Therkildsen Field Station at Emiquon: Data Management Beginning in 2013

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Outline

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Abstract

Attention to data management at Therkildsen Field Station at Emiquon (TFSE) began in 2013. The University of Illinois Springfield built this research field station by the Illinois River between Lewistown and Havana on land owned by The Nature Conservancy called Emiquon Preserve. TFSE became a member of a partnership of university, government, and non-profit organizations that supports research activities including floodplain restoration. An ethnographic investigation studied data practices and the introduction of data management at the station as well as at Emiquon Preserve. Site history and data-related topics based on interviews of participants are presented. Themes relating to data activities are presented along with observations of existing digital infrastructure arrangements. This case study provides an example of data management planning by scientific research participants for a site-based, multi-partner community.

1. Introduction

Prior to a monthly meeting, environmental researchers including large-river ecologists, wetlands researchers, and other participants chatted as they gathered by a window looking out over the water isolated by a levee from the Illinois River. Conversations were wide-ranging: a university ecologist mentioned recent measurements at Thompson Lake; a Nature Conservancy manager reported on rains that produced a 'hundred year flood'; researchers from the Illinois River Biological Station and the Forbes Field Station compared recent fish counts with waterfowl counts; specialists from the U.S. Fish and Wildlife Chautauqua National Wildlife Refuge commented on the current status of invasive species in local aquatic areas; and a staff member at the nearby Dickson Mounds Museum reported on findings from summer excavations of a native American village before inviting all present to contribute to planning for an 'Emiquon Experience' exhibit scheduled to open soon. Eventually, conversation centered on a common interest in understanding natural systems and in planning for Emiquon Preserve where management is informed by data measurements and observations collected at the site. I attended the meeting to observe before beginning a series of interviews.

This study of data practices and data management took place at a time when science was undergoing transformation fueled by the twin forces of collaboration and data sharing. It reports on the introduction of data management to scientific research associated with the Therkildsen Field Station at Emiquon (TFSE), a facility built and operated by University of Illinois Springfield (UIS). Recent recognition of the need to develop large-scale systems and digital information infrastructure has drawn a great deal of attention and funding to big data and cyberinfrastructure initiatives (NSF 2007; Hey, 2009). The focus on participant understandings of and plans for data management at the launch of a new field station within a site-based community has been less frequently documented.

Local activities and decisions about data management are described. *Data management* is defined as "an active process by which digital resources remain discoverable, accessible and intelligible over the longer term, a process that invests data and datasets with the potential to accrue value as assets enjoying far wider use than their creators may have anticipated" (Pryor, 2012). When there is complexity due to the extent and diversity of resources, services, and connections, the work may be described as *information management*. Further, in library and information sciences, *data curation* is a term used to describe work aimed at supporting the preservation of data. Data curation is defined as "the active and on-going management of data through its life cycle of interest and usefulness to scholarship, science, and education" (CLIR, 2013). The use and scope of these terms differs across fields. They are drawn together, however, by the concepts of infrastructure (Edwards et al, 2009; Bowker et al., 2010) and more recently by the active process of *infrastructuring* (Karasti, 2014)

Background on the organizations involved and the conduct of this study is given in Section 2 including reference maps (Figures 1), a timeline of major events (Table 1)[1] at Emiquon, and lists of acronyms with organizational links (Table 2). Section 3 reports on site history and issues, often using selected quotes that capture participant voices and anchor the report with local views. These issues and related topics are discussed in Section 4 followed by final thoughts in Section 5.

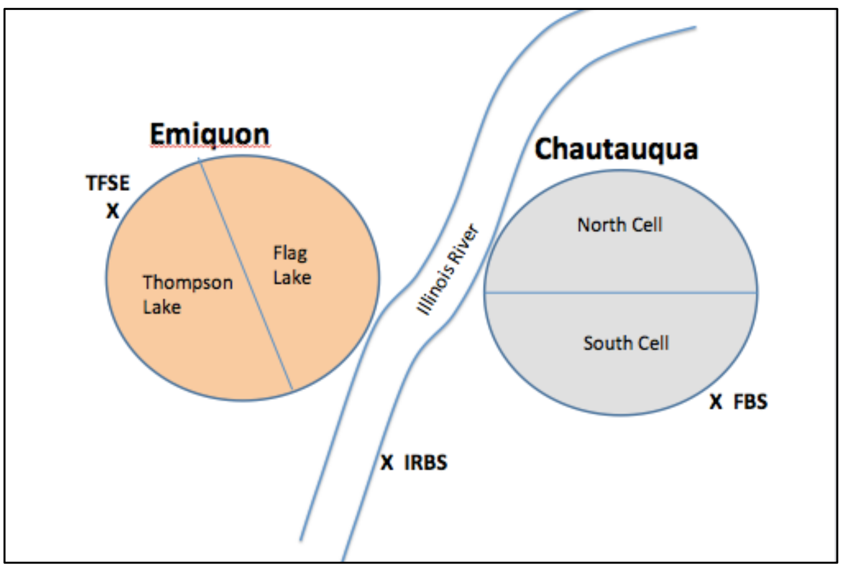

Figure 1a. Emiquon partner lakes and field stations. Graphic created by Keith Miller from "The River Floodplain as a Giant Petri Dish Experiment" concept. Locations of the three field stations mentioned in the text are marked with an X: Therkildsen Field Station at Emiquon (TFSE); the Forbes Biological Station (FBS); and the Illinois River Biological Station (IRBS).

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[1] For related timelines see the Illinois Natural History Survey timeline at http://wwx.inhs.illinois.edu/organization/history/inhs-timeline/ and the Emiquon Experience timeline at http://www.experienceemiquon.com/content/emiquon-place-nature-place-time. For background and another timeline by Emiquon researchers see Walk et al. (in preparation).

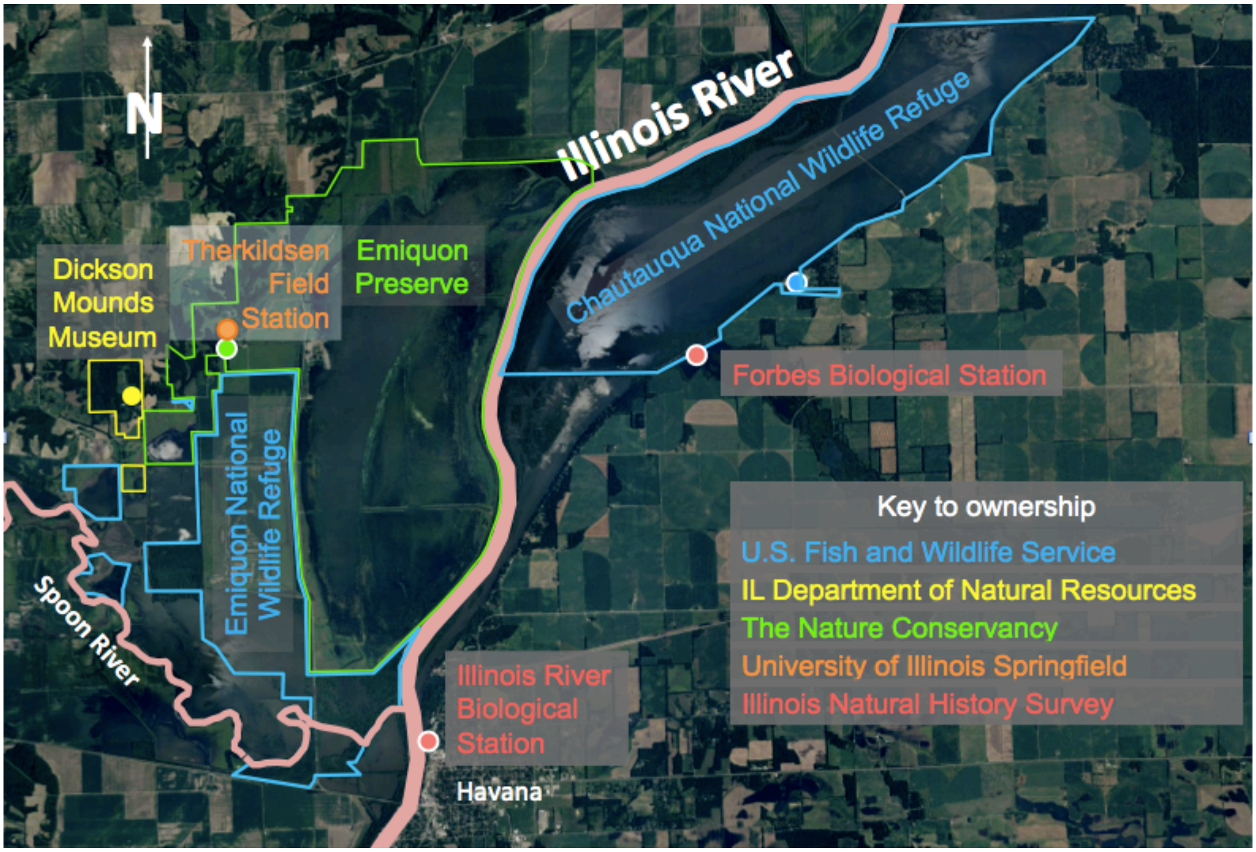

Figure 1b. Aerial map of Emiquon partner land holdings, from D. Blodgett.

2. Background: This Study, Emiquon Preserve, and Therkildsen Field Station

2.1 This Ethnographic Study

The focus of this ethnographic study, carried out in 2013 as a summer class project and summarized in this report, is data management for a community of scientific researchers who were conducting fieldwork at the Therkildsen Field Station at Emiquon and at Emiquon Preserve. It aims to identify current circumstances, practices, and understandings in addition to prompting discussion about existing structures and knowledge that may be tacit, implicit, or explicit. The study highlights activities that occur as data management is introduced in conjunction with the opening of a field station. This case adds to other case studies that investigate data and data management in the life sciences (e.g. RIN, 2009). The selection of TFSE for this study is opportunistic and yet purposeful. Community members invited my participation at the preserve where location made field visits relatively straightforward.

Visits to the field station and to the University of Illinois Springfield were made to gather background information and conduct in-person interviews. During observations and interviews, field notes were jotted down. A tour of the levee at Emiquon (March 15, 2013) included visits to The Nature Conservancy headquarters and the two INHS field stations in Havana: the Illinois River Biological Station and the Forbes Biological Station. Subsequently a stay at TFSE (May 12, 2013) provided an opportunity to talk with others working at the field station. Participant observation was carried out at two TFSE meetings and at the Emiquon Annual Science Conference. Participant-observation included a participatory design approach with exchange of experiences and insights about data and data management. Seven semi-structured interviews were conducted with four ecologists and a computer scientist, a research assistant, and a manager. Two interviews were with a key informant who has worked since 1972 with the many partners of Emiquon – academic, nonprofit, state government and federal government. One interview was with a participant who wrote the first TFSE data management plan. Interviews were transcribed and coded for thematic analysis.

Excerpts from the interviews that appear in the text are labeled to indicate research scientist (RS), research assistant (RA), and resource manager (RM). All interviewees attended a science planning grant meeting as well as the annual science meeting. The scope of this study (the unit of analysis) is defined as scientific researchers associated with TFSE and the Emiquon Preserve. The object of analysis is community data management as researchers pursue data assembly and access for collective use.

2.2 Emiquon and Its Lakes

The construction of a levee on the Illinois River in 1921 to separate Thompson Lake and Flag Lake from the Illinois River, initiated a series of events culminating in eventual restoration of the lakes starting in 2000 and construction of a field station in 2008 on a rise overlooking the lakes in an area now known as Emiquon Preserve. This was one of many levees, locks, and dams created along the length of the Illinois River. The privatization and drainage of what became levee districts is part of this area's contentious history. Drainage and levee districts built these levees in an era when nature was perceived as 'wasteful' and seen as something to be improved upon. The districts were formed by associations of resident and absentee landowners under a state legal framework dating from 1879 (Thompson, 2002). Levees and pumps transformed floodplains and their associated wetlands, side channels and lakes into dry land suitable for agriculture. Side effects included loss of fish and wildlife habitat and constriction of the river, which helped maintain a single channel for navigation but also increased flood heights. The Thompson Lake Levee and Drainage District constructed a levee and pumped Thompson and Flag lakes dry in 1921, making room for row crop farming.

The history of Thompson Lake is a story of wetlands drainage, contestation and land enclosures from the 1880s (Schneider, 1996; Thompson, 2002; Havera et al, 2003). The story makes clear the complexity of issues that confounds multiple layers of political systems and foregrounds differences of opinion about land use. These differences typically impact wildlife, sometimes prove fatal to humans, and typically lead to destruction of aquatic productivity. The work at this floodplain site, including scientific studies as well as land and water management, provides an example of the kind of scientific management required to support biodiversity and restoration. Such efforts contribute to development of understandings ultimately needed to ensure habitability of earth for humans.

In 2000, The Nature Conservancy purchased the acreage with the aim of increasing biodiversity by restoring some of the natural functions of the land. The land was cleared of agricultural buildings, underground fuel tanks, and a feedlot; a pond for animal waste was reclaimed. For several years, The Nature Conservancy allowed farming under contract until 2005 when the pumps that drained the lakes were turned off (Table 1). The regional director of the Natural Conservancy coined the phrase 'faith-based management' to describe their no-cost strategy of watching rainfall recreate the lakes behind the levees. Thompson and Flag lakes reappeared and were stocked with native fish. The result was a clear lake, or a 'fishbowl', disconnected from the river, quite unlike the original floodplain lakes that had been seasonally connected to the river. There were lively discussions and strong arguments among stakeholders about whether to reconnect the lake to a river known to be high in pollution and invasive species.

> "But if you never have a connection to the river, most of the organisms and ecological processes of the Illinois River aren't going to be helped by something that is on the other side of the levee. There are some migratory water birds that are still going to use the area … but when it comes to river fish that need to find wintering areas or production of this area needed to fuel the mussel beds in the river and things like that, without some type of connection you are not going to have it. So one of the outcomes was that most people thought that we needed to be some place in the middle with a managed connection for now - not complete isolation, not complete connection but a managed connection. The other thing that the group talked about was that this was a really important project that could serve as a model for restoration of the Illinois River backwaters, floodplain and other rivers - regional rivers, the Mississippi, the Upper Mississippi, and worldwide as well." (RM)

A flood that occurred in April 2013 was an exceptional event that impacted plans by bringing about an unmanaged connection; that is, the river overtopped the levee and connected the lakes to the river.

The Illinois River is a large river system of significance because of the size of its watershed and its productivity (see Section 3.1; Sparks, 1992). From single-issue investigations into human alterations of the landscape during the environmental movements of the 1970's (e.g. water pollution, acid rain), scientific research today is entering an era of multi-partner projects formed to study large-scale environmental systems. One Emiquon researcher explains the complexities involved in working with natural systems:

> "You have to think at multiple scales … and to explain the mechanisms that are happening at one level, you have to delve into finer scales. But then to understand what's happening in any one level, you have to understand that that's embedded in things that are going on at broader scales and longer time spans. So you just have to go in both directions. Finer if you are trying to get some mechanisms … and coarser scales if you are trying to see the big picture… shifting up through scales of time and geography." (RS)

As site-based scientific project groups began to aggregate data, 'shifting up through scales' introduced issues associated with management of the data as well as the land. As more researchers learned to augment traditional discipline-specific approaches with broader, interdisciplinary perspectives taking into account larger contexts and multiple scales, they also began to realize not only the value but also the challenges associated with assembling data collectively. It is recognized that a particular measurement made for and used in a particular study of a particular location would gain 'added value' when considered together with other measurements from same site as well as from other sites.

2.3 Therkildsen Field Station and Data Management

Before the pumps were turned off at Emiquon in 2005, the idea emerged to build a field station to assist the study of changes that would occur over time on this land. The goal of researchers at the University of Illinois Springfield (UIS) was to establish a nearby facility supporting field research that would also contribute to teaching by providing more opportunities for students to acquire field-based experience. Universities have recognized field stations for some time as creating an important sense of place (Billick, 2010). The field station aims were complimentary to The Nature Conservancy mission of supporting biodiversity and partnering with scientists (Reuter et al., 2005). Therkildsen Field Station at Emiquon opened in 2008 as a station equipped for overnight accommodations and providing kitchen facilities, a wet laboratory, a conference room, and some storage sheds. Scientific researchers including aquatic and terrestrial ecologists interested in the wetlands and prairie carry out studies at the Emiquon field site today. They joined other organizations in the area supporting conservation and restoration of the river ecosystem (see Section 3.2).

A NSF planning grant, awarded in 2011 to a researcher at UIS to consider the future of the field station, was the first time data management became an explicit part of research and field station discussions. The associate director of the station, a professor in computer science, explored data management expectations, experiences, and examples available online prior to writing a two-page data management plan required for their two-year NSF planning grant proposal.[2]

3. Site History and Science

The following subsections document topics that emerged in interviews and community conversations. They describe the history of Emiquon and the field station and views on science and data management. The development of community data management at this site continues to be a subject of discussion, taking into account past and present scientific practices and activities.

3.1 The Illinois River: A Large River System

Despite its relatively short length (439 km) and modest average annual flow (657 m^3/s), the Illinois River once had the expansive floodplains and protracted seasonal flooding that characterize much larger lowland rivers and contribute to their exceptional biological productivity and diversity (Sparks, 1995; Bayley, 1995; Welcomme, 1985). The large floodplains (2.4-11.3 km wide) of the Illinois River are a geological legacy of the ancestral Mississippi River and the ancient Teays River, which once drained much of eastern North America (Janssen, 1952). One researcher recalled how he heard the Illinois River referred to as “a babe in a giant’s cradle”. The large bedrock valley was subsequently nearly filled by alluvium following successive great floods as the last continental glaciers melted away, and the Mississippi established itself west of its old course as the glaciers retreated. The ancient Teays River valley is now mostly buried under alluvium in central Illinois and Indiana, except where it is exposed downstream as the lower Illinois River

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[2] Beginning January 18, 2011, proposals submitted to NSF required a supplementary document describing a data management plan. With broader scope, on February 22, 2013 the US Office of Science and Technology Policy (OSTP) announced that all federal agencies with research and development budgets equal or greater than $100 million that they fund are required to develop policies that provide open access to publications and data resulting from the research.

Valley and upstream as the valley of the Kanawha and New rivers in Virginia and West Virginia. As a result of the filling, the river and its oversized floodplain had exceptionally low gradients (2.8 cm/km), so the river typically filled the large floodplain slowly and then drained the floodwater away slowly, in comparison to rivers with steeper gradients. Also, both the Illinois and Upper Mississippi rivers could flood simultaneously because of snow melt and rainfall in the Upper Midwest, in which case the Mississippi would back water up the lower-gradient Illinois River for at least 200 km, thereby protracting floods on the Illinois (Alvord and Burdick 1915:44). Researchers familiar with its history recount how "the lower Illinois is the Mississippi" referring to its geologic history.

Since the Illinois River lacks the gradient to create the rapid flow typical of many rivers, it results in an unusually rich aquatic environment teeming with life (Mills et al, 1966). Researchers sometimes speak of how "the Illinois out produces the Mississippi by a lot"; its slow movement supports an uncommonly rich network of streams, lakes and floodplains. The lack of a strong current also means the river is extremely susceptible to silt and sedimentation.

The area inundated when a river overflows its channel is a *floodplain*; the expansion and contraction are known as the *flood pulse*. As one researcher explained, the floodplain and flood pulse distinguish large river systems from rivers with more rapid flows:

> "It [identification of a large river system] is based on the duration of the flood pulse in time and the extent of the flood in terms of a big floodplain." (RS)

Typically there are oversize floodplains associated with shallow slopes and slow moving rivers. These rivers overflow into huge adjacent areas that take a long time to fill up and then a long time to drain away (Junk et al., 1989). The limited number of large floodplain-river ecosystems that exist around the world include the Amazon, the Nile, the lower Yangtze, the Mississippi and the Illinois.

Wildlife was abundant along the Illinois River until the 20th century, when within a short period human settlement created industrial discharges and agricultural runoff, brought levee construction and dams to improve navigation and farmland, and harvested wildlife for commerce and sport (e.g. Sparks, 1992; Schneider, 1996; Thompson, 2002). Pollutants and sediments had not yet altered the river significantly when Illinois Natural History Survey researcher Stephen Forbes initiated his historic studies of the river (Sparks, 1992; Schneider, 2000). Forbes had an early interest in the productivity of the Illinois River as it related to flooding:

> "Part of the excitement and challenge that Forbes wanted to undertake, is explaining the [Illinois River] productivity. And he had an idea that it had something to do with the flood pulse. Although they didn't call it flood pulse back then." (RS)

A comparative study for both the Illinois and the Mississippi Rivers was possible since Forbes made measurements providing a baseline prior to pollution resulting from redirection of the Chicago channel waters into the Illinois River. This sparing of Lake Michigan by redirection of the outflows from Chicago had serious, unanticipated environmental impacts. The problem of contamination was simply diverted out of the Chicago area to become a problem for the biota along the length of the Illinois River as well as for all the floodplain inhabitants south of Chicago. The problem of river pollution eventually shifted the Surveys' investigations to the impacts of human alteration on the river. The early work of Forbes and the Survey scientists informed the work of other researchers who followed (Hays, 1980; Bocking, 1990, 2010). The field station of the Illinois Natural History Survey at Havana was eventually renamed the Forbes Biological Station (Havera and Roat, 1989).

3.2 Emiquon Preserve: Scientific Partnering on the River

The name Emiquon is traced to the time of Illinois Indian tribes and early explorations of the land by Europeans (Esarey, 1998). Some aspects of the Emiquon partnership are captured by the cooperative known as The Emiquon Experience[3]. The Emiquon Project was formulated as an Illinois floodplains restoration initiative in 2000. The Nature Conservancy purchased more than 7,000 acres of land that had been leveed off from the Illinois River. This was a large purchase for the Conservancy. The original plan was to resell the land to the U.S. Fish and Wildlife (USFWS), an agency that owns the leveed Chautauqua National Wildlife Refuge across the river from Emiquon. The land sale was halted when a difference in philosophy was identified. The difference was one of focus: the U.S. Fish and Wildlife aim is to disconnect pools of water from the river as refuges for migratory waterfowl which in turn supports recreational hunting. This differs from The Nature Conservancy's broader aim to connect with the river to manage and restore the area as a natural system supporting biodiversity and providing ecosystem services that contribute to sustainability of the functionality of the natural environment. As a result, alternative arrangements were made with USFWS in lieu of selling the land, and The Nature Conservancy began planning for Emiquon as a new restoration project.

The number of individuals and organizations involved at the Emiquon Preserve is bewildering to a newcomer. Maps (Figures 1) show the Emiquon areas and neighboring properties where the partners are learning collectively about managing this land by taking into account the structure and function of the ecosystem. Some of the associated names, acronyms, and online links are given in Table 2. On one hand, a partner recognizes the strength of the collaborative arrangements and comments, "the partnership just works. It brings so much together." On the other hand, it is also recognized that an excessive amount of time is needed to maintain a vibrant collaboration, and comments emerge like "there are meetings … and partner meetings take frick'n forever. And then there are the one-on-one meetings … ". This is an apt reminder of the time required to ensure collaboration continues and remains a beneficial undertaking.

Organizational Coordination

There is a history of coordination and cooperation in association with the river starting with the Illinois Natural History Survey (INHS) carrying out the organization, collection and analysis of specimens and data. The INHS, dating from 1858 when the State Natural History Society was organized, was directed and influenced early on by Stephen Forbes (Howard, 1932).

A series of locks and dams were constructed in the 1930s and early 1940s by the Army Corps of Engineers on both the Upper Mississippi River and the Illinois River to maintain water depths for navigation during low flows in the river (Sparks, 1992a). Since portions of the Upper Mississippi River, as well as most of the Illinois River fell within the boundaries of Illinois, the Illinois Natural History Survey and the Illinois Department of Conservation (later, the Department of Natural Resources) participated in federal-state cooperative programs on the Mississippi. Both rivers were recognized as large floodplain rivers that shared many

[3] The Emiquon Experience, http://www.experienceemiquon.com.

characteristics and species so that approaches and findings from one river often could be applied to the other. They were both regarded as part of Upper Mississippi River Navigation System in the Water Resource Development Acts passed by Congress. The Upper Mississippi River Conservation Committee (UMRCC) was formed in 1943 with natural resources agencies from the five states bordering the Upper Mississippi River and the US Fish & Wildlife Service (Sparks, 1992b). The initial focus was on a coordinated survey of fishes and on the effects of dam operations on fish and wildlife, particularly the harmful winter drawdowns of the pool levels behind the dams. Later, technical sections for wildlife, mussels, water quality, conservation law enforcement, and outreach and education were added. There was also an Upper Mississippi River Basin Commission through the 1970s until it and most other basin commissions were terminated by executive order of President Carter in 1981. The governors of the five Upper Mississippi River Basin states created the Upper Mississippi River Basin Association (UMRBA) in 1981, as a successor to the old Commission. Each governor appointed a voting member, usually from a state agency responsible for water resources, "to maintain communication and cooperation among the states on matters related to water planning and management" (UMRBA, 2016). The UMRBA develops regional positions on river issues and advocates for the five states' collective interests before Congress and the federal agencies. Finally, a group of scientists, mostly from academic and research institutions, formed the Upper Mississippi River Research Consortium in 1968 (it later broadened its purview by dropping the "Upper"). Approximately 100 river researchers gather at an annual meeting, usually in La Crosse, Wisconsin, to present their research results, discuss common problems, and get better acquainted. The abstracts are published as annual proceedings. Those associated with these cooperative endeavors continue to contact and consult each other. Sparks (personal communication, 2013) mentions that "we're all comfortable working together", an indication of the collaboration supporting integrative science centering on these rivers. The maturity of this collaborative approach plays a significant role in spanning the interests of science, land management, and politics.

Organizational Differences

The Environmental Management Program (EMP), coordinating across five states and several federal agencies in the 1980s, was an unforeseen outcome of a political situation.

> "It [the EMP] is the result of a stalemate in Congress and a court decision. The stalemate was between navigation interests and the natural resource interests. There was a proposal to expand the navigation capacity on the Illinois and the upper Mississippi Rivers and the shipping industry was behind it. Most state governors were behind it, because it's all federal funding. The opposition came from Sierra Club, American Rivers, and others that said, 'if you increase navigation you are going to increase the detrimental impacts on the environment and the river'. And this was especially strong from the upper Mississippi River that is a federal Fish & Wildlife Refuge. I mean the whole floodplain is in a refuge. So Fish & Wildlife Service was particularly strong in this and all the state departments of natural resources that have preserves and hunting areas and fishing areas along both rivers. So, neither side could get its way. There was a stalemate in Congress. And there was also a lawsuit brought against the Assistant Secretary of the Army for Civil Works by Sierra Club and the Association of Western Railroads." (RS)

The situation prompted Congress to create a compromise plan that limited expansion of navigation and funded an Environmental Management Program. The legislation was a milestone in that it identified and labeled the ecosystem as nationally significant and on a par with commercial infrastructure:

> " … the Upper Mississippi River System, which includes the Illinois, is a nationally significant ecosystem as well as a nationally significant waterway." (RS)

The Environmental Management Program today is an active program defined by two sub-programs: a) a Long-Term Resource Monitoring Program (LTRMP) that tracks status and trends in the rivers and b) the Habitat Rehabilitation and Enhancement Program (HREP) that counteracts impacts when harmful effects are identified. The natural resource departments of five states coordinate with the US Geological Survey and the US Army Corps of Engineers. Service. During the years preceding 1998, the Illinois Natural History Survey was moved from a place of 'benign neglect' within the Department of Registration and Education to the Department of Energy and Natural Resources and then to the Illinois Department of Natural Resources (IDNR).

> "IDNR was separating their preserves from the river, treating the river as this noxious thing that would degrade their areas… I was being asked to comment by the Corps of Engineers and Fish & Wildlife Service on some of these HREP projects that were going forward, some of which were IDNR projects with Corps of Engineers funding flowing in. And I was critical of them because I thought some were going in the wrong direction." (RS)

At the time when IDNR was working with the aim of separating public hunting and shooting areas and conservation areas from the river, Sparks' research was highlighting the cyclical and natural occurrences of river flood pulses. There was growing awareness of the importance of investigating and understanding connectivity within natural systems. The difference in approach to management – isolation versus connectivity – continues from the 20th century to affect plans and partnerships today.

3.3 The Building of Therkildsen Field Station at Emiquon

Therkildsen Field Station at Emiquon (TFSE) is a research facility overlooking Thompson Lake, the levee, and the Illinois River northwest of Springfield and across the river from Havana on land owned by The Nature Conservancy. It adds to scientific research carried out by the consortium of Emiquon partners. The station exists because of the unique alignment of partners who are intent on the development of scientific management required to steward the Emiquon wetlands that are severely impacted by human alterations.

In 2005, Douglas Blodgett, regional director of The Nature Conservancy, and Michael Lemke, a professor at the University of Illinois at Springfield (UIS) and aquatic ecologist, began a discussion about the feasibility of establishing a UIS research field station on the Nature Conservancy land at Emiquon. After multiple attempts to capture university interest, a modest interest emerged at UIS and Lemke quickly assembled a team to assist in the project and its activities. Keith Miller, UIS professor and future associate director of the field station, contributed the first $1000 of personal funds and initiated a funding track that developed into a multi-year campaign, a moderately effective avenue to fund the field station. Lemke, the first field station director, recalls these years as a series of unforeseen events including some 'Zen moments'. The Alfred O. and Barbara Cordwell Therkildsen family provided most of the funding for construction of the field station that was subsequently named for them. One stumbling block for The Nature Conservancy was planning for the contingency should UIS lose interest and abandon the station. The Nature Conservancy was cautious about new construction due to previous difficulties with legacy structures such as underground fuel tanks. UIS was cautious because state of Illinois buildings cannot be built on land that is not state of Illinois owned. After one and a half years, Lemke conceived a plan that addressed UIS legal concerns by budgeting for the removal of the building in the budget to build the building. This meant UIS assumed responsibility for removing the building whenever its use of the station ended. Planning for the end of a building before it existed is one of the unique events in the history of the field station. Another stumbling block for UIS was finding a way to finish the dirt road up the bluff to the field station. The funds eventually identified were those available for constructing modifications and parking so that the station would be accessible by handicapped visitors. Today Dr. Lemke still smiles as he points to the prominent (and only) paved parking spot next to the station that is posted for handicapped parking. By addressing issues for a minority population, access for everyone became available. With support from UIS and some Zen-like moments, the station opened as 'Emiquon Field Station' in 2008. It was subsequently renamed 'Therkildsen Field Station at Emiquon'.

Having built the station, planning for its future continued. After a number of unsuccessful efforts to obtain NSF funding largely based on restoration that had yet to begin, Lemke was advised by an NSF program officer to start the field station process by joining the Organization of Biological Field Stations in order to learn from the experiences of a community of approximately 400 other field stations and then by writing a two-year planning grant for the field station. The grant required identification of Emiquon participants as well as their plans for science. Attendance at OBFS meetings reinforced for TFSE attendees the importance of planning for data management. One researcher recalls:

> "I know the emphasis on data management came in part because of reports to the board at some point that data management is a big thing that NSF is looking for. So we knew to incorporate that into our planning and into the grant request. That was a big piece of what we were going to try to figure out. And this planning process was how to manage the data so that it would be useful for other researchers as they came in and as the site grew." (RS)

The grant supported three meetings, which included a field station participants' meeting November 8, 2012 and an education outreach meeting February 22, 2013. Ongoing field station sampling was reviewed and future plans considered. Discussions included planning for a multi-investigator proposal to NSF that would support a site-based research effort. Ideas ranged from a focus on microbial ecology, a scientifically oriented topic that complements the waterfowl and fish studies of the two nearby Illinois Natural History Survey field stations, to other ideas centered around ecological restoration, a sustainability-oriented topic that represents a larger-scale vision for ecological research. Final thoughts were assembled and reviewed at a TFSE retreat on May 22, 2013 where a final NSF report was discussed that would summarize accomplishments, plans, and overarching vision for the Therkildsen Field Station at Emiquon.

Researchers who use the new field station are shaping its future. Extending it beyond the initial view as a site for wetlands study, one terrestrial ecologist highlighted a part of the preserve that had been designated 'Emiquon West':

> "One of my students … when he presented at one of the Annual Science Symposiums, he said we like to call it [their terrestrial work area] Emiquon West … it doesn't get as much press as Thompson Lake and Flag Lake and all the wetlands. But they [The Nature Conservancy] are doing these other restorations too." (RS)

One researcher in thinking about the current and potential state of the field station, seemed to stretch their personal view to include a long-term timeframe as well as the collaborative nature of the endeavor:

> "How do we bring together the ecology that is restoration of a place? I mean how do we put together what they have done for seventy-five years in Madison?[4] I guess, in a way, we are doing it because they started planting a bunch of trees and getting out of there a bunch of farm plants. … And this is the stewardship that I don't think I will accomplish in my life-time, but I hope some day they understand that we have three field stations … two already internationally renowned and a little baby one starting." (RS)

3.4 TFSE: A Field Station for Site-Based Field Research

One of the pressing issues for a new field station is to come to terms with its identity. One researcher described this as figuring out "what the field station means to scientists". Some scientists have individual uses in mind, e.g. a site for teaching or for carrying out their own research. Others may want to use it to bring together colleagues in their own field or for interdisciplinary site-based ecological studies. Still others may be interested in exploring restoration ecology.

> "Field stations come about in different ways. Sometimes people, a bunch of people can gather on an idea. Or it's a great spot and people start showing up and a bunch of scientists buy a farmhouse and start studying the place. Therkildsen is one of those places where it was a great opportunity … it was also the idea, hey we'll build a clubhouse there but you have to figure 'what are we going to do with the clubhouse?' (RS)

UIS Emiquon participants initiated an Emiquon Annual Science Symposium that is attended by the many partners outside of TFSE. Further, the science is carried out at multiple locations – Thompson Lake, Spunky Bottom, Chautauqua National Wildlife Refuge, and the Illinois River – so TFSE is not necessarily in a singular or pivotal role. In addition, science at Emiquon Preserve is sometimes carried out by contract, such as in the case of The Nature Conservancy support for measuring Key Ecological Attributes (KEAs; TNC, 2006).

At a planning meeting in 2012, the role of UIS researchers and the identity of the field station were discussed. Discussion centered on a perceived need to frame the work of the field station: is it strong in microbial studies, ecological studies, and/or in restoration science in

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[4] Refers to the Arboretum at the University of Wisconsin, Madison. At the formal dedication on June 17, 1934, research director Aldo Leopold outlined the focus of re-establishing "original Wisconsin" landscape and plant communities, particularly those that predated European settlement, such as tall grass prairie and oak savanna. The Arboretum Committee introduced a then-new concept in ecology: *ecological restoration*—the process of returning an ecosystem or piece of land to a previous, usually more natural, condition.

particular? Further questions were considered. If they were to develop an ecosystem focus, would it be redundant with the work of INHS? If they were to highlight restoration science, would they need to advocate for a faculty position in order to be in a position to hire a restoration scientist?

> "Because the fish guys are going to write some great fish articles … and the plant people and the duck people will write great duck articles and someone else will write a micro paper. It doesn't make us a great restoration science place." (RS)

There is an understanding of the responsibility to manage the property and its processes as a whole. With managers and staff scientists, TNC often plays a role in communication and coordination. They bring consultants, the field stations, and other research scientists together to focus on particular issues. The Nature Conservancy reinforces the role of research scientists:

> "The Nature Conservancy says over and over, 'We listen to the scientists, but it's not our job to be research scientists. We're managers' " (RS)

and the potential for cooperation is high for broader investigations given the collaboration and the multiple levels of research:

> "the different thing with Thompson Lake is that they are monitoring on so many different trophic levels. (RS)

> "And maybe it would be easier to bring in the other people and get more close cooperation with the other field stations if we weren't competing you know for our various sub-disciplines, but in fact we are cooperating in this more broad effort. (RS)

The discussion is ongoing about situating the work at the field station given the mix of contract-based and investigator-based science and of views - a collaborative ecosystem-based approach together with a restoration management perspective.

3.5 Focusing on Restoration

To manage an area for the well-being of both the environment and humans is a complex endeavor. From the variety of terms that describe change for an ecosystem – restoration, mitigation, rehabilitation, and transformation – Emiquon partners have adopted 'restoration science' to describe the efforts at Emiquon. The concept of restoration provides an approach to conservation of rivers and bodies of water as well as terrestrial sites impacted by humans (Ormerod, 1994). The term 'restoration' may be interpreted in many ways; it has different meanings for different communities that make the term ambiguous at best and a potential communication barrier when ill defined.

The NRC 1992 Report 'Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy' is comprehensive in its recognition of environmental issues and presentation of case studies. It adopts a fairly narrow definition of the term 'restoration':

> *RESTORATION* - Return of an ecosystem to a close approximation of its condition prior to disturbance.

In farm communities, however, one researcher explained:

> "Restoration was defined [by the Farm Bureau] as clearing humans off the land and returning it to the condition when the Indians were here. And so we go to talk to people and as soon as we said restoration, their minds are turned off and they just rejected anything we had to say." (RS)

In this situation, the term implies restoring back to an earlier state of some kind. Often, the earlier state is assumed to be 'original', 'pristine' or undisturbed. It could, however, also refer to a state that supports return to some defined amount of biodiversity or of some measure of ecosystem services.

> "My understanding is restoration in this day is a term that is evolving, is changed itself. And now I think my understanding of restoration is not exactly that you try to go back to an original, pristine state but you at least go back to a historic range. For example, maybe here there used to be native fish and maybe 200 different plant species. But we can go back to a historic range, not exactly the same number, but maybe have 15 or so that we think is a good restoration project, successful." (RS)

One way to consider restoration is to ask, "What would be considered a successful restoration"?

> "For example, Emiquon used to be a big floodplain, two big lakes. Thompson Lake, Flag Lake, they link to the Illinois River. And around I think probably 1920 they changed the lake and converted to the system of cropland. So this is basically a change of ecosystem. Quite different. And so the concept of restoration at Emiquon, basically we try to restore back to the original floodplain or wetland. … Of course, as the time has changed dramatically, obviously you cannot go back exactly, for example to 1920 … but hopefully maybe some native species could come back, including plant species and fish" (RS)

One researcher captured a partnership dimension in doing restoration:

> "Aside from defining what restoration is in the long run, a restoration project is a long-term commitment for one thing. Secondly, it's rare for restorations to occur just by one agency or one project. So a restoration of this means it has to, you have to, deal with the politics … with the practicalities of just moving physical water around. … the people who support this conceptual model are probably not all from one department, one school, probably not even one university. And ecology knows that, so that's when I say restoration ecology, you know its multi-faceted and multi and interdisciplinary." (RS)

A managed site may have restoration activities and adaptive management as part of its plan. It is worthwhile noting that site-based restoration does not preclude traditional ecological science. Ecosystem science may be conducted at such a site:

> "I might want to have some hypothesis-driven questions to better understand the nutrient dynamics, but I think maybe from a management or KEA point of view too as, is nitrogen

> high? Is nitrogen low? Is the water green? Is it not green? Are the fish, are x-species spawning, or are they not spawning? I mean I know there are gradients in-between on that. That's a good adaptive management approach. But it's exactly that. It's adaptive management. … it's not necessarily exclusive from restoration ecology. And what can we learn about this system from a restoration ecology point of view?" (RS)

A researcher explained why the research is referred to as restoration science as an alternative to ecosystem science:

> "Because it's directional. I mean it can be directional… as Mathews is writing about now about wetlands … it can be a directional change, it can be completely chaotic, or it can be, what does he call it, dispersive … the simplest type is like a community takes on kind of a linear change from being really screwed up by whatever fashion to this really nice stable system, highly diverse. But it doesn't always go that way, and why? So there is good theory out there for testing." (RS)

An ecologist's interest may be how things change in time and how to capture a record of these changes in some of the many examples of disturbed ecosystems. Spunky Bottom is another preserve owned by The Nature Conservancy not far from Emiquon that started out in the mid 90s and by 2005 had reached a fairly stable state. The floods of 2013 that first overtopped and then burst its levee have disturbed this state.[5] Not enough is known about changes in these managed ecosystems:

> "restoration, if not linear, certainly has a strong time component as succession does. Now is restoration like succession? I don't know. A lot of things are driven by some kind of succession because I think we could agree that a farm field makes a lousy lake. So the structure of a farm field is relatively simple and therefore the function of those things that are aquatic were rather simple and not well developed. As you dumped water into this farm pond fish bowl, the structure out there still was very simple. You had mud that was still aerobic and you had cornstalks. But say you dumped a bunch of fish in there … some plants. Its easy to argue that as the structure of the habitat increased so did the function of how well its doing ecosystem services. Will they change very fast and slow down? You know will they go up and crash and do this?" (RS)

Restoring an ecosystem is sometimes seen as resetting its functional clock. In such cases, local development may be referred to as 'before restoration' or 'after restoration'. At Emiquon, for instance:

> "2000 is when Nature Conservancy purchased the land…So I mean, you could argue in a way that began restoration, but that's really just changed hands and changed, ah, politics and all that kind of thing. But it was 2007 when physically efforts in earnest took place to start restoration. These soy fields [at Emiquon] … the prairie that are burnt and so forth, … was seeded … so that they had somewhat of the same genetic makeup. And then there were I don't know how many thousand saplings and plants planted in the open

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[5] Personal communication, prior to RS interview

> hardwoods. But plants came back very quickly … dredge tunnels [channels] were all refuge for some of the wetland plants. But also a lot of airborne plants came in. And of course we have a lot of seed dispersal happening through ducks and other animals carrying things around on them." (RS)

The purchase of Emiquon prompted one researcher to devise a 'before restoration' sampling strategy at Emiquon:

> "For three years, I think it was '05, '06, and '07, we decided that we would sample three connected lakes, and three non-connected lakes. Connection being that the river at some points in the year floods that lake. Emiquon was 'ditched'. Because we knew restoration was coming, we used Emiquon ditch, and we called it a non-connected lake." (RS)

Restoration science brings with it the need for restoration scientists. The University of Nebraska-Lincoln defines the role of environmental restoration scientist through its undergraduate program:

> "All students majoring in Environmental Restoration Science will receive a thorough understanding of the soil-water environment, environmental regulations, toxicology, environmental sampling, and restoration techniques.
>
> "Because environmental problems are complex, the environmental scientist will often work with interdisciplinary teams to find solutions. In fact, many environmental consulting firms and government agencies commonly employ both scientists and engineers to work hand-in-hand" on various restoration projects - soil, surface water, groundwater, and habitat. (RS)

Mitigation, another term defined by NRC (1992), is sometimes avoided since it carries negative connotations in that it acknowledges a problem exists:

> *MITIGATION* - Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.

There's also ambiguity in use of the alternative term 'reclamation'. First, there's the idea of reclaiming a 'human produced product' that is, reusing a human created product for positive economic benefits, i.e. recycling wastewater. But it has its own history where one is reclaiming a resource from a natural but wasteful 'nature' for some human purpose.

> "I'm trying to remember some of the terms. … the idea was that you use the resources and that nature was wasteful and so you reclaimed things and you utilized nature. And for example, the classic example would be the Columbia River … all that water running down to the sea not producing anything. So lets harness the river, put those dams in, hydroelectric dams and it will generate power for us. … Oh it's the Wise Use Movement. (RS)

One researcher familiar with the changes at Emiquon preferred the term 'transformation':

> "I think of transformation. That I think works. Transformation. It [Emiquon] used to be farm fields and now it's not. Exactly what it is, is unclear… From a row crop agriculture to a fish bowl. I mean it used to be a wetlands that was connected to the Illinois River. Then for 70-80 years it was separated from the Illinois River and it was periodically pumped so that it became a row crop agriculture site. And now the pumps were turned off, and it turned into this rain collected fish bowl, a really beautiful fishbowl. I really admire that fishbowl but it's a fishbowl. And now the question is should it be transformed into a fishbowl that takes in river water? But you're not restoring, you're not reclaiming it, you're reusing it in a different way. It certainly hasn't been what it is now before." (RS)

Another term, little used today, is rehabilitation defined by NRC (1992) as

> *REHABILITATION* - Used primarily to indicate improvements of a visual nature to a natural resource; putting back into good condition or working order.

The term 'naturalization' has been used subsequent to the NRC (1992) report to refer to a particular kind of restoration (Sparks et al, 1998):

> "They define naturalization as trying to restore some of the aspects of a natural system like meanders in the stream, but still preserving economic or productive human use of that system. So it's less stringent objectives than pure restoration which means returning it to a completely natural condition." (RS)

The term 'naturalization is problematic, however, as one might think of removing a manmade levee as naturalizing. Yet, unnatural means such as levees, floodgates or seeding, may be used to 'naturalize' an area. To avoid this issue, a researcher describing the Emiquon restoration effort settled on 'managed wetland' after considering some of the options:

> "It's controlled reconnection. I mean, there isn't a good name for it. It's more natural than the current state but it's not natural. It's artificial. It's controlled. It's managed. A managed wetland." (RS)

As an alternative to an isolated fish bowl, the concept of a managed connection between the river and the lake developed in time:

> "Migratory water birds are still going to use the area. And it will still be beneficial that way. But when it comes to river fish that need to find wintering areas or production of this area that needs to fuel the mussel beds in the river and things like that. Without some type of connection you are not going to have it. So that was kind of one of the outcomes was that most people thought that we needed to be some place in the middle with managed connection for now. Not complete isolation, not complete connection. But managed connection." (RS)

And the realization developed of the need for small steps once a major construction is in place and of the need to see these steps as being 'a lot of successes':

> "The idea of adding the water control structure you know, originally the idea at Emiquon was to blow up the levee and reconnect to the river. Uninhibited. That would have been the original vision. … But they have accepted the idea that no one is ever going to let them blow up the levees until they can show unequivocally that it won't be bad. The perception exists. They can't fight the perception. What they can do in the meantime though is do experiments inside Emiquon to give it as natural a variation as it would have with the river and use that somewhere down the road to say, look, we are literally with pumps flooding/drying, flooding/drying. Just exactly like the river is. It's fabulous. … Somewhere fifty years down the road somebody is going to stand on top of the levee and tell the governor and the DNR and the Corps of Engineers, tear the levee down. … So the next step is to put in that flow control structure … establish a controlled connection to the river. … a baby step of progress. Everyone wants to hit a home run when they come to the plate. It is going to take a billion baby steps to get to that point. And that's where Emiquon is having a lot of successes." (RS)

In order to understand an ecosystem as well as to monitor its state and how it changes, data is collected. For long-term work such as the restoration via scientific management, the management and preservation of, and access to, the data are key activities. The next section then turns to considering data.

4. Considering Data

In gathering participant views on work with data, a few broad topics were explored. Views on data management, data sharing, and data repositories in addition to infrastructure and data policy are described below.

4.1 Data Management

Data collection, sample analysis, and data tasks grow with projects as they include a greater number of participants. The coordination work required with data for 'pulling it together' is often underappreciated until the task is undertaken. Further, the complexity of decision-making and long-term ramifications introduced by digital constraints that enable data coordination are often underrepresented. Voices of participants working at Emiquon were laden with experience as they reported on lessons learned about data.

> "When we started out, we were just trying to get everybody coordinated and I had a grad student do this, and a chemist doing this. And even though they would kind of know what they were doing, pulling it together and looking for consistency, and especially if you get a lot of students who are learning this stuff, then maybe they don't pay attention to a decimal point." (RS)

> "There'd be pieces missing. Like you'd ask a student to do these dates, and then you know you'd look at the data, you've got these dates, but its hard because you have a block of data and you didn't notice until you put it into the spreadsheet, oh there's a block missing.

> Well where is it? Well where is that student? Where is that sample? You know, samples are starting to get misplaced, there are so many of them. So it's getting that organization, dealing with those matrices, all set up." (RS)

> "It became clear very early on about this coordination of previous research. And people will simply ask the question, has anybody done anything on the insects here? … I said oh, well we'll do that. We'll just put up a map and we'll have people do this. And then well it was a little hard to do that. … And so it became clear that something I just assumed would be trivial for computing is in fact rife with all sorts of interesting technical and policy problems. You just can't … it isn't trivial, it's non-trivial at several levels. … I thought it was a great idea. I still think it's a great idea, but it's absolutely something that is going to take a lot of work before it can be operationalized." (RS)

Change is evident in the field sampling at Emiquon with some scientists recognizing data taking as cumulative rather than as a one-time project activity. A redistribution of work was evident. In one case, what was previously a research assistant role that included collecting and analyzing samples morphed into a role of coordinating data taking and collecting as well as of data aggregating and checking. Sample analysis was frequently delegated to students. A researcher explained how he used to do the data management:

> "At the beginning, we had undergraduates helping do the chemistry and then I was helping do all the molecular stuff and the lab tech was kind of in the middle of trying to help for everything … It was good; it just wasn't good enough. What we've gone to is…well we've got some NSF funding so we could get the DNA out to a student that was trained at UIUC and then students were entrained for longer periods of time, at least through a whole season. I put myself out of the picture of sampling and got a student in the boat and then I was able to … try to keep things coordinated." (RS)

> "It used to all pretty much be me or a graduate student. And then, now we have a half-time technician doing it. And I kind of made that her assignment. It's really easy to have me to do things, but I give her basically three [tasks]. I hope she can do a whole bunch of other stuff. But I basically took most laboratory analysis away and asked her to do three things. Make sure we are ready to sample, and sample every week, if something's broken let me know, we'll get it fixed. Help make sure we are in supplies which keeps sampling and the whole thing going. But then on the other end, make sure that, that we establish a database, data gets put into that, and then it's checked for accuracy." (RS)

Short-term projects were manageable as one-time efforts but became untenable when aggregating data over time in a research environment where 'more is always better' and sampling is typically intensive. With changing amounts and distributions of work with data, it was not surprising that one researcher inquired about a new title to identify a new role:

> "If you give it [the data] to one person, they check it through, make sure its right. You know, does this look like last year? And that was a significant thing to do. And necessary. You need some kind of curator or librarian. What do you call these people?" (RS)

The reality of new data requirements is one thing, but as with most researchers dependent upon grant funding, there was the reality check in terms of increasing costs:

> " It's very necessary, but I don't know who pays for it" (RS)

A research assistant currently fills the role of overseeing the data. An experienced microbial ecologist, she did not think of herself as a data manager. She described her work in terms of the physical activities involved and then her view of data management:

> "I have to train and supervise my assistant. I have to keep the boat going. Make sure all the sampling materials are stocked so I have to do orders. I have to make sure that samples are accounted for. I have to know where they are, what stage of processing they are. I have to then keep track of the data that we've generated from those samples. I'm a data recorder and organizer. I just don't think of it as data management. I think of it as, I just put the data in the sheets and put it in an order that I can find it." (RA)

> " [As a data manager] I think you are working with data that's more different than that. Everything that I'm working with is very, very similar. And I'm thinking if you are working with different projects, from different people, you are getting more, more input from different sources." (RA)

The views of data management by other researchers varied, for instance focusing on the data itself where it is part of the 'stuff' of all researchers. Thoughts on data also included data help services at the field station and a community website:

> "To me a data management section means that it's a data library. So there's certainly data that you can use, and a reasonably good idea of some kind of quality control, that someone has looked through it. But then also it has the ability to be queried. You know ask things of it as opposed to a dataset of fifty-five different spreadsheets with twenty-five different formats and so forth. And then there is some kind of uniformity to it. The fields match up, wherever the common element is, by GPS, location, by date. Whatever that is. And then that the units line up. So you know that's true for every other person's stuff. I know that's a lot to ask but lastly, and if possible, if the methods can't be standardized, at least they are stated someplace. So when I go back and I look at, and I try to understand this guys idea of organic matter estimation. And you know the way I do it. Maybe it's not exactly the same, but I have some idea of how to state what's going on … Standard methods of course are always better." (RS)

> "What I would like a data manager at the field station to be doing is helping scientists get their stuff backed up with us and archived, making sure they know the kinds of things they can do to be compliant with the National Science Foundation because that is going to be important to them. And it will be important to our archive. To make sure that all the backups are being done both locally and at UIS. And then keeping the information, using the metadata, keeping the information current with what's up there on the website. You know, periodically doing a review to check to see if that accessibility can be increased with new software tools that are available." (RS)

> "Well I guess if I had to think about it [data management] conceptually, what I would think is that you have some type of a location. You know, URL or whatever that you go to and or maybe software that would combine and organize data from a lot of different studies." (RS)

The data management spoken of was seen as a library or archive, a queriable set of data and metadata, as well as a collection with standardized units and methods. A researcher used a 'soil-dirt' analogy to make clear the importance of metadata:

> "I know that metadata is a big thing. When I think about numbers I think about well you know data without knowing how it was collected, its kind of like dirt and soil. Right? Soil if you know which layer it came from its still soil, you can say it came from this location. This is the a-layer, this is the b-layer, you know. But once it is just on your shoes or whatever its dirt. You know and then I think of the same with data management, right. Its like you know data you know if you know where it came from and who took it and how many samples they did and what their methodology, you know, then it's still data. But once it's a number without that context then it's, you know it's kind of like dirt … you can't understand what that number means anymore." (RS)

There was not only acceptance that data management would be part of the planning process, there was vision expressed that included "establishing a good framework", "phasing it in", "all using the same template to make it easy for people to submit their data.'' A new organizational chart provided evidence of change. In the new chart, data management was a label on one of the boxes. Some concern was expressed about whether they could find somebody to do the job of data management and whether they could get funding for the position. There were also plans to hire a field station manager. Following a suggestion made by the two information managers who were present at the science meeting, field station planning included consideration of whether to begin by having a designated role of data management with the role filled part time either by a field station manager or a field technician. The field technician had the advantage of having hands on data entry while the site manager was seen as having more longevity than techs "who will kind of cycle through as they work on their degrees".

Some thought was given to coordination with other stations since as one researcher reports, "it seems to me that we all have to be moving in this direction". There was interest in contributing to a partnered effort with other, more established organizations:

> "I would like to think of the field station as I can't say a disinterested third party, as the broker … We're thinking about it as the new guy on the block; these other guys on the block are steeped in tradition so maybe we could do this. Maybe we could be the data management people." (RS)

Protocols, also referred to as methods or 'standard operating procedures', and the work of ensuring they are followed is an important part of fieldwork. Some individuals doing fieldwork at Emiquon described protocols and their experiences with protocols:

> "There are all our methods we have written up in a book, electronically. And citations

> and if there have been any alterations, that is all done." (RS)

> "I was supervising but then people had a tendency to sometimes think that protocols aren't important. I don't know how you did it except that you just have to keep sticking your nose in there and trying to figure out why they do it that way." (RS)

> "Well one thing that's nice in having a lot of Masters students involved is they have to do their thesis proposal. So a lot of it [methods] get written down in a very formal way in the proposal which they defend before they do their summer fieldwork." (RS)

4.2 Data Sharing and Data Repositories

In scientific communities new to sharing data, the term collection is rather uncommon. Participants tend to think in terms of data need, use and availability. There are differences in use of terms such as 'data', 'files', 'datasets' and 'database' since scientific measurements and observations are aggregated and organized in a variety of ways. The use of these terms seems to remain particular to individuals and situations until there are concrete shared examples around which common vocabulary can develop.

Data Sharing

With data taken at Emiquon, what is called 'the physical and nutrient data' in one circumstance was referred to as 'the physical dataset' at a later time. The 'physical data' category included biomass, a biological measure. Although formal, standardized sharing of data did not yet exist for Emiquon participants, two researchers identified a five-year, weekly time-series as a core dataset, a 'data gem':

> "The five-year dataset that [they] had been keeping on lake Thompson. No doubt. I mean that absolutely, to me that is the data gem that has been created at that field station." (RS)

> "I think that five-year dataset would be a dataset … it would be all the DNA, and all the physical, and all the chemistry, and all the plankton. That would be the dataset." (RA)

This five-year dataset was described at various times as having two, three and four data streams so an illustration of the multiple streams was developed collaboratively (Figure 2). The exercise revealed the identification of an on-going time series of data streams bundled into a collection as a final data product.

Though community-wide views of Emiquon data and terms for collected data did not exist, the purpose for aggregating and sharing data was articulated in this simplified yet advanced vision of querying an established 'floodplain dataset':

> "Do we have a regime shift or an altered stable state going on in early restored lake? Well, I say, you can use our five-year dataset and look at that. … it would be nice if you just plug in some parameters into a database and ask that." (RS)

One researcher, with students who are each using the work of others, was aware of the importance of context and metadata. She explained how she would go about sharing data:

> "Most of our stuff is actually just in the Excel files … so that's what I would send you.

Before I send it to you though I would probably add another sheet in the front to try to put as much orientation on there so that you could interpret it. I think I have the information I need, but you know, obviously you have to look at it from the perspective of somebody who didn't do the sampling and doesn't have that recollection." (RS)

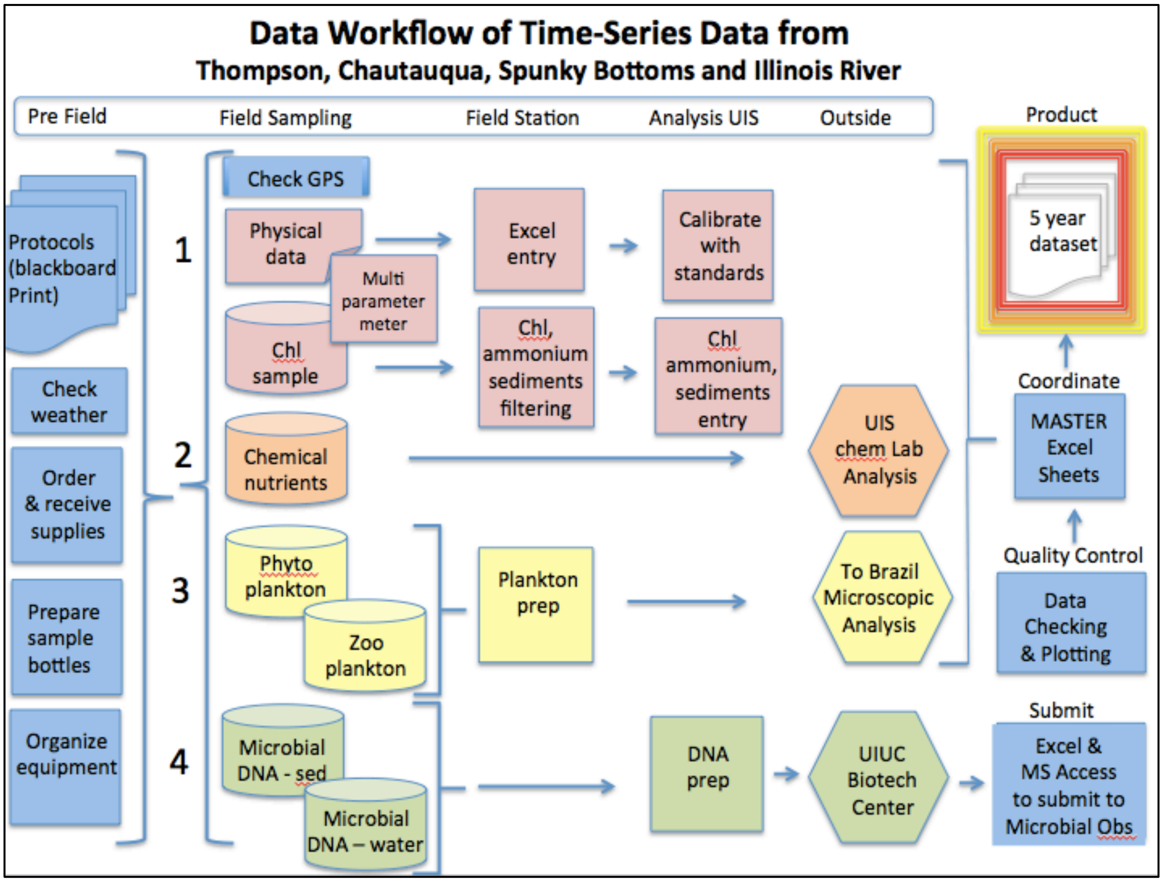

Figure 2. The four data streams of an Emiquon time-series dataset.

With respect to research partners, there was awareness of data at other sites but little knowledge about the management or access to these data:

"I know they generate a lot of data. But I don't know how they manage it." (RS)

"You know there are different studies going on in different lakes, with ducks on all these different lakes. And nutrients, what the USGS does … And even within the investigators here, I don't know how much coordination we have of the data. Like I know across river they have veg data and they have fish data, but you know I don't have access to their datasets. I don't know that I'll have any trouble doing that but it would be really nice if we could say, well what about this question?" (RS)

Having data available for query, brought to mind for one researcher what might occur serendipitously if data were available for reuse beyond its original intended use:

> " It's something as simple as: What are the states of the flood lakes on the La Grange Reach? Or the coordinates? When do they usually flood? Do they have a warm water flood? A cold water flood? And then what other data are available on those lakes at which times? … You might not find exactly what you want, but all of a sudden you might find a whole bunch of things that you start asking questions about." (RS)

Some scientific questions had been asked but not answered due to lack of data:

> "That question of the warm water versus cold water flood is in the literature and what its effects are. I don't if its been tested empirically at all or if there's data to support it. You know, to see if one's more … more sediment rich." (RS)

Data Repositories

A data repository is defined as a place where content and descriptions of the content are deposited and where basic services are provided (Heery and Anderson, 2005). It is a sustainable organization that is trusted. Services include storage, archive, preservation, organization, access, and management for one or more data collections.

One participant associated with TFSE field station provided their view of an individual's collections of digital data as

> "I guess this [a spreadsheet] is a data repository … My computer is my own personal repository." (RA)

and another individual identifies the data repository as an 'essential place' from which data can be accessed:

> "a location, it may be online … basically you can store the data in this essential place. And scientists can access, with certain permissions, access the data." (RS)

Another participant familiar with computers at TFSE showed awareness of the many issues that accompany an aggregation of data when defining a 'data repository', i.e. multiple stages of repository development (data description, archive, access), multiple stages of data (raw, cleaned), release date requirements, and need to deliver data from an imagined 'depository' as part of the identity of a field station or a program:

> "I think we would want the cleaned up data rather than this preliminary data. But their data is submitted to our archive with either a default or a negotiated date at which we can make it public. And that public [access] is through the field station's website. And it's a big data depository. At first it will simply be archived and you have to know the day and the person. Some day we will make it searchable for people. I would really like to have every dataset that is in that archive have as part of its metadata the physical locations by GPS coordinates, latitude and longitude coordinates." (RS)

This same participant described the importance of planning arrangements for community data from multiple sources that ensure security and public access, defining a data repository as:

> “ a place where you can store, archive, backup, a secure location for data. When I use the word repository I think of it as multiple people and institutions, multiple people have added their own data to it. … You could be a repository and archive without being publicly accessible. But this one I would want to have some provision for making it public.” (RS)

While national strategies for data are under discussion (Treloar et al, 2012; Berman, 2014), there are also strategies for local research communities to consider. Baker and Yarmey (2005) highlight the importance of the data repository position in terms of its ‘distance-from-origin’ of the data. They identified two categories of repositories - local and remote - where local refers to those associated closely with the community that has first-hand knowledge of and experience with the fieldwork and remote refers to those more distant from the origin of the data such as institutional repositories, community centers, and national archives. Though participants tended to talk about individual ‘sources of data’ rather than kinds of data repositories, TFSE participants mentioned a few remote repositories: the U.S. Army Corps of Engineers river gage data, the Illinois State Water Survey weather data, and the U.S. Geological Survey water quality data. Beyond these repositories, field researchers at Emiquon were generally not connected or exposed to the many past and ongoing data efforts and repository development activities.

The one data repository all researchers in this study had heard about is GenBank for genomic data.

> “I guess the model I think of is NCBI, you know GenBank. I mean I gotta have all my sequences in FASTA format. And then there's all this metadata that goes in there. And I have to enter that. And then there's a way to batch file it and so forth. But you know, somebody has figured that all out. Now that's just for specific genes and where they are collected and so forth … there's just tons of different genes too … And you know what, and that's such a smart thing, you can't publish your data until you submit your work into GenBank. I don't know if we can ever pull it off, but whoever worked up that agreement was really thinking ahead as far as the whole gene revolution.” (RS)

GenBank provides a general understanding of shared data. The requirement for submission of data to a repository prior to publication was a pivotal event in the life sciences (Jones et al, 2006). As a model for heterogeneous biological data, however, it is misleading in that genomic life sciences data and biological field sciences data have significant differences. The need for protocols, description, vocabularies, dictionaries, collections, and formats in the biological field sciences has not been fully articulated or coordinated. New processes are required for developing and maintaining dictionaries and even standards by engaged community participants at all levels – individual, laboratory, department, state, national and international levels – and coordination across many fields – domain science, information science, and library science. Indeed, the roles for and relations among various kinds of field data repositories have yet to be identified as part of a web-of-repositories or an ecosystem of data systems.

At Emiquon, one researcher in considering the meaning of ‘local’, took into account not only the data needed for scaling to larger ecosystem questions at the site but also the community work needed to define how to organize and share their data. If it is ‘site-based’, how is the site defined, i.e. Thompson Lake, the floodplain lakes, the Illinois River or all the preserves?

> "I think it might be regional. Because I think people at Spunky could come to our field station. People at Chautauqua. … It's up on the bluffs, it's down the river, it's up the river, and people have done things with mussels …You know it's going to be broader." (RS)

Rather than defining data repositories, the National Science Board Report (NSB, 2005) provided a general definition of a digital data collection that includes "not only a database or group of databases, but also to the infrastructure, organization and individuals essential to managing the collection." They defined three kinds of data collections: research, resource, and reference data collections. Meanwhile, data repositories are emerging with one, two or all three of these kinds of collections. In practice, data may begin as 'research' and through time and community use may be recognized as 'resource' or 'reference'.

4.3 Infrastructure and Data Policy

Both infrastructure and data policy are central to data management efforts.

Infrastructure

Infrastructure is a concept discussed in the science studies literature as a way of considering the coordination or alignment of multiple elements that support collective endeavors. Examples of infrastructure include telephone systems, information system networks, and help desks (Edwards et al, 2007; Star and Ruhleder, 1996). Early work highlighted the technical aspects of infrastructure but more recently includes consideration of social or human and organizational aspects (Ribes and Lee, 2010; Bowker et al., 2010; Bowker, 1997).

From a data collection perspective, the Therkildsen Field Station represented a new element in the infrastructure supporting scientific field research at Emiquon:

> "What Emiquon offers is the field equipment on site … we have it so that the prep can be done here and the post sampling processing. So by the time they get in every week, things are stable. They [the samples] are either on a filter, they are frozen, they are preserved, bam, done. As opposed to when we used to sample a big part of the data [by] hauling our boats out, sample, and then people are very exhausted. We'd get back [to the university] and then hand all these samples over to one group of people who are doing filtering, one group of people who are doing the processing. And it was pretty exhausting." (RS)

There are a variety of pieces that contribute to data infrastructure that must be in place to support contemporary field science. Not all participants have considered all the arenas and how they must align.

> "Well I would say there'd be machines, protocols, and a person, at least one person, designated at the field station. Then there would be machines, protocols and people here at UIS. And then there would be a virtual infrastructure, so that people from outside can access the data that is essentially received and processed at the field station and archived at UIS. And perhaps somewhere else in the cloud. But so I see it as a three staged, three-piece model. The field station, UIS, and Internet virtual presence. (RS)

In these statements we hear a researcher recognizing technical (machines), social (protocols), and organizational (positions) dimensions of data infrastructure that reaches across multiple arenas - field station, university, and public arenas – in support of data management.

Data Policy

To carry out sampling at Emiquon, a permit from The Nature Conservancy is required. There is awareness and discussion of the possibility of creating a data policy clause in the permitting process. This idea was explicitly discussed during the field-station planning workshop. Permission is generally granted to applicants although when digging is involved, there are more factors to consider given the number of archeological sites in the area. One researcher imagined a policy where a permit would put in place a plan for data to be submitted to a central database associated with TNC:

> "OK, in the best of worlds I like to see it as some kind of cooperative. I think we all recognize, or certainly they [TNC] recognize the need. I don't know if they have staff, I don't know that we have staff, enough staff. But we all see the importance, so I'd like to work out a policy that they basically invoke. Rather than handing the data over for them to curate, I would hope that the field station could have someone who gets it massaged or tells you how to massage it to put it into the database." (RS)

There are a number of unrecognized assumptions in this approach including establishment of a new data repository and the tie of permitting to data submission. At the time, the permitting procedures, practices, and records were overseen by one individual. Design work on a process, a database and/or automated online functionality would be required to tie permitting together with a data repository for a community. Another example of over simplifying was the suggestion that an overview log of activities could quickly enable plotting of sampling sites across projects. For those new to collective data work that is scaled beyond the individual researcher to a community level, the costs involved and complexity of such tasks are often underestimated.

5. Discussion

5.1 Considering Data Management at a New Field Station

Biological field stations are recognized as an important part of the natural sciences (Brussard, 1982; E.O. Wilson, 1982; Billick et al, 2013). A field station marks a shared geographic space; it creates a focal point around which research is conducted. The field station is a 'place', a 'site' or a 'destination', where observations and measurements of the natural system are made by a number of researchers tied together by location. Site-based studies may be contrasted with laboratory-based, event-based, project-based, and computationally based efforts. Having field site logistics and the biome in common as well as having station personnel who share information across projects as part of their everyday work, heightens awareness of related studies. Cross-project interactions can range from unplanned information sharing to informal cooperation or more formal coordination and collaboration. Scientifically, the field station may be regarded as a site where field researchers can count on meeting others – either serendipitously or by design – with interests in the same locale.

Though recently established, TFSE had site check-in procedures and station use permission forms. An array of options relating to support of the physical structure were still under consideration. Decisions about field station arrangements and orientation will influence the degree to which the station supports individual and/or collaborative data endeavors (see Section 3.4). There are a number of kinds and levels of data services that a field station can develop to support work with the community of researchers engaged in data collection at the site. For example, back up services and centralized shared storage can be developed to support the exchange of files among researchers as well as multi-level permissions for file access. Additional services may include shared equipment such as GPS units, data work sheets, procedures, and data bases as well as maps and description of established site sampling stations.

With data sharing requirements mandated recently for scientific research, some field stations with agency funding have a growing awareness of the need for data management. Scientific collaboration as well as data management have been identified as a priority at these field stations including those associated with the Organization of Biological Field Stations where a registry of field stations and a collection of resources have been developed (Brunt and Michener, 2009). European and Nordic countries have also initiated efforts centered on 'platforms' as an approach to coordinating science and data (Singh et al., 2013; Mauz et al, 2012).

5.2 Recognizing the Role of Language

Identification and use of terms and concepts by a community involves negotiations that are an important part of scientific knowledge generation. Subtle but important distinctions in terms are worked out over time as was the case with floodplain restoration in Section 3.5. Differences may seem minor or pedantic to an outsider but are critical to creating a shared vision and vocabulary, a foundation upon which researchers can build collectively. The scientists interviewed for this study all had experience with the concept of wetlands and ecosystem that had been explored in earlier disciplinary discussions. The concepts of floodplain ecology and restoration science, however, were the subject of ongoing discussions. Emiquon participants mentioned a number of pairs of terms with critical distinctions between them such as rivers and waterways, reaches and pools, natural and unnatural, and mitigation and restoration.

Many concepts relating to data management were emergent, under discussion by researchers in a number of disciplines as well as researchers within data centers and in schools of information science, librarianship, and informatics. Data practices in particular existed until recently as tacit knowledge exchanged informally at various levels, i.e. within laboratories, projects, and domains as well as in the field (LSE, 2013; Borgman, 2012; Palmer, 2007). Data management plans require scientific researchers to put into words how they conceive of their data as well as how they plan to manage and share datasets. Language, aiming to make more explicit the handling of data, is being developed through ongoing research into data organization and information systems that focuses on fundamental concepts such as collections, datasets, and standards (Yeo, 2012a, 2012b; Renear et al., 2010; Wickett et al., 2011; Rumble et al., 2005). Such concepts are deceivingly simple, requiring great care to define effectively for those situations involving data from more than a few researchers.

Identification and explication of concepts relating to data such as 'data management' (Pryor, 2012; Strasser et al., 2012) and the 'data lifecycle' (Higgins, 2012) has increased in recent years. Yet, conceptualization of data management and its elements differed among participants in this study (see Sections 3.6 and 3.7) who have little experience with organization of heterogeneous data and data systems design. The differing views are not incompatible but impact perception of priorities.

A poster was presented at the Emiquon annual science conference (Figure 3) addressing the use of the term 'database'. When 'database' refers to 'the next step' in technical development, it seems to convey the idea that all the data and information issues will be solved by a singular digital effort to implement a relational database. To open up this technology-oriented database view, an information system view was presented side-by-side with a database view. Three of the major elements of data systems are shown: a) data gathering and format transformations required in support of data ingestion, b) backend database elements that handle metadata and datasets, local content such as personnel, bibliographic materials, and events as well as global content such as policies, codes, keys and vocabularies, standards and protocols, and c) front end interfaces that provides web access and download of data. The science-oriented information system view also includes mention of a data advisory committee, data policy, data manager, data catalog, data download and connections with remote repositories.

At the TFSE meetings and in the interviews, stories of the field station and data collection circulated, appearing over time in multiple guises, some of which are captured in Section 3. There were 'origin stories' as well as stories about history, wildlife, individual experiences, and the 'imagined future'. There were stories about events, e.g. the years of major floods and about The Nature Conservancy 'doing the right thing' with restoration of Emiquon. Such stories contributed not only to field station identity and visioning but also to the context within which data were generated and sustained.

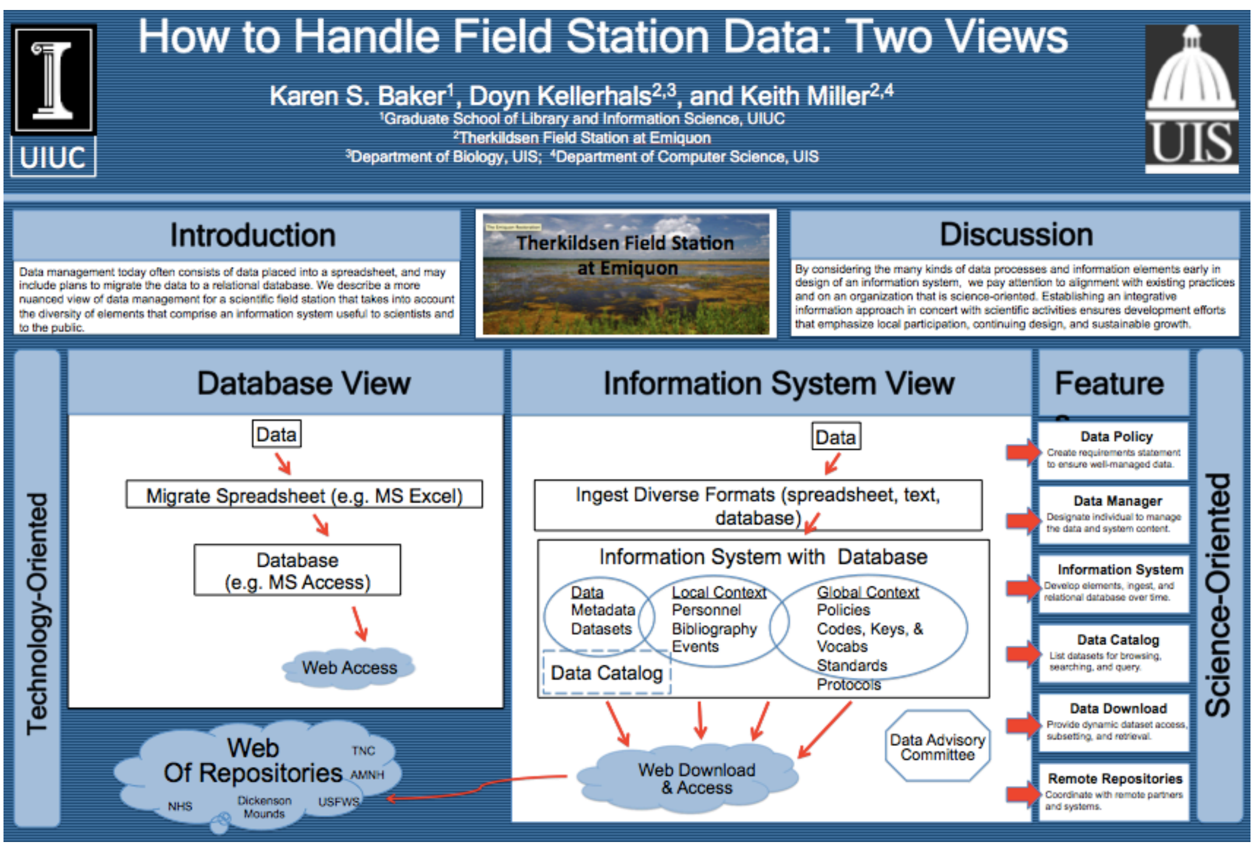

Figure 3. Emiquon annual science meeting poster at UIS on March 7, 2013.

5.3 Considering Elements of Digital Infrastructure

A three-part model developed to describe the distinct arenas where infrastructure pertinent to TFKE existed: the field station unit, the university (UIS) sphere, and the Internet virtual environment. Infrastructure building began in each arena, informally and formally. Inclusion of data management in TFSE plans and scientific meetings at this early stage introduced options for and experience with scientific infrastructure in conjunction with field station projects as well as organizational partners. The role of the field station in the context of the differing data arenas and infrastructures has yet to be developed.

TFSE had a website although it did not play a central role in establishing identity for the field station, an unsurprising finding given its short history. Technological infrastructure for the TFSE website was located on servers at UIS. The website was overseen by participants in different departments rather than by a single web master. Emiquon participants spoke of the website as hard to keep up and mentioned that other social media might be more effective for communications. The Long Term Ecological Research (LTER) Network provides a contrasting example. An LTER site's webpage is an integral part of its identity and of its routine evaluation (LTER IM, 2007). For the twenty-six sites in the LTER Network, the data management component oversees the website so that data-related staff are tightly connected with the presentation of online resources. The capacity to represent the 'story' of a site grows over time, often driven by current scientific activities and concerns that are captured for delivery on the web. In the LTER cases, a website often serves as a record of the site's history.

UIS is well known for online learning which suggests an associated technical support component. Expertise with these systems differs from that of the myriad of software applications currently in use and under development across the world intended for use in both local and remote venues as data repositories. In exploring potential avenues for synergistic infrastructure growth, inquiries were made with librarians and technologists at UIS. Research participants pointed out that the UIS facilities had the benefit of being well outside the floodplain and of having a number of dedicated staff that are both familiar and trusted. As a teaching university, however, UIS has not had much call for preserving scientific data. UIS librarians are aware of some data curation activities at other sites. A typical first step for a university or library entering the digital arena today is to aggregate products of university individuals (their publications, reports, posters … and sometimes data) by establishing an institutional repository. For this activity, the UIS library currently makes use of the institutional repository established by its sister university, the University of Illinois at Urbana-Champaign (UIUC), a school that is much larger and research-oriented.

A variety of potential infrastructure-building activities were identified to explore in upcoming years. In addition to considering infrastructure at the UIS library and UIS IT department, data management strategies remain to be explored together with partners such as The Nature Conservancy and the Illinois Natural History Survey with its two field stations across the river from TFSE. A data management workshop for Emiquon was identified as a potential next step at the new field station meetings in order to create a forum where information on existing data practices and future strategies could be shared by the Emiquon community. In 2016 such a gathering was held and referred to as a data stewardship workshop (Walk et. al, 2016)

5.4 Data Management Actions and Activities

The writing of a data management plan by a member of the research community was the point at which data management was introduced into discussions at Emiquon. To write the data management plan, an online investigation of existing approaches to data management was carried out. The resulting plan was highly optimistic, ambitious, and solution-oriented. It revealed a theoretical understanding though was lacking in practical details and timeframes:

> "A major part of the proposed planning will be establishing among the partners a common protocol for collecting, processing, analyzing, and documenting data products; and for archiving, curating, and publishing these products." (RS)

In this statement, there were assumptions about archiving as a routine task, protocols as readily enacted, data products as easily identified, and publishing as an appropriate metaphor for data delivery. With its lofty expectations, the unfunded mandate to share data was seen as an opportunity to enhance local capabilities by engaging with contemporary digital issues. Organizational recognition of new data responsibilities was made visible briefly when data management appeared on the draft of an organization chart. The field station planning grant meeting for research participants supported attendance of two information managers (one currently at Andrews Forest LTER site and myself, a doctoral student at UIUC) who were invited at the suggestion of a researcher who received his doctorate while working at the Andrews Forest LTER. At the wrap up session, each participant generated suggestions about top priorities for the TFSE. There were two suggestions from the information management representatives: 1) recognize the role of data management by designating a data manager and 2) incorporate in The Nature Conservancy sampling permit process a statement about data.

Despite differences in definitions and conceptualizations of data management, TFSE and Emiquon leaders and participants were aware of and tending to introduction of data management at Emiquon. The following list summarizes data management related actions carried out during this study:

- Identify and include data specialists at initial planning meetings
- Include experienced data and information experts at science meetings
- Include presentations and updates on data management at annual science meetings
- Invite data management participants to meetings with partners
- Incorporate data management discussions in research planning activities
- Send delegates to meetings of the Organization of Biological Field Stations where data management is a recognized priority

Mentioned in the course of observations and interviews for this study, the following potential actions would benefit from discussion over upcoming years:

- Hold a data management workshop
- Create and designate titles such as data manager, specialist and/or contact as beginning data teams within an organization
- Form a data management committee with members from organizations situated at or near Emiquon
- Provide briefs at partners meetings on data management themes, issues, and opportunities
- Work on the sampling permit procedures to standardize project metadata
- Create a list of standard sampling site names and locations
- Design a mechanism that supports sharing of lists and catalogs

- Develop and make accessible a data dictionary that defines parameters and units
- Initiate and make accessible a collection of sampling and measurement protocols
- Consider development of a research-oriented website
- Consider inclusion of a statement about data in the permitting process

A data management trajectory includes all the factors that influence work with data – the diversity of the data itself, the kinds of individual investigator data needs, the particular talents and interests of staff members, the degree of collaboration established by field station participants, the infrastructure elements at local and institutional levels as well as the state of institutional and domain data initiatives. The number and complexity of interactions involved makes it difficult to develop a long-term vision of data management efforts. Future planning is particularly intractable with so many factors subject to change – organizational structure (e.g. library services and university arrangements), community membership (e.g. shifting department members and staff), technology resources (e.g. hardware and software), and funding streams. Faced with change, a data management strategy must plan for organization and migration of project data – to a new schema, a new system, a new location – by adopting a 'continuing design' mindset that assumes reconfiguration of data management elements even before any data are submitted. Such a mindset predisposes participants to a view of data management as an ongoing process.

Leaders asked 'who pays for this?' in reference to data management. The TFSE response will depend upon decisions relating to the position of the field station both within the university and within the Emiquon partnership. There are a number of possible approaches at TFKE:

A. Minimum Data Management Role: Provide basic technical services such as field Internet connectivity, data storage and back up for field station participants
B. Moderate Data Management Role: Establish basic data management procedures (e.g. metadata templates) and resources (e.g. protocols and data dictionaries) addressing data needs of researchers at the field station
C. Major Data Management Role: Develop and enact data management and data repository services addressing data needs of researchers at the field station and coordinating with other research efforts at Emiquon Preserve

The development of major and even moderate local data management has long-term implications in terms of support requirements but also in terms of a) enactment of new local procedures, b) requirements for programming and system expertise; c) ability to coordinate with Emiquon and other community data efforts. How data management work is configured at a site depends upon the infrastructure elements a site can establish or leverage from existing arrangements. Identifying and providing data management services is a long-term undertaking that requires careful planning in terms of benefits and budgets.

5.5 Levels of Organization and Situated Learning Processes

By the end of the TFSE two-year planning grant, there was recognition and interest accorded the role of 'data management'. Leaders were able to speak to the benefits of supporting data management, of "having one person… well, a data manager". There was both a sense of need and of inevitability about addressing new data requirements. This was influenced by a number of factors: the interdisciplinary approach with expertise in ecology, computer science and media studies; a tradition of taking in stride new elements in an ecological landscape; the relatively small scale of TFSE with a minimum of legacy technology issues, and even the serendipitous presence of one researcher having past experience with mature data management efforts and others having experience with collaborative scientific networks. In addition, there was the inclusion of outside advisors including experienced information managers in planning activities.

The development of both awareness of and interest in data management differs from reports in the literature about reluctance to share data (Birnholtz and Bietz, 2003; Cragin et al, 2010). It is an unexpected finding that prompts re-consideration of settings and events. The lack of resistance to the notion of data aggregation and sharing illustrates a desire to share data within partnerships. This suggests the need not only for discussions about motivation and incentives for engaging with data management but also for discussions about local infrastructure and the connection of local data efforts to larger-scale data initiatives.

6. Final Thoughts

The topic of data management was introduced early in the establishment of Therkildsen Field Station at Emiquon. Formulating a data management plan initiated data management thinking at the site and made data management part of the station development process. It brought data management into the discussion of aims for the field station and developed in the minds of research leaders at Emiquon as an integral part of the research process.

The notion of the development of data management incrementally as a process that proceeds in steps that you're able 'to phase in' is a difficult concept for those who conceive of information technology as providing 'solutions' to 'problems'. In addition, there is a general lack of understanding about the extent to which data management and data repository efforts are nascent and the subject of ongoing research. Initial perceptions of data management at TFSE varied from thinking in terms of phasing in data management to thinking it existed elsewhere and could be adopted at Emiquon. Even when data management was seen as an ongoing process of articulation, collaboration, and coordination in a landscape of shifting options, however, researchers still faced the need to identify and prioritize a multitude of potential activities.

The NSF approach of mandating data access and requiring data management plans initiated change at Therkildsen Field Station at Emiquon and Emiquon Preserve but the specifics of how to change were unclear. The new requirements for agency funding prompted the TFSE field station and its community to explore the concepts, aims, and products of data management. This case provides an example of the introduction of data management planning at a field station and across a multi-organizational, multi-sector community engaged in site-based environmental research and restoration science.

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Table 1. Timeline of Events for Emiquon

- 1818 Illinois became the 21st state. Emiquon was a largely unaltered floodplain of the Illinois River
- 1840s Floodplain forests along the river were logged for fuel for steamboats
- 1848 The Illinois and Michigan Canal was completed, connecting the Illinois River to Lake Michigan. The canal became obsolete by 1860 with the advent of railroads. It also became grossly polluted with wastes from towns and the city of Chicago.
- 1858 Illinois Natural History Society established at the Illinois State Normal University
- 1871 The Illinois and Michigan Canal was deepened, but Chicago sewage still flowed into the city's drinking water intakes in Lake Michigan during rains.
- 1872 The first navigation dam was constructed at the town of Henry. Stephen A. Forbes was appointed Curator of the Museum of the Illinois State Natural History Society at Normal.
- 1876 Stephen A. Forbes began his studies of Illinois River fishes
- 1877 The State Legislature converted the former Natural History Museum at Normal to the new State Laboratory of Natural History, with Forbes as Director. A State Historical Library and Natural History Museum were established in Springfield. Copperas Creek Dam constructed just upstream of Emiquon.
- 1880s The common carp (Cyprinus carpio) was intentionally introduced to the Illinois River and quickly became a dominant species in the commercial fisheries.
- 1885 The State Laboratory of Natural History moved to the University of Illinois, with Forbes as Director. The name was later (1917) changed to the Illinois Natural History Survey (INHS).
- 1894 Forbes established a Biological Field Station "for the continuous investigation of the aquatic life of the Illinois River and its dependent waters, near Havana." It was the first inland aquatic biological station in the world to undertake studies of a river system. In 1989, the station was renamed Forbes Biological Station (FBS, INHS)
- 1895 INHS scientist Charles Kofoid began a 5-year study of the plankton of the Illinois River.
- 1896 A 60-ft houseboat was built in Havana under Forbes' direction as a floating laboratory.
- 1887 Forbes published "The Lake as a Microcosm" in the Bulletin of the Peoria Scientific Association. It is republished and received wider attention in 1925 in volume 15 of the Bulletin of the Illinois State Laboratory. This paper was regarded as one of the landmark papers that helped define the then-new science of ecology. It also introduced the role of the advance and recession of seasonal floods in expanding and then contracting the habitats, food supplies, and populations of organisms.
- 1889 Another navigation dam was constructed downstream of Emiquon at La Grange.
- 1890s A pearl rush depleted mussel beds in the river.
- 1893 Another navigation dam was constructed at Kampsville, downstream of Emiquon.

- 1900 The Chicago Sanitary and Ship Canal opened, reversed the flow of the Chicago River, and flushed untreated wastes from Chicago (including the stockyard and meat-packing wastes) downstream into the Illinois River. The wastewater and the dilution water from Lake Michigan greatly increased the flow downriver and doubled the surface area of ponds, sloughs, lakes, and marshes on the floodplains. Bottomland forests at low elevations drowned.
- 1901 Market hunters continued to ship waterfowl by rail to Chicago and other cities. Not until 1903 were hunting limits (50 ducks per day) established. Thompson Lake and its environs were purchased by businessmen from Chicago and from Terra Haute and Indianapolis, Indiana, to form the Thompson Lake Rod and Gun Club, also known as the Indianapolis Rod and Gun Club.
- Early 1900s The Illinois River is the most productive mussel river in the U.S. The shells are used to make pearl buttons for clothing before plastics.

- 1908 The record annual fish harvest from the Illinois River: 20 million pounds (9.1 million kg), 10% of the nation's catch of freshwater fish. Forbes and Robert E. Richardson published Fishes of Illinois.
- 1917 The Illinois Supreme Court ruled that Thompson Lake and its surroundings were private, not public, property that could be leveed and drained.
- 1919 The state of Illinois begins construction of the Illinois Waterway to improve navigation.
- 1921 Construction of the levee around Emiquon began. By 1924 the former beds of Thompson and Flag lakes had been drained and were under cultivation. 1923 Pollution from Chicago killed fish, mussels, and plants as far south as Chillicothe. The upper Illinois River became hypoxic—a dead river. The yearly advance of pollution and the invertebrate indicators of various stages of pollution were documented by INHS invertebrate ecologist Robert E. Richardson.
- 1922, 1923 and 1926 Major floods cause millions of dollars in damages and force some levee districts into bankruptcy, including the levee district that eventually becomes the Chautauqua National Wildlife Refuge during the 1930s.
- 1930s USACE constructs locks and dams to create a nine-foot navigation channel from the Mississippi River to Lake Michigan. The Civilian Conservation Corps constructs state parks and lodges along the Illinois River (Starved Rock and Pere Marquette) and a building and foot bridge for the INHS field station on the Chautauqua National Wildlife Refuge.
- 1943 Fourth highest flood recorded at Havana gauge (26 May1943)
- 1970 National Environmental Policy Act (NEPA). USACE was subsequently required to assess the environmental impacts of the nine-foot navigation channel on the Illinois and Mississippi rivers and the potential impacts of a proposed increase in Lake Michigan diversion on the Illinois River.
- Council on Environmental Quality (CEQ)
    - 1972 Passage of the Clean Water Act by US Congress
    - 1974 Water Resources Development Act by US Congress
    - Nine subsequent related acts 1976 to 2007

- 1980-1986 Illinois Large River Long Term Ecological Research project (National Science Foundation)

- 1985 Third highest flood recorded at Havana gauge (9 March 1985)

- 1986 Upper Mississippi River Management Act of 1986
    - Twin mandates: economic development and river restoration
    - Upper Mississippi River Restoration Program established by USGS
    - Long-Term Resource Monitoring Program (LTRMP) established by USGS
- 1989 Illinois River Biological Station established (IRBS, INHS)
- 1993 Great Midwest Flood of 1993, 15th highest flood on the Illinois River at the Havana gauge (29 July 1993); highest flood on the Mississippi River at the St. Louis gauge (1 August 1993). Spurred a reexamination of the nation's flood management policy and serious consideration of nonstructural approaches to reducing flood risks, such as allowing some levee districts to flood during major flood events to reduce flood crests elsewhere. NSF SGER grant to INHS assessed the effects of the flood on nutrient status and vegetation communities of the floodplains.

- 1998 Emiquon Conservation Plan by The Nature Conservancy (TNC)
    - Worked with partner organizations to conserve biodiversity in the river
- 2000 Emiquon formed as Illinois River floodplains restoration project
    - Nature Conservancy >7,000 acre purchase designated Emiquon
- 2001 TNC Emiquon Science Advisory Council established

- 2005 pumps stopped at Emiquon; rainwater (re)creates lakes behind levees
- 2005 Therkildsen Field Station at Emiquon (TFSE) planning begins
    - Nature Conservancy land; University of Illinois, Springfield building
    - Friends of Emiquon non-profit established at UIS
- 2007 First annual Emiquon Science Conference

- 2008 Therkildsen Field Station at Emiquon, UIS established, Director Michael Lemke
- 2008 Prairie Research Institute (PRI) at UIUC created for transfer of four state surveys:
    - Illinois Natural History Survey (INHS)
    - Illinois State Geological Survey (ISGS)
    - Illinois State Water Survey (ISWS)
    - Illinois Sustainable Technology Center (ISTC)
- 2010 Illinois State Archaeological Survey (ISAS) added to PRI
- 2010 NSF 2 year field station planning grant (M.Lemke PI, UIS)
    - 2012 Science planning meeting with two LTER Data Managers invited (Nov 08)
    - 2013 Education planning meeting (Feb 22)
- 2012 Emiquon "Wetland of International Importance" designation by Ramsar Convention

- 2013 TFSE initial ethnographic study of data work (March – June)
- 2013 Emiquon Annual Science Meeting in March; first Data Management Poster
- 2013 Highest flood ever recorded at the Havana gauge (25 April 2013)
    - Emiquon levee briefly overtopped.
- 2013 Emiquon Rapid Grant funded by NSF (2013-2014)
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- 2015 Second highest flood at Havana gauge (1 July 2015)
- 2015 TFSE second director, Thomas Rothfus
- 2016 Fifth highest flood at Havana gauge (4 January 2016)
- 2016 Emiquon Data Stewardship Workshop by TNC (March 21)
- 2016 IRBS Data Rescue Project with UIUC Archives (April 13)
- 2016 Emiquon levee gate completed for managed connection to the river (July 2016)

Table 2. Acronyms and Links

Acronym	Name	Link
CNWF	Chautauqua National Wildlife Refuge (USFWS)	http://www.fws.gov/refuge/chautauqua/
Dickson	Dickson Mounds Museum	http://www.museum.state.il.us/ismsites/dickson/
DNR	Department of Natural Resources	http://www.dnr.illinois.edu
ENWF	Emiquon National Wildlife Refuse (USFWS)	https://www.fws.gov/refuge/Emiquon
Emiquon	Eminquon Preserve (TNC)	http://www.experienceemiquon.com; http://wwx.inhs.illinois.edu/fieldstations/irbs/research/emiquon/
Forbes	Stephen A. Forbes Biological Station (INHS)	http://wwx.inhs.illinois.edu/fieldstations/forbes
HREP	Habitat Rehabilitation and Enhancement Program	http://wcb.ca.gov/HERP
INHS	Illinois Natural History Survey	http://inhs.illinois.edu
IRBS	Illinoios River Biological Station (INHS)	http://wwx.inhs.illinois.edu/fieldstations/irbs
IWRC	Illinois Water Resources Center	http://extension.illinois.edu/iwrc
LTER	Long Term Ecological Research Program	https://lternet.edu
LTRMP	Long Term Resource Monitoring Progam	http://www.umesc.usgs.gov
NGRREC	National Great Rivers Research and Education Center	http://ngrrec.org
NMF	National Marine Fisheries Service	http://nmfs.noaa.gov
NSF	National Science Foundation	http://nsf.gov
TFSE	Therkeldsen Field Station at Emiquon (UIS)	http://uis.edu/emiquon
TL	Thompson Lake	http://www.experienceemiquon.com/content/thompson-lakeemiquon-story; http://www.ifishillinois.org/profiles/display_lake.php?waternum=15099
TNC	The Nature Conservancy	http://nature.org
UIS	University of Illinois at Springfield	http://uis.edu
UIUC	University of Illinois at Urbana-Champaign	http://uiuc.edu
UMRBA	Upper Mississippi River Basin Association	http://umbra.org
UMRCC	Upper Mississippi River Conservation Committee	http://umrcc.org
USACE	United States Army Core of Engineers	http://www.usace.army.mil
USFWS	United States Fish and Wildlife Service	http://umbra.org
USGS	United States Geological Survey	http://www. usgs.org