour of heterogeneous entities, including the Bois Forte Band members and the Nett Lake wild rice ecosystem.

But what if there is a discrepancy between assumed and real behaviours? What if, for instance, the Bois Forte Indians did not play the role envisaged for them by the dam designers? What if the three-foot water depth assumed to kill weeds did not work or the relationship between water level control and wild rice productivity did not materialise? If these happen, it is as if the dam was never built, as if it was a figment of the imagination, for it is in the confrontation between the behaviour of the entities assumed in the dam design and those that exist in practice that the boundaries of the dam, the Bois Forte, and the Nett Lake wild rice ecosystem become stable and a matter of fact. That we can point to the lake, the river, the dam and the Bois Forte Band members as distinct categories does not mean that the boundaries among them are stable. Rather, these divisions should be seen as a *consequence* of the interactions between, on the one hand, the projected user inscribed in the dam and the real user and, on the other, the projected behaviour of the wild rice ecosystem inscribed in the dam and the real wild rice ecosystem.

This means that if we want to understand the dam and its role in stabilising the heterogeneous alliances that brought it into being and that it holds in place, we cannot limit our analysis to the engineers' point of view. Neither can we limit our investigation to users' perspectives or how they have used or abused the dam. Nor can we assume that the Nett Lake wild rice ecosystem would have behaved as predicted even if the engineers had had much more thorough knowledge. Instead, we have to move constantly among the technical, the natural and the social, as well as what is assumed and inscribed in the technical content of the dam, its real user, and the real wild rice ecosystem. This can only be done by looking at what happened to the dam after it was completed. Only by examining this confrontation can we understand why the dam failed or, put differently, why the divisions separating the dam, the user, and the wild rice ecosystem did not stabilise.

THE FALL OF THE DAM

To understand what happened in the confrontation between the real user and the user inscribed in the dam design, let us start by recalling some characteristics of the user assumed by the engineers. The designers took for granted that Bois Forte residents would be unable to do maintenance work. Accordingly, they over-constructed both the channel and the dam. They also assumed that Band members would likely not want to use stop-logs to operate the gates and manage water levels. Thus, they designed a controllable weir gate. Third, the engineers decided that the gates would not be operated properly if they installed only a hand crank requiring the efforts of many people to raise or lower the gate.[56] Instead of delegating this work to Bois Forte residents, they delegated it to a hydraulic motor. These decisions were intended to ensure that the dam would work under all circumstances. Indeed, the engineers wanted such a fail-safe dam that they not only made gate operation the only point of contact between the dam and the user, they also designed features to prevent illicit use of the dam. First, they designed a portable manual crank and hydraulic motor that would stay with the operator, not with the dam. Second, they built chain-link fences to prevent access to the walkway and hoists.

While the engineers delegated certain responsibilities to non-human entities, they also delegated other responsibilities to the user, including a series of tasks for calculating the appropriate dam gate settings. The engineers prepared a detailed water management plan that required tracking of rainfall and snow pack amounts every week from the first of March until the spring melt began. Two sites close to the two major tributaries of Nett Lake were selected and appropriate measurement equipment was purchased and installed. The plan also provided detailed guidelines on how to calculate the appropriate gate settings for each growth stage of the wild rice plant. Calculation parameters for establishing gate settings included weekly evaporation rates, outflow, runoff, lake volume and discharge.

Thus, the dam (and behind it the engineers) defined the user – a user the engineers assumed would operate the dam in the approved way – by three aspects. First, it was assumed that user lacked certain competences, such as performing channel and dam maintenance work or operating stop-logs. Thus, to ensure dam functioning under all conditions, it would be better to delegate work to various non-human entities. However, second, the user was expected to have previously undeveloped competences such as tracking and recording changes in rainfall and snow pack and calculating gate settings. Finally, the user was defined by physical exclusion. Only a user with access to the chain-link fences, the hydraulic motor or the manual crank, and a vehicle to get to the dam could operate the dam.[57] The user was denied access to the inner workings of the dam, for the only point of contact between user and dam was the raising and lowering of the gates. In case of breakdown or maintenance, the user was expected to rely upon dam experts. In other words, as long as the dam was in place, experts would be part of the social relations in the management of wild rice.

So it was that the engineers had not merely engineered the river, lake, steel and concrete but also a user with specific behaviours, competences and motives that were articulated in the body of the dam. Many of the design decisions made by the engineers can be seen as delegating what work should be done by the user and what work should be done by the various non-human entities that they assembled and juxtaposed. Put another way, they changed some of the characteristics of the river, the Nett Lake wild rice ecosystem and the dam in relation to the Bois Forte residents, and vice versa. This important point shows that we could not have understood the dam and its role in stabilising the heterogeneous relations only in terms of its material components, i.e., if we had taken the dam as a mere tool. For, as we have already seen, its technical content is full of engineers, politicians and lawyers, mixing their wills and their desires with those of steel, concrete, beavers, wild rice, trees, sediment and water.

We also could not have understand the dam if we had taken the mirror image of the materialist position – social constructivism. Social constructivists would consider the dam to be nothing more than a *congealed* outcome of the negotiations, conflicts and compromises of human actors. But the dam is not only real, obdurate and physically localised; it also remade social relations in a new way. More importantly, it offers endless possibilities of action that do not precede its construction. The dam, for instance, has increased the flux of questions that can be addressed regarding the relationships between wild rice and water, weeds and fish. In short, the dam is obviously not a human thing, nor is it an inhuman thing that can be mastered. Rather, it offers a continuous but irreducible exchange between what the engineers inscribed in it and what it prescribes to the user and the heterogeneous entities that it holds in place.

Did the Bois Forte Band members come forward to play the role prescribed to them? Yes and no. Yes because from the day the dam was put in place to the writing of this essay, they frequently went to the dam and lowered or raised the gates. No because, to this day, they have not tracked rainfall and snow pack to calculate the appropriate gate settings.[58] There are many reasons for this. The first is financial. Until 1990, three years after the construction of the dam, the Bois Forte Band did not have the money to hire and train someone to do measurements and calculations. Thus, they could not systematically decide when and how much to raise or lower the gate. The financial problem was resolved in 1990 when a Conservation Officer was hired using funds from the Bureau of Indian Affairs (BIA).

However, the hired person neither had nor received training in how to track and record rainfall and snow pack data or in how to use this information to calculate appropriate gate settings. Moreover, he was also responsible for all issues related to the use and conservation of BFIR natural resources. For instance, he had to patrol the BFIR almost daily to prevent illegal hunting and trapping, a job so time-consuming that he could not do the dam-related tasks. Accordingly, dam operation continued to be haphazard until 1994.

In that year, the Bois Forte Band, using funds from Administration for Native Americans (ANA), hired an aquatic biologist and a technician. With the hiring of the biologist and the technician, the Bois Forte Reservation established a new division responsible for the management of Nett Lake, including the dam. In subsequent years, this division has grown substantially both in personnel and the scope of management and research activities aimed at enhancing wild rice production. However, systematic operation of the dam gates still has not occurred. Despite the keeping of rainfall records and the installation of highly sophisticated measurement equipment, none of this information is used to determine the appropriate gate settings. One reason for this is the failure of other entities to play the roles defined for them by the engineers.[59]

One such entity is wild rice itself. Recall that the engineers and Band members had assumed that regulating the water level would increase wild rice productivity. However, although the dam eliminated recurrent flooding in Nett Lake, the projected increase in wild rice productivity did not materialise. A decade after completing the dam, many Bois Forte community members saw productivity as fluctuating, while others believed that productivity had actually declined. Invasive weeds have also not acted as expected by the engineers, and many in the Bois Forte community attribute the increase in invasive weeds and other lake maladies to the dam.

Such mismatches between assumptions and the real wild rice ecosystem put into question the chain of processes that led to the dam construction. The dam was built on assumptions of the relationship between water level changes and rice productivity and that regulating water levels could lead to increased wild rice productivity. Since no one knew the exact nature of this relationship, the dam was designed to test the effects of a wide range of water levels. However, because the Bois Forte did not play the role envisaged for them, it has not been possible to determine the precise relationship between wild rice and changes in water level.

Indeed, by the year 2000, the BFIR had submitted several proposals to various funding agencies for either removing or modifying the dam. One such proposal was recently submitted to the United States Department of Agriculture (USDA). The proposal, in addition to showing the reluctance of the Bois Forte to act as the engineers had imagined, also illustrates that wild rice and invasive weeds did not behave as assumed by the engineers and that other entities (e.g., fish) had been ignored. The proposal requested over half a million dollars to 'initiate and support a two-phase evaluation and remediation program' that would include the possibility of either removing or modifying the dam. The Bois Forte Reservation did not receive the funding it requested for evaluating the dam. But the BFIR has purchased, at the cost of half a million dollars, a weed harvesting machine to mitigate the effect of weeds on the wild rice ecosystem.

It remains to be seen what the future holds for the dam, wild rice and, with it, the cultural identity of the Bois Forte Indians.

CONCLUSION

This paper has told a story of the rise and fall of the Nett Lake dam, a story informed by the interdisciplinary field of science and technology studies (STS). One lesson is that the dam was not an outcome of a 'rational' endeavour driven by scientific or technological logic. That is, it was not the application of a predefined hydrological principle to a predefined problem, but a product of their coevolution, contingent upon heterogeneous factors whose composition was impossible to determine beforehand. As such it represents a further example for unlearning not only the belief that the inner workings of dams, their designs and their evolution are driven by 'economic efficiency' or by some 'value-free' scientific or technological logic that can be explained without reference to the heterogeneous factors that stabilised their design, but also the view that dams are neutral tools devoid of any meaning.[60] As this case demonstrates, the dam not only embodied and concretised particular social configurations but also (re)made them. Its design, construction and use involved changes to the social organisation of wild rice management within the BFIR – changes that were not the automatic consequences of building the dam, but were themselves engineered in the face of conflict and resistance.

Second, the case also shows that not only the social organisation of wild rice but also the rice ecosystem itself were engineered simultaneously with the dam. This suggests that the relationship between the dam and the wild rice ecosystem is too intimate to be handled by positing their relation in terms of interaction. For this not only 'naturalises' the distinction between the dam and the wild rice ecosystem, but also assumes that it is possible to identify and attribute a clear, causal connection between the two, an assumption that is difficult, if not impossible, to sustain in a case in which changes occur simultaneously. Thus, not assuming a categorical distinction between technology and the environment may allow for more sophisticated analysis of the relationships between dams and the environments they inhabit and may transform the very way we think about technology–environment relations in a broad range of areas.[61]

Third, the story of Nett Lake dam has important implications for understanding interdisciplinarity. As we have seen, in the design stage, the characters of the dam, the user and the environment were greatly debated. What would the dam look like? What properties of the natural environment should be inscribed in it? What should be left untouched? What changes did the environment have to undergo for the dam to work? How would the dam be used? What competences would its users need? What maintenance would it require? Indeed, at the design phase, when the hydrologists and engineers were expected to engage in purely technical questions, they instead transformed themselves into sociologists, historians, moralists and politicians. In doing so, they challenged the very disciplinary frameworks and boundaries within which environmental issues are discussed. Clearly, addressing environmental problems cannot merely be about bringing in experts from different fields, but rather recognising that experts work in all of these fields simultaneously. This points to the possible contribution of students of human–environment relations in overcoming the extreme specialisation that has left our main disciplines hemiplegic: scientists knowledgeable of specific aspects of the world but estranged where humanity is concerned and, conversely, humanists knowledgeable about culture but estranged from the natural world.

Finally, if engineering the dam involved the simultaneous engineering of the social organisation of wild rice management, and if it also involved the simultaneous engineering of the wild rice ecosystem, then it follows that the relation between 'traditional' societies and modern expert systems must be rethought.[62] As the literature on science studies has shown,[63]the power of scientific knowledge over 'local' knowledge is founded not on the commonly accepted idea that the former represents 'truth' and the latter represents 'belief', but on the former's ability to attach itself with cascades of stabilised forms of machines, instruments, concepts, disciplined practices, social actors, and so on without the slightest attempt to differentiate among them. In other words, expert knowledge is local knowledge through and through, subject to politics, culture, or the environment. This means that just as legal and cultural institutions cannot be readily transferred to new social contexts because they are so intertwined with other aspects of the societies in which they originate, the same is true with the transfer of technology. Such broader reflections on the technology–environment–society nexus may contribute to designing projects better able to improve human welfare while minimising environmental degradation.

NOTES

[1] Much of this literature is informed by the idea that technology is not only autonomous with respect to its social and environmental contexts, but also that social and environmental changes are a function of technological innovation. Ecologists have written extensively

about environmental changes caused by water control structures (Baxter 1977; Sharma et al. 2005). Social scientists have highlighted the ways in which dams have led to human displacement (Dominique and Senecal 2003), community control over water (Parveen and Faisal 2002), health problems (Leonard and Schudder 1999) and exacerbated gender divides (Yan Tan and Potter 2005). Economists have concentrated on the link between social and economic development and dam building (Altinbilek 2002), while students of international relations have illustrated the links between dam building and national debt (Isaacman 2001) and water security (Gleick 1993). For an excellent overview of the environmental, social and economic impacts of dams see the report by the World Commission on Dams (WCD 2000).

[2] This perspective is in the tradition of the *social shaping* of technology, which has its roots in post-empiricist philosophy of science and the idea that technologies do not develop as the result of some inner logic but rather as a function of complex social, technical, economic and political factors. For an excellent review and applications of this view, see MacKenzie and Wajcman 1985, Bijker 1999, and references therein. Studies that apply this approach to dams include Shallat 1994; Jackson 1996; Stevens 1988; Wolf 1996; Schneider 1996.

[3] For works that more or less hold an interactive view see Scarpino (1985), Palmer (1991), Pitzer (1994), Dietrich (1995), and White (1996).

[4] Latour 1993.

[5] Kidder 2000.

[6] The field of STS is vast and involves many disciplines, including philosophy (Chalmers 1990; Hacking 1983; Hess 1980), sociology (Barnes 1977, 1995; Bloor 1991), history (Shapin and Schaffer 1985) and anthropology of science (Knorr-Cetina 1981; Knorr-Cetina 1999; Latour 1988, 1993; Latour 1986). For a survey of the development of the philosophy, see Kuhn 1970, Feyerabend 1975 and Suppe 1977. For an excellent review of work in the sociology of science see Shapin 1982. For more recent developments in STS see Pickering 1992, and for a general introduction to the science studies literature see Jasanoff et al. 1995. For a comprehensive review and critique of this body of literature see Sismondo 1996 and Hacking 1998.

[7] Bloor 1991.

[8] Callon 1986.

[9] The reservation was established by a treaty with the United States government in 1866. The band has an enrolled membership of nearly 2,600 persons, of which some 550 live on the reservation. Except for the village at Nett Lake, forests, water and wetlands cover the entire reservation of approximately 103,000 acres.

[10] Warren 1984.

[11] Vennum 1988.

[12] Regan 1928.

[13] Several Bois Forte elders told me that in the 1920s their parents used to build temporary dams during dry years when the water level was too low for canoeing. This may be true, but I failed to find documentation of such practices. No material available in the archives of the Minnesota Historical Society or National Archives Center in Kansas City, Missouri, mentioned such practices. Even the annual reports of federal agents residing at Bois Forte, which cover every aspect of Bois Forte life, made no reference to temporary dams. Nor did the various engineering reports prepared during and after the construction

of the stop-log dam. This may simply indicate an oversight by those who prepared these documents. In any case, due to insufficient information, I could not investigate how these temporary dams, if they existed, were built, maintained and used.

[14] Walker, H. 1938, cited in Minnesota Department of Natural Resources (MNDNR). 1977.

[15] Department of Conservation, Division of Water Resources & Engineering memorandum (28 May 1943).

[16] Moyle, J.B. 1957. Report on water level and wild rice in Nett Lake, Bois Forte Reservation.

[17] Bill S.F. No. 1472 appropriated money for construction of a dam on Nett Lake in Koochiching County.

[18] For ease of reading, I present the story in a linear fashion starting with the constitution of a new social relationship and moving towards the transformation of the Nett Lake wild rice ecosystem and dam building. However, it is important to remember that all three were being forged simultaneously.

[19] The bill stated '[It is] appropriated from the general fund to the Commissioner of Natural Resources [i.e., the MNDNR) $1,200,000, or so much thereof as may be required, for the purpose of constructing a dam and appurtenant regulatory devices or structures to regulate the water level on Nett Lake in St. Louis [this is a mistake; the dam is actually in Koochiching] county'.

[20] As one MNDNR staff hydrologist of the time explained, 'that was funny. Because usually, if there is a capital proposal that goes in to reconstruct a dam some place, we are very much involved in putting together that capital proposal, lobby it through the legislature and take the legislation through the various steps and answer all kinds of questions about it. This particular time we did not know about this appropriation or did not know much about it until it was passed. It was done independently and was led by a powerful legislator'. Interview by the author, 7 September 2000. Tape recordings of this and other interviews are in the author's possession.

[21] Although the grant was for the Bois Forte who lobbied for it independently, they could not receive the money directly from the state because state money can only be spent by a state organisation. The MNDNR is a state-authorised agent for natural resources so the money was appropriated to it.

[22] This hostility relates to hunting and fishing rights on land ceded by the Chippewa to the United States government during the treaties of 1800. For a historical and legal analysis of this issue see Clinton et al. 1991.

[23] Architect/engineer agreement between Bois Forte Reservation Business Committee and Toltz, King, Duvall, Anderson (TKDA) and associates, incorporated for the improvement of the Nett Lake dam, 10 March 1986.

[24] State of Minnesota, Office Memorandum from the hydrologist to MNDNR Bureau of Financial Management dated 27 March 1986.

[25] TKDA chief engineer. Interview with author, 12 September 2000. According to his recollection, the first thing he did was to call an information-gathering meeting with the Bois Forte Reservation Business Committee (BFRBC), the DNR, and tribal members to discuss the project, various sources of hydrologic data, sources of water quality data, historic water levels, historical rice production and other topics related to the project.

[26] A handwritten memorandum dated 10 May 1985 by a MNDNR hydrology division staff member that refers to the following inadequate past studies: the MNDNR 1977 hydrology study report (see footnote 7) and the feasibility study conducted by Seaway Engineering in 1978 (see endnote 8).

[27] Here I am summarising information from various interviews and documents describing key concerns of the engineers. Main interview sources were the project manager (MNDNR hydrologist) and TKDA chief engineer. Interview by the author on 19 and 12 September 2000 respectively. Main documentary sources were a letter sent by TKDA to BFRBC on 2 April 1986 entitled 'Proposed Nett Lake River channel improvement' and a 21-page document prepared by TKDA and sent to BFRBC (April 28, 1988) entitled 'Water management plan for the Nett Lake dam'.

[28] Job No. 85071.01. TKDA Nett Lake Survey: Nett Lake River profile and cross sections, 4 March 1986.

[29] Latour 1986.

[30] The relation between laboratory techniques and scale is discussed in various anthropological studies of scientific laboratories (Knorr-Cetina 1981; Latour 1986).

[31] The intent of using the USDA Soil Conservation Service TR-20 computer model was to 1) evaluate the response of the Nett Lake watershed to rainfall events of 10, 25, 50 and 100 years, and 2) determine the size of the overflow spillway and gate opening sizes for the new dam. The US Army Corps of Engineers HEC-2 water surface program was used to help determine the extent of water flow restrictions along the Nett Lake River. The USDA Soil Conservation Service DAMS-2 computer model was used to determine the discharge capacity of the stop-log dam and to explore alternative dam improvement options, such as changing the height, weir length and sill elevation of the new dam. The proposal submitted by TKDA, entitled 'Proposal to provide consulting engineering services for improving the outlet hydraulics of Nett Lake', 27 November 1985, describes these models.

[32] Referred to in a letter dated 2 April 1986 from TKDA to the Bois Forte Reservation Business Council.

[33] Ibid.

[34] Ibid.

[35] Vennum 1988.

[36] Interview with the author, 12 September 2000.

[37] Ibid.

[38] Ibid.

[39] Ibid.

[40] Interview with author 19 September 2000.

[41] A long history precedes and explains this refusal; briefly, their rejection was based on the type of research the scientist did on wild rice. Prior to 1970, the wild rice market was solely dependent on wild rice harvested from lakes. The Bois Forte and other Indian reservations were therefore the main sources of wild rice. In the late 1960s, the Minnesota State legislature began appropriating money to the University of Minnesota to find ways of cultivating wild rice. In subsequent years, as the result of research by the university scientists, cheap cultivated wild rice flooded the market. In so doing, the Chippewa Indians lost virtually their entire hold of the industry. The University of Min-

nesota scientist hired by TKDA was one of the pioneer scientists who began the work of domesticating wild rice. Thus, the Bois Forte and other Chippewa bands in Minnesota had strong negative feelings toward the university and the scientists who worked on the wild rice improvement program. For more details on the effect of paddy-grown wild rice on the Ojibway see Vennum 1988.

[42] TKDA chief engineer, interview with the author, 12 September, 2000.

[43] For a perspective that takes 'local knowledge' seriously but that assumes a radical distinction between 'traditional' and 'modern' societies see Johannes 1989; Posey and Balee 1989 and Berkes 1998. For a critique of this perspective see Latour 1993.

[44] Hydrologist, interview with the author, 19 September 2000.

[45] Interview with the author 12 September 2000.

[46] Memorandum from CCC-ID Engineer S. S. Walker to M. L. Burns, Acting Superintendent, Consolidated Chippewa Agency, Cass Lake, Minnesota (15 September 1939).

[47] Interview with the author July 2000.

[48] Interview with the author 12 September 2000.

[49] The River and Harbor Act of 1899, Section 404 of the Clean Water Act and Section 103 of the Marine, Protection, Research and Sanctuaries Act, authorize the Department of the Army to give permits for activities that affect navigable waters in the United States, which includes the discharge and transportation of dredged or fill material. The Department first issues a public notice. Interested parties may then submit detailed written objections within 20 days and request a public hearing.

[50] Public Notice. NCSCO-RF (86-646-02). Section: (404)- Clean Water Act.

[51] Letter from United States Department of the Interior, Fish and Wildlife Service, St. Paul Field Office, to the U.S. Army Corps of Engineers, 20 June 1986.

[52] Letter from the Minnesota Pollution Control Agency to the U.S. Army Corps of Engineers, 23 June 1986.

[53] Early treaty negotiations, congressional use of the treaty ratification process, and the opinions of the Supreme Court considered Indian treaties to have been negotiated between sovereigns. For an extended treatment of this see Cohen 1982. As Cohen (1942: 123) summarises:

> the whole course of judicial decision on the nature of Indian tribal powers is marked by adherence to three fundamental principles: (1) An Indian tribe possesses, in the first instance, all powers of any sovereign state, (2) Conquest renders the tribe subject to the legislative power of the United States…but does not by itself affect the internal sovereignty of the tribe…, and (3) These powers are subject to qualification by treaties and by express legislation by Congress…

For a more recent restatement of this view see Kawashima 1969 and Kerr 1969. Historical documents associated with the Nett Lake dam also confirm this view. Among the various problems encountered in getting a contractual agreement signed between the state of Minnesota and the Bois Forte include: (a) whether a MNDNR waters permit will be required for the work, (b) whether the state environmental review requirements apply, and (c) whether any federal environmental permits or reviews is required. According to the letter sent by the Bois Forte lawyer to the Special Assistant to the Minnesota Attorney General, the lawyer argued (citing the Indian Reogranization Act (25

U.S.C. 476) that the Bois Forte need 'no approval [from state or federal agencies] for the proposed project'.

[54] Hydrologist, interview with the author, 21 September 2000.

[55] Interview with the author, 12 September 2000.

[56] For example, it takes 20 minutes of manually cranking the gates to lower or raise them only two inches.

[57] The road was rebuilt to access the dam and is approximately 42 km from the Nett Lake village.

[58] BFDNR Water Division Director, interview with the author, 29 March 2000.

[59] This and what follows are from my own observations of the day-to-day management of the BFDNR for almost nine months.

[60] Bijker 1992; Bijker 1999; Mackenzie and Wajcman 1985.

[61] Callon 1986; Latour 1988; Latour 1999.

[62] Latour 1993; Goody 1977; Hutchins 1995.

[63] See for example Barnes 1977 and MacKenzie 1981 in the sociology of scientific knowledge (SSK) that supports this view. See the work of Lynch (1985), Pinch (1986), Traweek (1988), Martin (1991), Hess et al. (1992), Downey (1998) and Rabinow (1996) for anthropological studies of scientific knowledge. For an excellent general review of anthropological studies of scientific laboratories see Knorr-Cetina 1995.

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