MEASURING STAKEHOLDER VALUE OF THE FOREST ECOSYSTEM SERVICE OF PROVIDING DRINKING WATER

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ABSTRACT

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Billions of people around the world rely on forest land to filter and provide clean drinking water. The high value that people place in drinking water can be a strong rationale for conserving and sustainably managing forests, however, people are often unaware of this forest ecosystem service of providing clean drinking water (FESDWQ). Understanding the value that stakeholders place in the FESDWQ is critical to informed and strategic conservation actions. A mixed-methods approach rooted in value-belief-norm theory and using social network analysis was employed measuring the value stakeholders place in the FESDWQ in three watersheds in Michigan. This research assessed 1) how stakeholders value the link between forests and drinking water, 2) the social network of stakeholders impacted by the FESDWQ, 3) the value of the FESDWQ as influenced by stakeholder interactions, and 4) the potential support for watershed management programs that utilize this FESDWQ.

Semi-structured interviews of individuals from a diverse array of stakeholder categories were conducted. Results show that stakeholders place the most value in water quality as a forest ecosystem service over other forest benefits, but this value does not transfer to the FESDWQ. Regulating over provisioning ecosystem services of water quality was prioritized in each watershed. No stakeholder groups engage in any projects that explicitly address forests and drinking water. Industry and policy makers have a large influence on the functioning of the FESDWQ, and non-profit groups are the best positioned to influence conservation strategies that include the FESDWQ.

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KEY TO ABBREVIATIONS

AS	Au Sable River Watershed
CWA	Clean Water Act
DET	Detroit River Watershed
EPA	Environmental Protection Agency
ES	Ecosystem Service
FES	Forest Ecosystem Service
FESDWQ	Forest Ecosystem Service of Providing Drinking Water Quality
GI	Green Infrastructure
HEP	Human Exceptionalism Paradigm
HUC	Hydrologic Unit Code
LGR	Lower Grand River Watershed
MEA	Millennium Ecosystem Assessment
NEP	New Environmental Paradigm
NPDES	National Pollutant Discharge Elimination System
NPO	Non-Profit Organization
PES	Payment for Ecosystem Services
PWS	Public Water Systems
RR	Rouge River Watershed
SDWA	Safe Drinking Water Act
SNA	Social Network Analysis
SWP	Source Water Protection

TMDL	Total Maximum Daily Loads
TPB	Theory of Planned Behavior
USDA	United States Department of Agriculture
USFS	United States Forest Service
UWS	Urban Water Systems
VBN	Values-Beliefs-Norms

CHAPTER I: INTRODUCTION

1.0 Forests and Drinking Water

Over 4.6 billion people rely on forests to provide their supply of clean water, but deforestation and forest habitat fragmentation contribute to the degradation of drinking water quality (Millennium Ecosystem Assessment 2005). Prior research demonstrates a critical link between forested land and the provision, filtration, and regulation of clean water (Anderson et al. 1976; Ellison et al. 2017; Neary et al. 2009). While current research stresses that the link between changes in forest cover and treatment costs is not always direct, there are some examples of this link in literature. According to a survey of 27 water suppliers in the US, heavily forested watersheds can halve drinking water treatment costs compared to less forested watersheds (Ernst et al. 2004; Postel and Thompson 2005). In a survey of 37 drinking water treatment plants, a 1% increase of forest cover in a watershed reduces turbidity by 3%, and a 1% increase in turbidity in a watershed increases water treatment costs by 0.19% (Warziniack et al. 2017). Urban areas provide the clearest example of the importance of forests providing drinking water. In fact, one-third of the world's major cities get a large proportion of their water supply from protected forest areas. These cities rely on the forest function of filtration to provide drinking water that requires little treatment (Calder 2007; Dudley and Stolton 2003) (See Table 1). In the U.S., two-thirds of the clean water supply comes from stream surface water that filters through forests (National Research Council 2005).

The forest provision of quality drinking water is an example of an ecosystem service (ES). The Millennium Ecosystem Assessment (MEA), a report issued by the United Nations in 2005, defines ESs as,

> "The benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling" (MEA 2005: pp v).

The link between forests and water is considered both a provisioning and regulating forest ecosystem service (FES). Drinking water as an end product of the biophysical processes and functionality of forests is a provisioning FES. Forests also have many regulating services that are connected to water: Forests regulate the flow of water (e.g., slowing down the rate water flows into streams by trapping rainwater and facilitating soil formation that slows down water flow), prevent soil erosion with their roots which would otherwise lead to degraded water quality, filter wastewater by trapping pollution as it filters through forest soils, remove bioavailable contaminants from soils by incorporating them into their tissues (i.e., phytoremediation), and trees will transport water into groundwater through root networks when water is abundant (i.e., infiltration and hydraulic redistribution) and will draw up water from groundwater when water is scarce (i.e., hydraulic lift) (Bharati et al. 2002; Ellison et al. 2017). The FES of focus in this research is the Forest Ecosystem Service of providing Drinking Water Quality (FESDWQ). The regulating FESs (regulation, filtration, and infiltration) are closely connected to the FESDWQ, however, this thesis focuses on the FESDWQ as a provisioning ecosystem service over that of a regulating service.

Table 1: Examples of cities worldwide sourcing their drinking water supply from forest land.

City	Program/Water Source
Tokyo, Japan	Protects forest land in source water at Tama River
Sydney, Australia	Protects forested buffer zone around drinking reservoirs
New York, U.S.	Protects source water in Catskill forests instead of expensive treatment in the city
San Francisco, U.S.	85% of the city's water supply comes from the forested Hetch-Hetchy Watershed
Seattle, U.S.	Unfiltered water taken directly from forested Cedar River
Manilla, Philippines	Five water districts get their water from the Mount Makiling Forest Reserve

1.1 The Challenge

Given the importance of the FESDWQ, it is necessary to understand stakeholder perceptions and values because a person's perception (or lack of perception) and values toward an ES affects choices they may make about managing and conserving that ES (Meyfroidt et al. 2014). In ES research an important first step is to value the ES to inform resource allocation, policy, and management. *Value* here refers to the worth of something generated by the mental process of a stakeholder or stakeholder group. This mental process of valuing something "involves the assessment of situations, comparing it to some reference value and making decisions on whether to act or refrain from action" (Costanza et al. 2017; pp 8). In this thesis, *stakeholders* refer to any individual or group that is affected by the FESDWQ (or perceives that they are affected) or who affect the FESDWQ directly and/or indirectly (European Commission 2003). Traditionally, valuing ESs is done with economic methodologies determining revealed preferences when possible (e.g. valuing the recreation service of a lake by determining how much people pay to visit the lake) or stated preferences when the ES is a passive use value (e.g.

willingness-to-pay, contingent valuation, etc.). However, a critique of economic methods in valuing ESs is that these services are not always translatable to monetary terms, and some value may be lost in the commodification process (Costanza et al. 2017). Arrow et al. (1996) warn that researchers must be aware of tradeoffs when quantifying ES, for "care should be taken to assure that quantitative factors do not dominate important qualitative factors in decision-making" (Arrow et al. 1996, pp 222).

There are few examples in literature exploring the value stakeholders place in the FESDWQ. Meyer and Schulz (2017) find that stakeholders in the urban forest of Augsburg, Germany valued recreation highest closely followed by drinking water when scoring FESs. More than 80% of this forest is designated as a drinking water protection area, so the FESDWQ is already spatially relevant to stakeholders (Meyer and Schulz 2017). Not surprisingly, research finds that people place a high value in water quality (Keeler et al. 2012), and across the globe there is a high willingness-to-pay for clean drinking water and for infrastructure that provides this water (Olmstead 2009). However, the forest *provision* of drinking water is not considered in this high value placed in drinking water: In the US, the value of drinking water is quantified by water utility bills. Utility bills (except for New York City and some other forest-to-drinking water program examples) address treatment and transportation costs, but do not include the cost of the water itself, the costs of sustaining the source forest areas, and consumers' concern with source water protection. Essentially, the forest provision of "clean and abundant water is passed on to water consumers free of charge" (Todd & Weidner 2010, p. 11).

Rising awareness of the ES concept has led to the incorporation of ESs into environmental management and decision-making across the globe. In the US, the FESDWQ has been incorporated into management strategy documents (e.g. United States Forest Service strategic plan) (Small & Lewis 2009). Researchers, Public Water Systems (PWS) and water works associations have collaborated to find this value of source water protection (SWP) on PWS (Abildtrup et al. 2013; Gorzalski et al. 2019; Price et al. 2018). However, additional research is needed to contextually understand the FESDWQ in different geographic scales (e.g. large verses small PWS) and under complicated hydrological regimes (Price et al. 2018). Understanding the value of the FESDWQ by quantifying the direct cost relief to drinking water treatment plants from forest functions is an example of revealed preferences valuation. While these kinds of valuations are important and necessary, they may incorporate only the value held by economists over the value of those of the affected individuals (i.e. stakeholders) (Arrow et al. 1996). If stakeholders do not value the FESDWQ, the quality and flow of the service may deteriorate and support for policy and regulation may be lacking (Aguilar et al. 2018; Arriagada & Perrings 2009).

Stakeholders place a high value in drinking water generally, so there is potential to leverage this value to increase forest conservation or even payment for ecosystem services (PES) programs that incorporate the FESDWQ. There is also an emerging priority for incorporating adaptive management or innovative solutions to drinking and wastewater service issues across the US (Bartlett et al. 2017). It could take $1 trillion dollars over the next 25 years to update and replace failing water infrastructure across the nation (AWWA 2012). Emerging contaminants (e.g. lead in Flint, MI; PFAS) will stress these water systems further, compromising the water systems' ability to provide safe drinking water to its customers, and will become more frequent and difficult to address in the coming years (Bartlett et al. 2017). While people in the US place a high value in drinking water, they may not have the ability to pay for that service; US water unaffordability could increase by 12-36% for households over the next five years (Mack and

Wrase 2017). While addressing these issues will take a concerted effort of a diverse array of stakeholders, water systems could benefit from adaptive strategies, innovative solutions, and natural solutions like SWP and PES programs that incorporate the FESDWQ. To ensure the success of a system that institutionalizes FESDWQ, the value that stakeholders place in this service must be understood.

1.2 Research Objectives and Questions

The first research goal was to determine the value stakeholders place on the FESDWQ. The specific objectives were to 1) determine how stakeholder value for the FESDWQ compares to other FESs, 2) understand what stakeholder values and perceptions exist concerning the FESDWQ, and 3) determine if these values activate behaviors that affect the FESDWQ. The second research goal was to determine how stakeholder value in the FESDWQ is affected by interactional processes between stakeholder groups. The specific objectives were to 1) characterize the social networks of these stakeholders by determining the structure of the social networks, the roles that stakeholders have in their network, and the flows of resources and information within these networks and 2) investigate stakeholder value of the FESDWQ by exploring how stakeholder groups impact the FESDWQ, and 3) determine whether the interactions between the different stakeholders influenced the value the stakeholders place in the FESDWQ.

1.3 Epistemological Framework

The definition of an ES inherently includes the interaction between human systems and the environment. Nature and humanity are not separate spheres but are irrevocably connected as a complex and comprehensive whole. While natural sciences tend to treat nature and humanity as distinct spheres, in ES and natural resource literature, there cannot be one without the other.

Historically, social science traditions have treated human systems and natural systems as separate in what Catton and Dunlap (1978) described as the Human Exceptionalism Paradigm (HEP). This anthropocentric view is based in Western cultural themes of the doctrine of progress and humanistic optimism. Catton and Dunlap viewed human systems and natural systems as linked and therefore claimed the HEP inadequate in describing social phenomenon, so they proposed the New Environmental Paradigm (NEP) as a more comprehensive framework for sociological inquiry. The NEP designates human beings as one species among many, human actions as linked in complex feedback loops with nature, and nature as finite and therefore constraining human systems. While this did not lead to a paradigm shift in sociology in the Kuhnian sense, or a fundamental change in the methodology of sociologists (Kuhn 1962), the NEP has loosened the social sciences to include an environmental understanding. With the acknowledgment of environmental sociology and an ecosystem-centric anthropology, the social sciences recognize that humans do not reside in a vacuum but change and are changed by their natural environment (Catton et al. 1978; Freudenburg, William et al.1995; Greider and Garkovich 1994; Mol 2006; Vayda and Walters 1999).

Valuing ESs is rooted in neoclassical economic methodologies nested in the epistemology of logical positivism (Van Hecken and Bastiaensen 2010). In the two decades since ESs emerged as a critical aspect of functioning global economies in Costanza's 1997 *Nature* article (Costanza et al. 1997), ES research has relied on economic values of ESs. For example, the theory behind a PES program incorporating the FESDWQ internalizes positive externalities, or the positive consequences of forest ecosystems providing clean and abundant water, into a more comprehensive environmental market. Commodifying the non-market value of the ES becomes the way to measure this value and include it into conservation mechanisms. This commodification often takes the form of a quantitative research process that elucidates stated preferences of stakeholders in a contingent valuation experiment in willingness-to-pay for the ES (Aguilar et al. 2018; Olmstead 2009; Roesch-McNally and Rabotyagov 2016).

Commodification of an ES can be an important step in determining ES value, but solely monetizing an ES can lead to a myopic translation of value (Martín-López et al. 2012; Olander et al. 2017). Economic valuation is only one aspect of measuring the worth of an ES. For example, Costanza et al. (2017) mention that valuation can also refer to generic appreciation for an ES, intrinsic or existence value of an ES, cultural value of an ES, or co-created value based in community or societal preferences for that ES (Costanza et al. 2017). Economic valuations of ESs fail to address the complexities of the valuation process of stakeholders. The theory of "social constructivism," or that reality is socially constructed and a product of the human mind and interactions between individuals (Malekian et al. 2017), can more adequately define stakeholders' perceptions of ES value. Kumar et al. (2008) illustrate this point perfectly when they call on researchers of ESs to engage in "qualitative research methodologies informed by social constructionism" in order to comprehensively measure the value that humanity places in ESs. In this research, a qualitative social constructionist approach, as opposed to a quantitative positivistic economic approach, was employed to investigate the creation of value of the FESDWQ.

1.4 Study Area

Michigan, U.S.A., is abundant in forest and water resources and thus is an ideal location to implement research of the FESDWQ. The state is covered by 20.3 million acres of forest (56% of total state area), is bordered by four of the Great Lakes and contains 46,000 inland lakes and 76,439 river and stream miles (MDEQ 2017; Pugh et al. 2016). There is a net increase of forest land annually: The rate of reforestation outpaces the rate of deforestation by harvesting or conversion (MDNR 2010). However, the structure of these transforming and emerging forests may impact forest health and function. Many of these forests are highly fragmented, developed, and dissected by impervious surfaces (MDNR 2010). Michigan policy makers and government officials have begun to operationalize the sustainable management of forests for the protection of water resources, including drinking water quality (OGL 2017). Over 75% of Michigan resident drinking water comes from surface water while the other 25% comes from groundwater (MDEQ 2004). Michiganders largely rely on natural filtration systems (e.g., forests and wetlands) to provide for their drinking water quality, but the extent of this reliance is not explicitly measured, and the public is usually unaware of this forest ecosystem service (MDNR 2010), however, Michigan residents are aware of drinking water quality issues because of many contamination events (e.g. PFAS, lead, PCBs, etc.).

1.4.1 Case-Study Approach

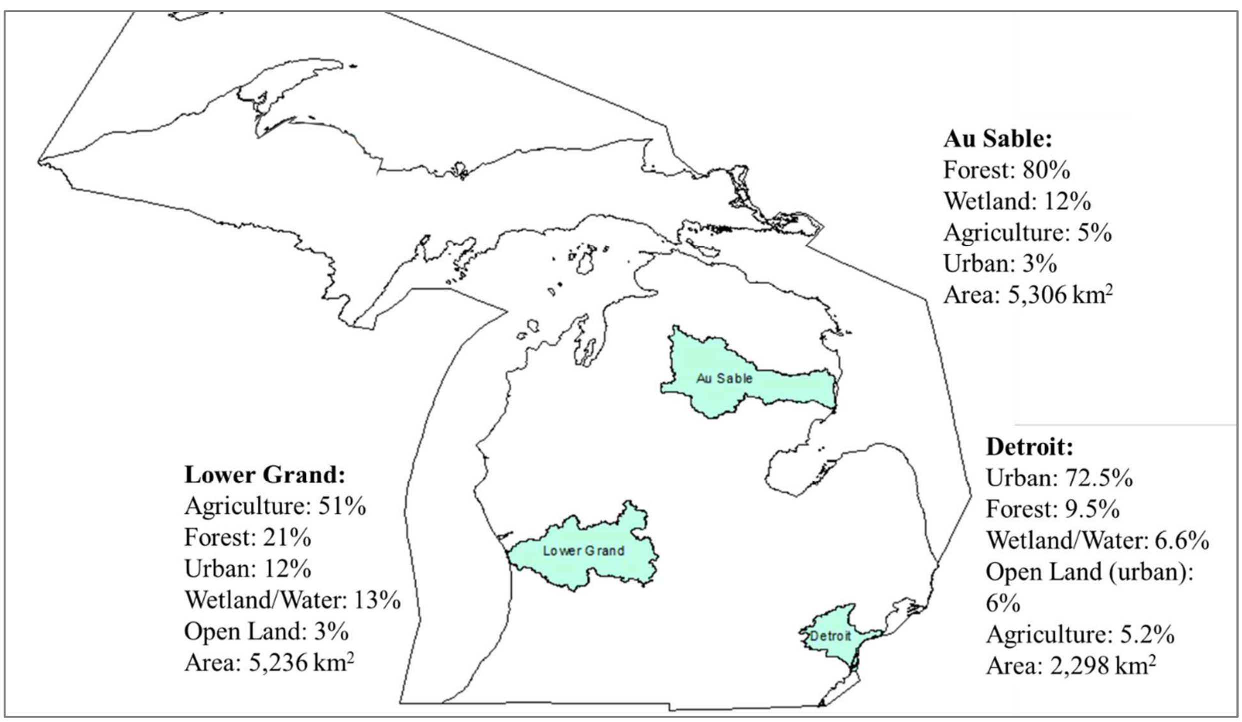

Figure 1: Map of the three Michigan watersheds studied and their land cover percentages.

Table 2: Social demographic data for each watershed.

Demographic*	Watershed		
	DET	LGR	AS
Population	2,434,337	767,261	72,065
Median Age	37.8	37	50.8
% under 5	6.10%	7.10%	4.80%
% over 65	13.10%	11.90%	22.40%
% Black	32.90%	5.00%	0.70%
% Native American	1.00%	1.10%	1.50%
% Asian	4.60%	1.50%	0.50%
% Hispanic	4.80%	6.00%	1.30%
% White	59.00%	91.40%	98.40%
Household Size (mean)	2.4	2.7	2.2
Housing Units	1,095,103	312,765	59,652
% Vacant Housing Units	12.10%	10.00%	47.40%
Median Income	$52,203	$51,049	$38,923
% 4+ year degree	16.40%	18.40%	9.80%
% Language not English	2.20%	2.20%	8.10%
% Unemployed	8.80%	6.70%	7.30%
% Public Assistance	4.20%	5.10%	3.60%
% Households Poverty	8.80%	7.20%	7.60%

* Summarized from the American Community Survey and Census Data.

A multiple case-study approach to develop an in-depth analysis of stakeholder perceptions, values, and networks connected to the link between forests and drinking water quality was implemented in three watersheds in Michigan's Lower Peninsula. The purpose of the case-study was to describe the stakeholder value constructions of the FESDWQ. A case study approach is the ideal study design because the views of stakeholders are crucial for valuing an ES, and those stakeholder perceptions are rooted in an in-depth understanding of contextual knowledge and geographic scale (Creswell 2013; Hauck et al. 2013). Three cases were chosen because literature suggests that too many cases can dilute the level of detail a researcher can describe, but three cases still gives enough options for cross-case comparisons of themes (Wolcott 2008). A critique of case-study design is that because it is highly case-specific, results from this type of research are not generalizable. However, specificity is a strength here because the benefits of the FESDWQ are locally contextualized and so is the corresponding value that stakeholders place in this value (Redford and Adams 2009). Additionally, "the force of example" or the detail of a contextually specific case is equally important to scientific development as generalizability (Flyvbjerg 2006). A qualitative case-study approach taps into the specificity of stakeholder value that may be overlooked in general quantitative methods.

To generalize the results of this research to inform potential conservation programs for the entire state of Michigan, three cases were chosen in the geographical extent of three Hydrological Unit Code-8 (HUC-8) watersheds. These watersheds are the Detroit River Watershed (DET) in the southeast, the Lower Grand River Watershed (LGR) in the west, and the Au Sable River Watershed (AS) in the northeast. The variances between watersheds also give an opportunity to evaluate how those differences may impact themes. These watersheds were chosen because of their varying degrees of urban to forested land cover: DET is highly urbanized; LGR has a mixture of urbanized, forested, and agriculture; and AS is highly forested (see Figure 1). The four watersheds also have varying populations: DET is the most densely populated, followed by the LGR, and AS (see Table 2). All these watersheds contain populations that directly obtain their drinking water from surface water that filters through forests in their watershed, but also from personal or municipal wells that contains groundwater from land that filters through forests.

1.4.2 Au Sable River Watershed

The AS covers an area of 5,306 km^2 including parts of Otsego, Montmorency, Crawford, Oscoda, Alcona, Roscommon, Ogemaw, and Iosco counties in the Northern Lower Peninsula of Michigan. The AS basin is around 90 miles long and 10 to 30 miles wide dropping 650 feet from its point of origin in northwest Crawford County to its mouth at Lake Huron near the town of Oscoda (DNR 2002). Part of the main stem of the Au Sable River (23 miles from Mio Pond to Alcona) was designated as a "Wild and Scenic River" in 1984 which was a law passed by Congress in 1968 to "preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations" (Wild & Scenic Rivers Act 1968). The AS was also designated as a natural river through "Michigan's Natural Rivers Act" in 1987 which is a law that contains stricter regulations for property owners along the river (Isely et al. 2007). The AS is known for its pristine waters that provide the "finest fly-fishing east of the Rockies" and camping and canoeing opportunities that are some of the "best in the Midwest" (USFWS n.d.). Historically, the AS was home to the Ottawa and Ojibwa tribes and is currently under the tribal service area of the Little Traverse Bay Bands of Odawa Indians (Huron Pines 2001; MDHHS 2016). In the 19^{th} century, extensive logging resulted in clear-cut land that was unsuccessfully farmed and eventually reverted to forest by the end of the 19^{th} century (Huron Pines 2001). Currently, the AS is mainly rural (Appendix A.1) with a relatively low average population density of approximately 14 people per square kilometer (US Census 2010). The watershed, like many other Michigan tourist destinations, experiences developmental pressures from recreational opportunities and a rising seasonal homeowner population, both of which impact forest and water resources (MDNR 2010; Huron Pines 2001; Zorn and Sendek 2001).

1.3.3 Lower Grand River Watershed

The LGR covers an area of 5,236 km^2 including parts of Barry, Eaton, Ionia, Kent, Montcalm, Muskegon, Ottawa, Allegan, Mecosta, and Newaygo counties in western Michigan. The main branch of the Lower Grand River is 51 miles long and the LGR includes a total of 31 subwatersheds. The river drops 209 feet from its eastern edge in Ionia County at the confluence of the Looking Glass River and the Grand River to its mouth at Lake Michigan near Grand Haven. The State designated the Rogue River and Flat River (both subwatersheds of the LGR) as "Natural Rivers" according to the "Michigan Natural Rivers Act" in 1973 and 1979 respectively (Isely et al. 2007). As of 2011, 11 subwatersheds of the LGR have EPA approved Total Maximum Daily Loads (TMDLs), or regulations of nutrient loading to address water bodies that are not attaining designated uses under the Clean Water Act (CWA) (LGROW 2011). Historically, the LGR was home to the Hopewell Indian Tribe and is currently included in parts of the tribal service areas of the Huron Potawatomi, Saginaw Chippewa, Gun Lake, and Little River Band of Ottawa Native American tribes (MDHHS 2016). Industrialization and frequent navigational use during the 19th century led to channelization and pollutant loading that degraded the quality of the watershed. Since the 1960's, clean-up efforts and regulation from the CWA have greatly improved water quality (LGROW 2011). Currently, there is an average population density of 147 people per square km (US Census 2010) and the watershed is mostly agriculture with urban areas (e.g., Grand Rapids, Grand Haven) and forests scattered throughout (Appendix A.2).

1.3.4 Detroit River Watershed

The DET covers an area of 2,298 km^2 including parts of Oakland, Wayne, and Washtenaw counties in the eastern part of Michigan. The DET is mainly made up of the Rouge River Watershed (RR) which contains 17 of the 21 subwatersheds that make up the DET, and watershed units and management have mostly organized around the RR. The DET includes more subwatersheds that surround the Detroit River from Lake St. Clair to Lake Erie. In this study, the DET was chosen as the main designation for consistency with the HUC-8 watershed categorization of the USDA (both LGR and AS are also HUC-8 watersheds), however, it is important to realize that the community identifies this area as the RR over the DET. The RR is 126 miles in length and drains to the Detroit River (which eventually drains to Lake Erie). Historically, the DET region has been home to various Native American Tribes (majority of which being the Huron, Potawatomi, and Odawa), and many Native Americans are contemporary residents of the City of Detroit (Danziger 1991; Teasdale 2012). The DET is heavily populated and heavily industrialized (Appendix A.3) with an average population density of 1,059 people per square km (US Census 2010). The river itself is highly augmented and channelized like most urban rivers, and consequently, a major goal for governance in the area is to incorporate and maintain green infrastructure (GI) to address impervious surfaces and flashy flows (SEMCOG 2014). Because of a history of rapid industrialization in the 20th century, the RR has elevated contaminated sediment levels, decreased stream biodiversity, a flashy streamflow, and direct sewage discharge events (some communities have Combined Sewer Overflows) (Napieralski et al. 2015). In the past decades there have been many collaborations to clean up and restore the RR including an improved watershed management plan (ARC 2012).

CHAPTER II: STAKEHOLDER VALUES AND PERCEPTIONS OF FORESTS AND DRINKING WATER QUALITY

2.0 Introduction

2.0.1 Valuing Ecosystem Services

Billions of people across the globe rely on forests to provide clean drinking water, yet threats to forests result in the degradation of drinking water quality (MEA 2005). General water quality is highly valued by the public (Keeler et al. 2012) and drinking water quality is valued even more highly: If one wants to get people to care about conservation, focusing on drinking water may be an important way of doing so (Granias et al. 2018; Olmstead 2009). Forests are critically important to preserving the provision of drinking water, but in the US, this service is not included in forest valuation (Todd and Weidner 2010). When an ecosystem service (ES) is not valued or understood, decision-makers have a difficult time establishing policies and management strategies that conserve that ecosystem. For example, forest managers may prioritize the goal of maximizing profits from tangible goods (e.g. timber) over an intangible forest ES (FES) (e.g. water provision), and so the quality and flow of these "intangible" services deteriorate (Arriagada and Perrings 2009; Obeng and Aguilar 2018; Roesch-McNally and Rabotyagov 2016).

Much of ES literature focuses on valuation, or the worth of something generated by a mental process which may include assessing scenarios regarding the ES, comparing the ES to some reference value, or deciding whether to act or sustain from acting in a way that impacts the ES (Costanza et al. 2017). As the ES concept has gained traction in natural resource management across the globe and has been incorporated into transnational agreements (e.g. UN's sustainability goals, the Intergovernmental Panel for Biodiversity and Ecosystem Services), the ES expert community have agreed upon several "musts" when it comes to valuing ESs. This valuation must incorporate the spatial and temporal link of the ES to the community that depends on the service (Redford and Adams 2009). Value must be based in research that quantifies the biophysical characteristics within adequate temporal and spatial scales (Symstad et al. 2003). An ES valuation must conceptualize the interlocking nature of both the ecological and social aspects associated with the ES (Farley and Costanza 2010; Reed et al. 2017). Olander et al. (2018) define these important ecologic and social outcomes as "benefit-relevant indicators," which are rooted in clearly understood measures of social value.

Conservation efforts could be informed by valuing forest-based provision of drinking water, but this valuation must be highly contextualized. This means the social (i.e. historical, cultural, and political) and biophysical context must both be understood (Hauck et al. 2013). Value of the forest ecosystem service of providing quality drinking water (FESDWQ) is not simply created between upstream forest landowners and downstream water consumers but is co-created by a multitude of stakeholders directly or indirectly involved in the FESDWQ (Matthies, Kalliokoski, et al. 2016). "Stakeholder" refers to "any relevant person, group or organization with an interest in the issue either because they will be affected by the [ES] or because they have influence, knowledge or experience with the [ES]" (European Commission 2003: pp 63). There are two important components of this definition: 1) stakeholders can be both active and passive, and 2) influence, knowledge and experience play an important role in stakeholder dynamics and in the link between stakeholder and ES (Stanghellini 2010). Stakeholders involved in the FESDWQ include 1) public or private forest landowners whose decisions about forest management affect the function of the FESDWQ, 2) industrial and commercial entities whose activities affect the function of the FESDWQ, 3) water utilities whose infrastructure treat and transport drinking water and wastewater, 4) policy makers and enforcers who create and enforce laws that impact the FESDWQ, 5) non-profit/non-government organizations (NPOs) that are directly involved in projects that preserve/restore the FESDWQ, 6) local government whose initiatives may impact the FESDWQ and services to the community may influence behavior, and 7) consumers who consume drinking water (see Figure 2).

Decision-makers must understand the social preferences of multiple stakeholders concerning the ES in local contexts. When researchers and policy makers fail to incorporate the value of multiple stakeholders into decision-making and conservation programs regarding an ES, it can lead to conflict between stakeholder groups, inequity in ES distribution, and further degradation of the ES (Darvill and Lindo 2016).

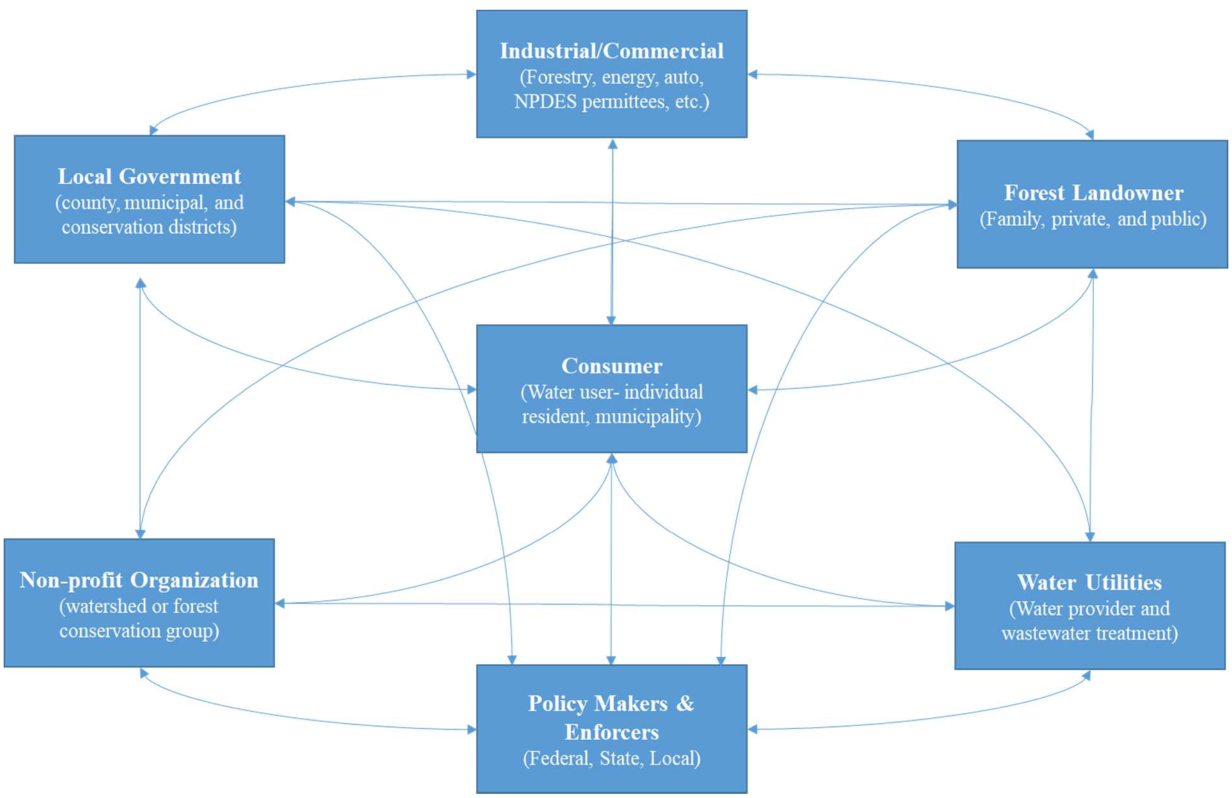

Figure 2: Stakeholder network diagram of stakeholders impacted by or impacting FESDWQ. Arrows between groups are multi-directional representing interactions between groups.

2.0.2 Research Objectives and Questions

The central objective of this part of the research was to determine the value stakeholders place on the FESDWQ. In this research, the focus is on the FESDWQ as a provisioning service over that of a regulating service. The corresponding research questions are 1) how does value for the FESDWQ compare to other FESs? and 2) what guiding principles and perceptions are present in these three watersheds surrounding forests and drinking water, and do these principles activate behaviors?

2.1 Methods

2.1.1 Methodological Framework

Stakeholder perceptions and values of an ES drive the decisions they make regarding that service (Meyfroidt et al. 2014). Valuing an ES by understanding people's preferences or perceptions is called sociocultural valuation or the valuation of non-monetary ESs (Lapointe et al. 2019; Scholte et al. 2015). There are many social psychology environmental behavior theories that explain how perceptions impact environmentally-responsible behavior. Schwartz's moral norm-activation theory of altruism states that because a healthy ecosystem is a public good, people will be altruistically motivated to care for it (Schwartz 1973, 1977). Knowledge that a service is a public good may motivate people to conserve an ES, however, having an awareness of this FES and its degradation does not necessarily lead to behavior that protects the service (Grese et al. 2000; Nisbet et al. 2009). Therefore, this research goes beyond a testing of knowledge that different stakeholders have about the FESDWQ. Common environmental behavior theories are the Theory of Planned Behavior (TPB) and value-belief-norm theory (VBN). In TPB, behavior is influenced by behavioral beliefs (beliefs in the likely consequences of actions), normative beliefs (beliefs about expectations of others), and control beliefs (beliefs about factors that positively or negatively impact performance) (Ajzen 1991; Kaiser and Gutscher 2003).

Researchers often use VBN and TPB in concert to study environmental issues (Genskow and Wood 2009; López-Mosquera and Sánchez 2012). VBN describes how "personal values [guiding principles] (especially altruistic values) …beliefs about general conditions in the biophysical environment, and personal norms for pro-environmental action" lead to environmentally friendly behavior (Stern 2000). Values activate norms which influence behavior, all while being mediated by beliefs (Steg and Vlek 2009). VBN is commonly used as a theoretical framework for understanding social dimensions of watershed and natural resource management and governance (Genskow and Wood 2009; Roobavannan et al. 2018), and is used in ES literature to elucidate the values that are placed in an ES and the preferences that individuals and stakeholder groups have for that ES (Aguilar et al. 2018; López-Mosquera and Sánchez 2012). This research is guided by the VBN/TPB framework and Constanza's definition of value by elucidating stakeholder value and situating the FESDWQ within the context of overall FESs.

2.1.2 Methods

A multiple case-study approach was employed in three watersheds in the state of Michigan to make qualitative comparisons based in varying land cover and population sizes (the less populated and heavily forested AS; the more populated agricultural, forested, and urban LGR; and the heavily urbanized DET). A total of 42 semi-structured interviews were conducted from June 2018 through January 2019 in the three watersheds targeting a sampling of stakeholders within seven stakeholder categories (see Table 3). A snowball sampling technique was used to identify key stakeholders from the seven stakeholder categories and detail theories and themes (Cohen-Shacham et al. 2015). While researchers often explore local and regional stakeholder perception of ESs by using survey methods (Darvill and Lindo 2016), qualitative stakeholder interviews more richly describe stakeholder perceptions (Cohen-Shacham et al. 2015).

Table 3: Interviews reached by category in each watershed.

Watershed	Stakeholder Category							
	NPO	Policy Maker	Local Gov.	Forest Landowner*	Water Utility**	Consumer	Industry***	Total:
AS	8	3	1	1	0	0		13
LGRW	3	4	4	2	1	4		18
DET	3	3	1	0	1	0		8
Total:	14	10	6	3	2	4	3	**42**

*Forest landowners in Detroit were not reached, however, county parks are a major landowner stakeholder and the local gov. category represents this here.
**Water utilities represent stormwater and environmental services individuals at municipal and county level over water providers.
***Industry interviewees represent the entire state of Michigan.

To date, agriculture has been more fully represented in ES literature than forestry (Meyer and Schulz 2017). In Michigan, there is one study about farmers' willingness to participate in a program that would pay them for agricultural land management that protects ESs (Ma et al. 2012), but there are no studies that include stakeholder value of FESs. Because forestry is less represented in the ES concept and there are not examples of FESs valuation in Michigan, there is no literature foundation that supports the initial variables needed for effective quantitative valuation. Therefore, a qualitative exploratory method on valuation of the FESDWQ is preferable to provide the opportunity to contextually understand stakeholder perceptions.

A semi-structured interview approach allowed for more flexibility in following relevant themes during the interview process. All interviews were recorded and transcribed. Interview length varied from 0.5 to 2.5 hours. The data collected from these interviews were treated as "member's meanings" or "situated knowledge" (Emerson et al. 2011; Harding 1993). In other words, the interviewee's account was taken as an "expression of the speaker's experience and views at a particular moment in time before a specific audience that is intended to accomplish particular purposes" (Emerson et al. 2011, pp 140). During the data collection and analysis process, interviewees were treated as "socially situated" bringing with them their own biases and situated knowledges (Harding 1993). The researcher practiced reflexivity during the entire research process to ensure ethical practice and to be fully aware of the impact the interviews may have on the interviewees (Guillemin and Gillam 2004).

Qualitative data analysis software (NVivo 12™) was used to code transcriptions. One individual was responsible for coding the transcripts. The reliability of that single coder was tested by performing two inter-rater reliability (IRR) tests during the beginning and end of the coding process. The first IRR found a percent agreement of 67% among five coders, and the second IRR found a percent agreement of 48%. After both IRRs, coding was reevaluated and edited according to the IRR disagreements to ensure overall code reliability. A combination of open coding and thematic coding was used. This allowed for coding based on themes from the epistemological framework of this research (social constructivism) and allowed for developing themes grounded in the systematic analyzation of the data using a grounded theory approach (Charmaz 2006). The semi-structured interview format naturally categorized answers to deductively analyze themes designed pre-data collection, and the semi-structured interview format also allowed for flexibility to inductively analyze themes from the raw interview data (Emerson et al. 2011). These themes came out of structured questions in the interviews based in sociohydrology literature using VBN and environmental behavior theories applied to the organizational scale (not the individual) (Roobavannan et al. 2018). Themes also came out of open coding of the interview data.

2.2 Results

2.2.1 Forest Ecosystem Services

All interviewees were asked to list any FESs they could think of (explaining the term ecosystem service to them if needed). Knowledge of the ES concept varied throughout the stakeholder categories: NPOs and local government were aware of the term (with the exception of one member of a smaller NPO and one member of local government who needed further clarification), all other stakeholder categories varied between previous knowledge of ESs and quickly understanding the term when explained. Those with previous knowledge were able to mention a nearly exhaustive list of FESs (Figure 3).

Most interviewees mentioned the FESs of climate regulation (e.g. shade and air quality provision), economic resources (e.g. wood products), recreation (e.g. hunting and tourism), water quality (including both water provision and regulation), and wildlife habitat (both aquatic and terrestrial). Most interviewees in each stakeholder category mentioned water quality as a FES. While this may be understandable given the topic of the interview and the stakeholders targeted, all stakeholders associate forests with quality water in their watershed. Water quality is used in the general sense here which includes the provision (i.e. drinking water as product) and regulation (i.e. filtering out pollutants, infiltration and storage, and regulating the flow of water). Overall, stakeholders referred to water quality as the regulating service over the provision of clean water, however, there was at least one NPO from each watershed that mentioned the provision of clean water (including drinking water quality).

Forest Ecosystem Services by Stakeholder Category

Consumer
- Climate Regulation
- Quality of Life
- Water Quality
- Wildlife Habitat

Forest Landowner
- Climate Regulation
- Economic Resources
- Recreation
- Wildlife Habitat

Local Government
- Water Quality
- Wildlife Habitat
- Economic Resources

Industry
- Climate Regulation
- Economic Resources
- Recreation
- Water Quality

Policy Maker
- Adds Aesthetics
- Recreation
- Water Quality
- Wildlife Habitat

NPO
- Climate Regulation
- Recreation
- Water Quality
- Wildlife Habitat

Water Utility
- Erosion Regulation
- Water Quality
- Wildlife Habitat

All
- Climate Regulation
- Economic Resources
- Recreation
- Water Quality
- Wildlife Habitat

Figure 3: The most frequently mentioned FESs by each stakeholder category. Any FES listed in bullet points indicates that most of that stakeholder type mentioned that service. Bullet points are listed in alphabetical order not hierarchical importance.

Stakeholders have differing yet similar most frequently mentioned FESs (Figure 3). All stakeholders, excluding industry, mentioned wildlife habitat, or the forest's structure providing the supporting service of either terrestrial or aquatic wildlife habitat. District foresters in LGR and AS, whose role is to work with forest landowners in their county, pointed out that landowner "concern is wildlife habitat and let's translate that into 'How do we get more deer?" (LG, AS). Landowners were also the only group that did not have most interviewees mention water quality. However, all landowners said they were concerned about erosion control on their property, and one landowner in LGR was very knowledgeable about forests and water quality. Water utilities, whose services in the watershed include regulating drinking water, stormwater, and wastewater, mentioned the water quality aspects of regulation, filtration, and erosion control. Economic resources, mainly timber, were frequently mentioned by forest landowners, local government, and industry.

2.2.2 Prioritizing Specific Forest Ecosystem Services

FES priorities within each watershed is shown in Figure 4. These are the priorities different stakeholders included when asked “what FES is the highest priority for your organization?” An alternate question was “what FES(s) is the most important for your organization?” The FESs involving regulatory water quality ESs (i.e. water flow regulation, water filtration, water infiltration, and erosion control) were the biggest priority for NPOs, utilities, and policy makers in all watersheds. Local government and consumers prioritized human health and economic services, while landowners prioritized both erosion control and recreation. Figure 4 shows that LGR has a diverse distribution of FESs priorities, while AS has a fairly equal distribution of FESs priorities but fewer priorities mentioned overall, and DET has a less diverse priority distribution including supporting services (biodiversity and wildlife habitat) and water regulating services (water flow regulation and water filtration). Water quality was a concern in all these watersheds but not water quality degradation due to forest management practices that degrade water quality (e.g., clear-cutting, harvesting within riparian or water body corridors, etc.). The forest sector (landowners, industry, foresters) in all watersheds were perceived as practicing efficient water quality best management practices.

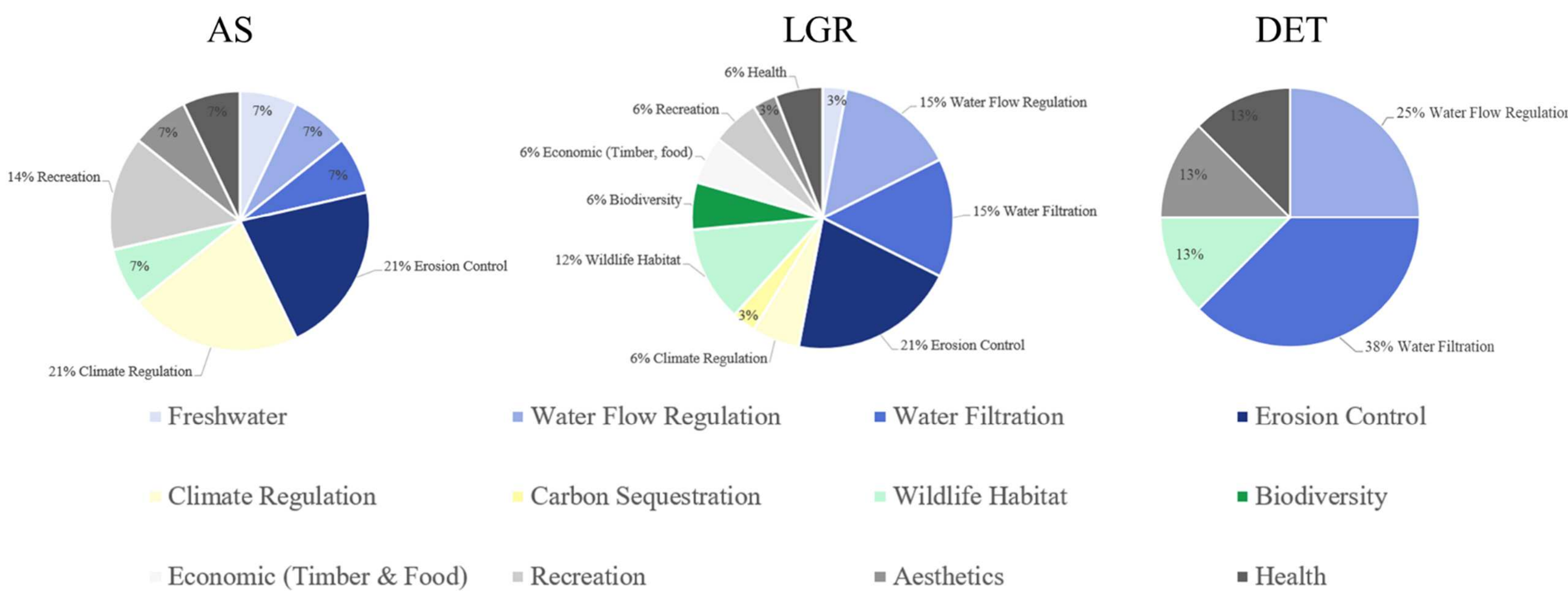

Figure 4: FESs interviewees mentioned as highest priority or importance in each watershed. The percentages indicate the proportion of the FESs mentioned as high priority. The higher proportions include descriptive labels. Blue shades are water quality related services (lightest blue is the water provisioning service of "freshwater"), yellow shades are non-water-related regulating services, green shades are supporting services, and grey shades are cultural services (including economic resources).

The forest ecosystem management priorities that interviewees mentioned also illustrate watershed-specific concerns related to FESs. The heavily forested AS watershed prioritized managing forests for sustainably harvesting timber and for managing municipal stormwater. Sustainable forest management was considered a mechanism that prevents erosion and water pollution. While the AS may not have as many stormwater or contamination issues as a more urbanized watershed, the concern threshold was low because regional tourism and recreation depend on the pristine quality of the river and surrounding forests:

> "There is a lot of tourism dollars that are brought in for fishing a beautiful, clean, pristine river. It's important to have good forest management and good agricultural practices, although there is not a lot of agriculture in that immediate area: Healthy forests, good septic tanks and systems all prevent that leaching." (NPO, AS)

The urbanized, forested, and agricultural LGR watershed prioritized managing forests for timber production using sustainable forestry and increasing forest canopy cover in urbanized areas. One consumer and one landowner mentioned the importance of trees in preventing erosion. One consumer and one landowner also stated that sustainable management should always be a priority, and water utilities and local government corroborated that sustainable forestry is a realized goal in their county. Local policy makers, consumers, NPOs, and local government all mentioned the importance of increasing tree canopy cover in the city of Grand Rapids.

The heavily urbanized DET watershed prioritized managing forests for stormwater management (infiltration) and erosion control. NPOs, local government, and policy makers in the

DET watershed consistently reiterated the use of forests as green infrastructure for stormwater management:

> "The reality is I live in a watershed that is mostly urbanized and will be completely urbanized in my lifetime. That, of course, stresses rivers. The best we can hope for is to try to reduce the peak flows and the amount that is being runoff. Trees are an excellent way of doing this" (PM, DET).

Most individuals displayed discomfort in prioritizing FESs. The more knowledgeable a person was about FESs the less that person wanted to prioritize any one service over others. The below quotation from an NPO individual in LGR illustrates this phenomenon:

> "Aesthetics is going to be really important so that people understand why we want to keep them [Forests]…but control of the water cycle and keeping green space…I don't know. I'm a zoo person: Habitat. It is really hard for me to rank them [FES] because I think it's important for all these things. My house is a wood frame: I mean, timber is important too! It is really hard for me to rank them because I'm so over-educated about it. If I have to say something, we can't live without water…Helping control water quality: We'll go with water."

This interviewee thought about the importance of green space, wildlife habitat, timber, and aesthetics; but ultimately decided on water as being the most important FES because it is the service humanity cannot live without. The interviewee attributed their discomfort in ranking FESs to being "over-educated" on the topic. In general, the interviewees who displayed more knowledge of FESs (i.e., listed many FESs in the interview) had a harder time choosing FESs to prioritize. Many of these knowledgeable interviewees commented on the importance of not prioritizing forest ecosystem services, or of managing a forest ecosystem so that all FESs would be sustained.

Three interviewees prioritized the forest's function of increasing biodiversity as a way to rank all FESs equally in a response to their discomfort in prioritizing FESs. However, when asked what ecosystem service should be prioritized specifically for policy or management, these interviewees mentioned that managers and policy makers could not rely on biodiversity alone and that public priorities like water quality and recreation should be prioritized.

2.2.3 Perceptions of the Link Between Forests and Drinking Water Quality

Only three (two from AS and one from LGR) interviewees mentioned the provision of drinking water as a priority for conservation in their watershed. Stakeholders strongly associated forests with water quality, but this association did not necessarily transfer to a strong perceived link between forests and drinking water. When asked whether they associate forests with drinking water, nearly half of stakeholder types across all watersheds answered in the affirmative. Those that answered "yes" generally had an interconnected view of nature that included the impact of land-use, human activity, and vegetation on the water cycle from the local to regional to global scales (i.e. humans are part of the natural environment and changes in one part of nature can have cascading impacts to nature as a whole). A common understanding was that a forest in their watershed would eventually impact the water quality of the Great Lakes; and because everything is interconnected, that will eventually affect drinking water quality. On the other hand, some of those that answered in the affirmative did not explicitly make the connection from forests to drinking water but rather to general water quality (Table 4).

Table 4: Characterization of link between forests and drinking water from those who associate the two together. Some quotations are paraphrased using an ellipsis.

#	Watershed, Stakeholder group	Q: Do you associate forests with drinking water? How so?
1	AS, NPO	"Yes, I do…forests kind of contribute to cleaning our drinking water."
2		"Absolutely. Trees hold the soil intact so that water can percolate down through the soil and leave the contaminants or solids behind before the water eventually makes its way into the groundwater, streams, and the Great Lakes."
3	AS, PM	"Oh sure, because whatever seeps through the forest will eventually make it to the groundwater."
4		"Absolutely...forests help keep the water clean. It works hand in hand: We need to have water to have forests and we need to have forests to help keep the water clean."
5	AS, LG	"I sure do but I've always lived in remote areas where you didn't give it a second thought."
6	AS, FL	"Absolutely. I understand how the hydrology works."
7	DET, NPO	"I do directly. The health of pervious surfaces are directly related to the quality of drinking water whether we're actually consuming it, recreating in it, pulling fish out which we're consuming, or just the quality of water for the biological diversity that's found within it."
8	DET, PM	"Yes, in the bigger scheme of things."
9	DET, PM	"I do. The forests are part of the natural landscape which is the most effective form of filtering water."
10	DET, LG	"Yes. Forest and tree coverage in general factor into the water filtration process in managing and slowing the absorption of rainwater back into the ground which ultimately ends up in the groundwater, stream tributary system, and out to the lakes."
11	LGR, LG	"Of course."
12		"Yes, I think so. The forest is good for drinking water, and likely clean drinking water is coming out of the forest, but the landscape is dominated by other land uses."
13		"Yes, because they improve water quality either by preventing soil erosion or having a positive effect on the different types of species that live within our waterways."
14	LGR, PM	"Yes. Trees help clean our drinking water, and of course they also address our stormwater issues because they capture so much stormwater. Everything is all tied together."
15	LGR, NPO	"Yes. If a forest is a healthy forest and it's functioning properly then it's going to have cleaner water."
16	LGR, FL	"Yes. I'm just very cognizant of water in general, especially erosion."
17	LGR, CON	"Absolutely. Because I live here where forests are just right next to the water."

PM: Policy Maker; LG: Local Government; FL: Forest Landowner; CON: Consumer

While nearly half of the interviewees associated forests with drinking water to some degree, the rest of the interviewees did not automatically make the connection. Many of the more knowledgeable individuals about forests and water quality commented that even with their knowledge, they do not associate forests with drinking water. For example, a policy maker in the AS commented that "even based on what I know, that is not where my mind goes immediately," and a NPO individual in the DET commented that "I should if I really think about it, but I do not think about it on a regular basis." For many of the interviewees, it was commonly stated that the connection between forests and drinking water was not something they typically think about. Some interviewees remarked on the perceptions of other stakeholder categories toward this link. Landowners, NPO's, local government, and policy makers all said they thought it was highly unlikely their fellow stakeholders or other stakeholder categories think about or value the FESDWQ. One NPO sums up this sentiment:

> "I'm not sure that beneficiaries always recognize [this link]. I'm not sure that water providers always do. I think scientists probably value it the most. If we're talking non-profits in terms of a watershed or forest conservation group, then I think they put a lot of value into it. I don't know if the general forest landowner would necessarily put a ton of thought into how much their forest is purifying their water. I don't know if industrial or commercial necessarily do either" (DET, NPO).

Knowledgeable interviewees both answered in the positive and negative in associating forests and drinking water, but people who admitted they didn't know much about the topic typically did not associate the two.

Some interviewees also perceived a disconnect between the provision of drinking water and the functioning of natural systems. This was especially prevalent from individuals living in urbanized areas: “The only real clean drinking water for me is what I’m going to take up out of the ground or what is coming through the filtration plant” (PM, LGR). This interviewee perceived forests as eliminated from the filtration process entirely when the water is coming from a filtration plant or deep wells. Another interview said something similar: “I don’t associate the two because drinking water goes through treatment facilities. That is where my water comes from. I'm not tapping a well in a forest someplace” (CON, LGR). This interviewee took this theme a step further by pointing out another perception of the link between forests and drinking water: If a forest was right next to a drinking water intake, preferably a wellhead over surface water intake, then the perception of the association would be stronger. Person 17 from Table 4 operationalized this by saying they do associate forests and drinking water because they live where forests are right next to the water. Person 5 from Table 4 mentioned that because they have always lived in remote areas the association between forests and drinking water manifests naturally. Another interviewee surmised that those in Michigan’s Upper Peninsula would associate forests with drinking water because they have personal wells within forests:

> “In West Michigan, we may not connect forestry and water together, but if you're going to go to the U.P. you could get a different answer on drinking water because maybe those people have a shallow well near a forest and somehow that forest benefits that source of water and they drink it.” (PM, LGR)

Interviewees characterized the link between forests and drinking water by associating this link more strongly with groundwater and to those who get their drinking water through municipal or private wells. Mechanistically, this association with forests is explained by the forest function of *filtering* water or *purifying* water before it infiltrates to groundwater. On the other hand, interviewees associated the link between forests and general water quality by associating this link with surface water. Interviewees mechanistically explained this association with the forest function of *regulating* and *intercepting* precipitation that leads to flood events or catching erosion that leads to surface water pollution. Water utilities bridge the gap between these two associations with forests and drinking water by incorporating source water protection and wellhead protection into the equation:

> "I see forests as part of the natural filtering system that provides potable water for our citizens who are on well water or even citizens who take water out of the rivers because [rivers] receive ground water as well. I see the forests as helping to assist surface waters as source water for the provision of drinking water to society" (WU, DET).

One NPO member from DET began to think about this disconnect between forests and drinking water in the context of stormwater: Their organization does not bring up drinking water when talking to the public about trees but they do connect with people on the importance of forests in stormwater management: As the interview progressed, the interviewee came to the conclusion that trees and "stormwater should be connected to our drinking water."

Stakeholder perceptions, knowledge, and values about forests and drinking water are linked to specific corresponding actions in their watersheds. Table 5 compares how both watershed and stakeholders link forests and drinking water: It shows stakeholder "perceptions of adverse consequences," or the belief that making changes to the forest landscape impacts drinking water quality, and the corresponding "action and behavior," or whether the group does anything that directly impacts forests and drinking water. Stakeholders in all watersheds associated forest "mismanagement" with negative changes in water quality indirectly linked to drinking water quality. No stakeholders witnessed mismanagement happening currently in their watersheds and viewed the forest sector as doing an overall good job in preventing water quality issues. Utilities and policy makers in LGR and DET alleged that negative consequences to drinking water quality from forest management was a policy error from past land and water management. The 19^{th}-20^{th} century practices of "draining the swamp" for agriculture or clear-cutting forests for development degraded or destroyed the forest function of providing drinking water, and now the FESDWQ is functionally degraded and replaced by technological solutions which do not rely on filtering support from forests.

No interviewees exhibited any behavior or actions in their watersheds that directly addressed forests and drinking water quality (See Table 5 responses to the third characterization). Stakeholders that have varying outreach or communication roles in the watersheds never framed their rhetoric around forests and drinking water. No interviewees mentioned any programs, projects, or policies that directly impacted this FES: Some projects may involve forest and water quality and may indirectly impact drinking water through the forest to general water quality connection, but the goals of those projects did not include the protection of the FESDWQ. However, interviewees were amenable to incorporating the FESDWQ into their goals. NPO's, local government, utilities, and policy makers mentioned that if there was a watershed specific quantification of the FESDWQ they may act on that knowledge: "I guess if I had a better understanding of how the forests around here were directly impacting drinking water then I would probably talk about it more" (LGR, LG).

Table 5: Table showing perceived link between forests and drinking water quality by stakeholder category. Numbers represent a Likert scale for each characteristic: These scales are an interpretation of discussion during interviews. "NA" stands for not available.

	Stakeholder Category					
Characteristic	**Water Utility**	**Policy Maker**	**Local Gov.**	**NPO**	**Forest Landowner**	**Con-sumer**
AS Watershed						
Nature of link	NA	4	5	4	5	NA
Perception of adverse consequences	NA	4	3	3	4	NA
Action & behavior	NA	1	1	1	1	NA
LGR Watershed						
Nature of link	3	3	4	4	3	3
Perception of adverse consequences	3	3	3	4	3	3
Action & behavior	1	1	1	1	1	1
DET Watershed						
Nature of link	5	5	5	4	NA	NA
Perception of adverse consequences	3	3	3	3	NA	NA
Action & behavior	1	1	1	1	NA	NA

Nature of link	**Q**: Does the group connect forests to drinking water? **Scale**: 1-not at all; 5-Yes, absolutely
Perception of adverse consequences	**Q**: Does the group connect forest mismanagement to drinking water quality issues? **Scale**: 1-not at all; 3-Yes, no occurrences within watershed; 4- Yes, but not a priority in watershed; 5-Yes, and current examples within watershed
Action & behavior	**Q**: Does the group do any projects or make any policies that address forests and drinking water? **Scale**: 1-no; 3-few; 5-many

2.2.4 FESDWQ Value-Increasing Qualities

A common theme from the open coding analysis across all stakeholder groups and all watersheds was the perception that certain qualities or effects could lead to increased value placed in the FESDWQ (these qualities could also be applied to all FESs). Interviewees perceived that if these qualities or aspects were present people would place greater value in the FESDQW. Table 6 shows a list of these qualities with a description and representative quote from the interviews. “Proximity to nature” and “experiencing nature” was mentioned the most frequently in interviews (by 9 and 8 interviewees respectively). “Awareness” and “quantification” were similar qualities that a combined 8 interviewees mentioned. Being aware of the existence of the FESDWQ is crucial to valuing the service, and the deeper the understanding of the FESDWQ, the greater that value could be (i.e., actually quantifying the FESDWQ within a watershed). “Reliance,” “impending threats,” and “retrospective value” are all qualities that involve the individual relationship between humanity and the FESDWQ. These were contingent upon awareness of the FESDWQ in the case of “reliance” and “impending threats” and those who may have been previously unaware would become aware after the FESDWQ is gone (“retrospective value”). The heavily urbanized DET, where arguably the FESDWQ would be most compromised, did not mention any lamentations over the loss of the FESDWQ, but they did frequently mention how the loss of water quality over the decades was the impetus for cleanup efforts.

Table 6: Qualities that increase the value of the FESDWQ or FESs.

Quality	Explanation	Example Quotation
Awareness	Understanding the mechanism of FESs increases the value one places in those services.	"There are people that are in water policy that don't recognize the value of forests. We have communities that have very strict tree ordinances and some that will let you cut anything down. They're the same kind of people but one is a little bit more educated than the next." (PM/NPO, DET)
		"I think it's really important to make sure we're raising young people with an awareness of the importance for maintaining trees - even in urban areas." (LG, LGR)
Overabundance	An overabundance of natural resources (e.g. freshwater) leads to *less value* placed in the FESDWQ (taken for granted).	"You can pour almost anything in Lake Huron, and it would be hard to measure it in any of those water intakes because there is an awful lot of clean water. That's not to suggest we shouldn't protect it [FES]: I'm just saying that the quality of the water is unlike anything in the world." (PM/NPO, DET)
		"You tell people your water comes from the mountains or the forests, and I think that connection is a little harder to make here. I don't know if it is a cultural thing of there being too much water around people here." (LG, LGR)
	An overabundance of forests leads to *more value* placed in FESs (FESs valued by utilization as abundant resource).	"If you've got a resource in your backyard like we have here, that's great. Let's take advantage of it, manage it, and manage it properly. When I say properly, let's not go out and be clearcutting mass areas that are going to cause sedimentation into our streams and such." (FL, AS)
Wealth of Time	If a person has the resource of time to spend researching FESs, value in FESs increases.	"And a lot of times they are older or retired and have more time to look up these things: They have the time to get themselves educated on it." (LG, LGR)
Proximity	Forests and water in close proximity increases the value of the FESDWQ.	"People understand the connectivity there [forest by rivers] better than a tree that is within the watershed but it's harder to explain to people. They don't understand how it already impacts water quality if it's not right on the river's edge." (LG, LGR)
		"In West Michigan, we may not connect forestry and water together, but if you're going to go to the UP you could get a different answer on drinking water because maybe those people have a shallow well near a forest and somehow that forest benefits that source of water and they drink it." (PM, LGR)
Experiencing Nature	Spending time in water and forest natural areas will increase value.	"If they don't see the river and they don't touch the river, they don't care about that river." (NPO, DET)
		"I don't want to underestimate recreation because that's the link that gets people to care." (NPO, LGR)

Table 6 (cont'd)

Quality	Explanation	Example Quotation
Reliance	Reliance on FESDWQ increases value (contingent upon awareness of reliance).	"That is one of the biggest concerns: Water quality. It always comes back to water management, flood control and water quality because it impacts us in every way." (WU, LGR)
		"We are beer city USA. They need water, clean water. I know they have a group that has been advocating for clean water in Michigan." (PM, LGR)
Impending Threats	When functioning of FESS compromised or threatened, value increases.	"As we start to look for more instances of that kind of groundwater contamination [PFAS], we're going to find it because the chemicals persist forever. So that's a problem, and it's on people's minds a bit more." (NPO, AS)
Retrospective Value	*You don't know what you've got till* the FESDWQ is gone. Loss of function will be felt and therefore value increased.	"Once you lose it [water quality], you got to spend a lot of money to get it back. Once you lose it, we would always be on the map as a county that had bad water quality and we didn't see it as a priority. So, we always must keep it a priority." (PM, LGR)
Quantification	Quantifying benefits of FESDWQ would increase value.	"We did a project where we developed a stormwater calculator to calculate costs and benefits associated with implementing green stormwater infrastructure…We use that as a tool to encourage more implementation of green infrastructure." (NPO, LGR)
		"If I had a better understanding of how the forests around here were directly impacting drinking water then I would probably bring it up more and talk about it more. But I don't have a firm understanding of where all the water is coming from. Aside from the well, it's not something I talk about." (LG, LGR,)
Money in the Bank	If it pays or benefits one directly, they will value FESDWQ.	"If it pays for a guy to look out for soil erosion and water quality, it's going to get done. If it pays to manage your forest...It works both ways I think. Having markets enables management; management equals a healthy forest; a healthy forest makes good water quality and fish jumping in the creeks. It's all really tied in together." (LG, AS)

2.3 Discussion

The overall objective of this research was to understand the value that stakeholders in three Michigan watersheds place in the FESDWQ. Different stakeholder perceptions in all three watersheds teased out the complexity and characterization of stakeholder value towards the FESDWQ. Most interviewees prioritized water quality as the most important FES. The importance of water quality as an ES did not translate to the FESDWQ, or in other words, to quality drinking water as a *product* of forest functions. Nearly half of interviewees believed there is a link between forests and drinking water, but most interviewees admit they seldom think about this link or deem it as low importance within their watershed. No interviewees directly addressed the FESDWQ in any of their organization actions or rhetoric. Interviewees perceived the link between forests and drinking water as being more valuable to those who get their drinking water from shallow wells in forested areas. On the other hand, those in more urban areas divorced impacts to drinking water from any forest or land management/changes within their watersheds, but still perceived a close connection between forests and stormwater (i.e. forests as green infrastructure to address stormwater runoff issues).

Stakeholder discomfort in prioritizing FESs may be due, in part, to their blend of anthropocentric and biocentric values. Having a blend of anthropocentric and biocentric values is not uncommon, even among groups one would assume to lean heavily toward one end of the value spectrum (Hunter et al. 2014; Jarvis et al. 2016). This blend of values could be explained by interviewee perceptions on how to motivate constituents. Policy makers, local government, and NPOs mentioned that they rely on anthropocentric values do get their constituents to care about the environment, and while their personal values may be more biocentric, many interviewees shared a belief that natural and human systems are interconnected. Having a blend of values makes it trickier to make decisions, but also minimizes conflict because more diverse values are addressed (Ives and Kendal 2014). Local government, NPOs, consumers, and policy makers were weary of prioritizing one FES over the other because they did not want to deal with trade-offs leading to degradation of those services not prioritized. This is a common challenge revealed by the increasing popularity of PES programs across the world: When managers target one ES to prioritize over others, the net benefit to the ecosystem may be negative or other ESs may degrade (e.g. Naeem et al. 2015; Redford and Adams 2009; Reed et al. 2017). A consumer, policy maker, and NPO in this study chose to name the FES of *biodiversity* to include all FESs in potential management and policies. While not always explicitly considered a FES there are some examples of biodiversity being considered a final ES (Mace et al. 2012). Whatever the case, literature shows that biodiversity enhances the functions of FESs (Ellison et al. 2017; Muys et al. 2014). In valuing non-market goods, hybrid approaches that consider stakeholder values of ESs and biodiversity could be very effective (Pascal et al. 2010). In fact, Thompson et al. consider that incorporating forest biodiversity into policy decision-making could lead to a more holistic protection of the forest ecosystem (Thompson et al. 2011). This study confirms that biodiversity would be an important measure to use when measuring stakeholder values and could be effective in advancing ESs in the nexus of science and policy, especially at a time when the issue of biodiversity loss is at the forefront of global issues (i.e., recent release of IPBES report on unprecedented global species extinction rates). Combining biodiversity with ESs could be an important conservation strategy. However, sensitivity should be applied when using the terms "biodiversity" or "ecosystem services" when communicating to the public: According to a public opinion survey on conservation language, these terms are not always perceived favorably or are often misunderstood by the public (Weigel and Metz 2018).

Knowledge of the FESDWQ did not lead to increased value in the FESDWQ which is consistent with ES and environmental behavior literature (Nisbet 2009; Kaplan 2000). However, many stakeholder groups expressed the importance of disseminating knowledge throughout the watershed about this FESDWQ for it to be used in conservation or management. While education is certainly an important and well-used tool for stakeholder engagement, finding shared stakeholder values around this FESDWQ may be a more effective tool for incorporating the service into future watershed conservation efforts (Cohen 2012; Pielke 2007).

Stakeholders in all watersheds associate forests with water quality directly and prioritize this ES, but that value does not transfer to forests and drinking water quality. No projects, policies, programs, missions, or goals from any of these stakeholder groups directly addressed the forest ecosystem service of providing drinking water. The positive externality of forests provisioning drinking water is in fact separated from the value of forests in these watersheds as is postulated in literature (Todd & Weidner 2010). In the DET, not having many forests to provide the FESDWQ (9.5% forested) may explain why there are no programs addressing forests and drinking water: The FESDWQ is functionally extinct. In AS, there are abundant forest resources that contribute to a pristine water quality environment. However, that does not mean forests moderate all threats to drinking water: Chemical contamination can still be an issue (e.g. PFAS contamination has been discovered at both the headwaters and mouth of the watershed). In a mostly forested watershed with a relatively low current threat of deforestation, there is no need for programs that address the FESDWQ because forest function is largely intact. However, protection of the FESDWQ against future threats from increased development could become important, but is not currently a priority within the AS. In LGR, non-point pollution from agricultural areas and stormwater pollution and wastewater from industrial and urban areas is a stronger priority for watershed projects over protecting and restoring the intangible FESDWQ.

Initiating programs that incorporate the value of FESDWQ may be a challenge for watersheds that do not view the FESDWQ as a priority. Alternatively, managers could start by using rhetoric that incorporates the FESDWQ into existing programs. Once the watershed is exposed to this rhetoric, value in the FESDWQ may follow leveraging support for more forest conservation. Urban dwellers near a forest in Germany valued the FESDWQ potentially because the forest was a designated drinking water protection area (Meyer and Schulz 2017). Many interviewees said they would incorporate the FESDWQ into rhetoric if they knew watershed-specific quantification of the FESDWQ. Biophysical quantification would be an important first step.

There is a disconnect between the provision of drinking water and natural land (especially in DET but also present in the urban areas of LGR). This is consistent with literature that shows that urban populations will value regulating ESs more than provisioning ESs (Lapointe et al. 2019). In the urban context, this high value for regulating services like air quality and water regulation is because these services are more connected to the urban population's quality of life (Martín-López et al. 2012). There was a perception from many interviewees across all watersheds that those who live on forested land and have personal wells or live in more rural environments would place greater value in this provisioning FESDWQ. This perception is consistent with studies of rural populations that show this favoring of provisioning ESs to be the case (Lapointe et al. 2019). Further research into differing perceptions of urban to rural populations about FESs in these watersheds is needed to study this theme, and the perception that groundwater over surface water is more associated with the FESDWQ is worth further exploration. The focus in current research about FESs and drinking water is on surface water: A common statistic used is two-thirds of the nation's clean water supply comes from *surface* water that filters through forests (Deal et al. 2016). The USDA's *Forests to Faucets* program created an index for all the US that gives importance of forest to drinking water, but which excluded populations of people who get their drinking water from groundwater (Weidner and Todd 2011b). This research suggests that these are the populations that would value the FESDWQ the most.

The value increasing qualities that interviewees mentioned of "experiencing nature" and "quantification" are consistent with previous findings. For example, there are documented positive effects that spending time in or experiencing nature increases a person's well-being (Biedenweg et al 2017). People often value those ESs that have a direct connection to their quality of life (Lapointe et al. 2019). Forest landowners, local government, and consumers mentioned that the value people have in forests and water quality go up when they spend time in nature (e.g. kayaking down a river in a forested watershed). Recreating in the pristine waters of the AS amidst forested riparian corridors is more concrete than the intangible forest provision of drinking water. Using this value increasing quality for the FESDWQ may not be as simple. Perhaps protecting forests for the express purpose of protecting drinking water would lead to increased value for those recreating in that forest. For example, stakeholders around a drinking water protected forest in Germany valued the FESDWQ over many other FESs (Meyer and Schulz 2017). Quantifying the forest ecosystem service of providing quality drinking water in all three of these watersheds could facilitate the conservation of the FESDWQ and potentially lead to higher value in forests and a corresponding increase in and support for forest conservation. Many interviewees admitted that if they had some sort of quantification of the magnitude of forests filtering drinking water within their watershed; they would place a higher value toward the FESDWQ and discuss it with their constituents. ES literature shows that a spatially and temporally specific biophysical quantification of an ES is necessary both for the valuation process and for making decisions about how to manage that service (Olander et al. 2018; Reed et al. 2017; Syrbe and Walz 2012). There has been no quantification of the FESDWQ to date in any of the watersheds. In fact, national research on the benefits of forests to drinking water systems is relatively nascent. However, the growing increase of source water protection and wellhead protection into state and national policies has increased research collaborations between scientists and public water systems (Barten and Ernst 2004; Gorzalski et al. 2019). A recent review of literature on the benefits forests provide to public water systems calls for research that incorporates both case-specific (i.e. single public water systems) and multisystem studies (Price et al. 2018). AS, LGR, and DET would welcome research collaborations such as this, based on statements from the interviewees in local government, policy makers and NPOs.

2.5 Further Research

Further research is needed to distinguish urban and rural perspectives about FESs in these watersheds. Additionally, collaborations with large and small water utilities and a forest hydrologist would help to quantify the biophysical properties of the FESDWQ within these three watersheds. Research could be prioritized to study the biophysical properties of forests and groundwater in these watersheds given stakeholders close association between forests and groundwater over surface water (the USDA’s Forest to Faucets program indexes forest importance to providing drinking water in all US watersheds, but it excludes groundwater). Also, more research should be done on perceptions about forests and groundwater in rural communities to test the findings of this research that suggests those populations would place a higher value in the FESDWQ. This research focused on key stakeholders within the three watersheds, but a survey of general public opinion and forest landowner opinion would be an important next step in research to further explore the potential success of conservation programs that incorporate the FESDWQ.

2.4 Study Limitations

The interviews included key stakeholders from non-profit organizations, local government, local policy makers, water utilities, forest landowners, consumers, and industry. Most of these individuals showcased environmentally-prone behaviors and environmental worldviews and were directly involved in watershed and/or forest conservation or worked in a field that impacts forests and/or water. The data from their interviews are not considered a representative sample of their entire stakeholder category within Michigan, but the stakeholder interviews included key perspectives from those within the three watersheds that were the most applicable to this topic. Time constraints, feasibility, and lack of recruitment response led to gaps in stakeholder categories interviewed in all three watersheds. Consumers and forest landowners from LGR were mostly individuals who were very active in environmental stewardship, leading to a potential bias in responses. All water utility stakeholders interviewed were from environmental services departments whose responsibilities dealt with runoff and wastewater over individuals from public or private water systems that provide municipal drinking water. This could impact the water utility perspective of stakeholders. Water providers in DET and LGR mention source water protection (SWP) on their websites, so it can be assumed that SWP would have come up more in interviews if these organizations had been interviewed. Attempts to reach water provisioning water utilities were unsuccessful. For future research, a different more aggressive recruitment strategy for water providers should be employed. To obtain a representative sample of the consumer population and forest landowners in each watershed, a survey method would be a useful design. Interviews of these groups did allow for exploring themes to be used for future survey research in the watersheds.

2.6 Conclusion

There is much untapped potential for forest conservation through the lens of providing quality drinking water. In urban areas, the FESs of water provision and regulation can be prioritized with the insertion of green stormwater infrastructure (GI). GI is already being used in Grand Rapids and Detroit to manage stormwater, but GI could also be a way to insert forests into critical areas for the provision of drinking water. By doing this, watershed rhetoric and conservation efforts would include forests in the entire water cycle. This study demonstrated that stakeholders are already aware of this interconnectedness of forests within the water cycle, but programs and policy focus on one side of the water cycle at a time, and overprioritize regulating over provisioning FESs. Forest degradation and parcellation can be prevented in more residential to rural areas. Stakeholder perception of the link between forests and drinking water already includes the idea of trees filtering drinking water from private wells so this perception could be leveraged into outreach, education, and watershed actions to further conserve forest ecosystems. Given that 25% of Michigan’s population gets their drinking water from private wells (MDEQ 2004), wellhead protection and source water protection will only become more necessary in a state that is battling the frequent emergence of drinking water contaminants and water infrastructure failures.

CHAPTER III: SOCIAL NETWORKS OF WATERSHEDS INFORMING THE FOREST ECOSYSTEM SERVICE OF PROVIDING QUALITY DRINKING WATER

3.0 Introduction

According to the Millennium Ecosystem Assessment, the degradation of global forests threatens the provision of drinking water (2005). One-third of the world's major cities source their drinking water from forests that completely or partially provide that purifying service (Calder 2007). This forest ecosystem service of providing quality drinking water (FESDWQ) is just one of many forest ecosystem services (FESs) that are related to water. Forests provide provisioning, filtering, and regulation of water resources (Ellison et al. 2017). While these services are interrelated, this research focuses on the *provisioning* service over the *regulating* or *filtering* ES. Given the importance that people place in drinking water (Granias et al. 2018), it is contradictory that the value of drinking water is ignored when assessing the value of forests (Todd and Weidner 2010). Disregard of provisioning ESs is common and so capturing the lost value of ESs is an important practice in conservation and stewardship of natural resources (Costanza et al. 2017).

Michigan is a state abundant in natural resources: It is covered by over 20 million acres of forest, surrounded by four Great Lakes, and filled with 46,000 inland lakes and over 76,439 riverine miles (MDEQ 2017; Pugh et al. 2016). While Michigan has abundant natural capital, there are many threats to that capital: Michigan's forests are highly fragmented by roads due to development, and all of Michigan's Great Lakes and over half of its riverine miles are impaired or failing to meet one or more federal water quality standards (MDEQ 2017; MDNR 2010). Threats to Michigan's freshwater not only impacts the people of Michigan: The Great Lakes contain over 21% of the *world's* available freshwater supply and the Great Lakes Region has the third largest economy in the world with a GDP of $6 trillion (Desjardins 2017). Water scarcity will be one of the greatest global crises of the coming era: Michigan and the Great Lakes Region is comparatively advantaged for the coming crisis (Annin 2013), so the decisions Michigan makes in managing its forest and water resources is of vital importance. To manage these resources, Michigan governance is beginning to incorporate FESs into management strategies and consider new solutions in management like Payment for Ecosystem Services (PES) programs that incorporate FESs into conservation strategies (OGL 2017). Agricultural PES programs have been implemented in Michigan (Claassen et al. 2008), but a lack of participation and understanding in these PES programs has hindered their success (MDNR 2010). If the FESDWQ were to be leveraged into conservation programs that protect Michigan's forests and water resources, stakeholder value placed on the FESDWQ must be ascertained.

ES concept literature states that measuring stakeholder value placed in an ES is the first crucial step for research into that ES. Value in this research refers to a mental process of determining the worth of the FESDWQ by assessing scenarios, comparing to perceived related reference points, and behaving in ways that impact the FESDWQ (Costanza et al. 2017). The value placed in the FESDWQ is an internal mental process, but it is also affected externally by interactions with stakeholder groups (groups that impact, are impacted by, or perceive to be impacted by the FESDWQ). Stakeholders do not create value statically by a simple transaction between an ecosystem benefit provided to humans such as between forest landowners and downstream water consumers; but value is dynamically co-created within various stakeholder interactions (Matthies et al. 2016). Social Network Analysis (SNA) methodology investigates social structures using network theory and is increasingly used to observe social networks between stakeholders and actors in natural resource management issues (Bodin et al. 2006; Larson et al. 2013). SNA follows the connections between individuals or groups (or the pattern of relationships between social actors) and the exchanges, flows, and directions of valued resources between groups (de Laat et al. 2007). SNA can characterize social networks and their ability to facilitate social cohesion, or the comprehensive inclusion and integration of stakeholder groups (Münch 2001). To measure interactional value co-created between stakeholders, a qualitative and quantitative application of SNA can also be employed to identify "relational value" placed in the FESDWQ by incorporating measures of social cohesion within networks. Relational value (added to the theory of intrinsic and instrumental value) has been increasingly used in applications of ESs to get at the dynamic nature of ES valuation (Baard 2019; Pascual et al. 2017).

To date, ES literature has focused on "unidimensional" valuing of ESs based in economic valuation methodologies (Aguilar et al. 2018; Costanza et al. 2017; Olmstead 2009). However, "pluralistic" valuation approaches which incorporate the value-laden aspects of the valuation process itself; and the impact that power relations, politicization, and stakeholder relationships have on the value placed on the ES; is likely to be a more equitable way of incorporating ESs into conservation strategies (Pascual et al. 2017). This research begins the pluralistic valuation process for the FESDWQ in three watersheds in Michigan, by incorporating that relational value in the FESDWQ that is integral to future equitable management of the FESDWQ.

3.0.1 Research Objectives and Questions

The first research objective was to determine how stakeholder value in the FESDWQ is affected by interactional processes between stakeholder groups. To fulfill this research objective, the structure of the social networks, the roles that stakeholders have in their network, and the flows of resources and information were explored. The second research objective further investigated stakeholder value of the FESDWQ by exploring how stakeholder groups impact the

FESDWQ in the three watersheds, and whether the interactions between the different stakeholders influenced the value that the stakeholders place in the FESDWQ.

3.1 Methods

3.1.2 Methodological Framework

SNA is typically a quantitative methodology; however, qualitative data can also be incorporated to better understand network characteristics. A qualitative engagement of SNA is more suited to reflecting “the permeable, partial and dynamic nature of social networks” (Heath et al. 2009). SNA was employed in this research by incorporating qualitative interview data to further contextualize and strengthen quantitative SNA of the watershed networks. This mixed-method approach adheres to the epistemological foundations of measuring the social constructions that describe social behavior.

3.1.2 Methods

Data Collection

Key stakeholders were recruited in seven stakeholder categories across all three watersheds (refer to Chapter 2, section 2.1.2 for specifics on data collection). During the interviews, information was collected on how often interviewees interacted with a list of stakeholders that was created a-priori through online research of each watershed. The exhaustive list of potential organizations, groups, and agencies within the watershed was narrowed to only those that may be involved in the functioning of the FESDWQ, but also are involved or impacted by forests and water resources in general (Table 7). The list was updated and edited for each watershed as interviews progressed based on feedback from the interviewees totaling to a list of 36 stakeholders in AS, 49 in LGR, and 40 in DET.

Table 7: Stakeholder types included in stakeholder list for each watershed with the code assigned on the right.

Stakeholder Types	Code
Universities	A
University groups	A
Federal Agency	FG
Environmental consultants	I
Forest Industry	I
Government affiliated NPO	LG
Drain Commissioners	LG
Government affiliated NPO	LG
Conservation Districts	LG
Tribal government	LG
Regional Planning Partnerships	LG
County Government	LG
Municipal Government	LG.M
Umbrella NPO	N
Advocacy NPO	N
Special Interest NPO	N
Advocacy NPO	N
State Agency	SG
Water Utilities	WU

Each interviewee was asked how often they interacted with each group on the list ranging from 0 (never) to 7 (daily). Network data was collected for 8 interviewees in AS, 16 interviewees in LGR, and 6 interviewees in DET (30 out of the 42 total interviewees). When forest landowners and consumers were interviewed (only in LGR), instead of interactions, the interviewee was asked whether they recognized the group and whether that recognition included an understanding of the function of the group within their watershed. Interaction and recognition data were used for quantitative descriptive statistics and SNA.

Data Analysis

Qualitative data analysis software (NVivo 12™) was used to code interview transcriptions. Two inter-rater reliability tests were performed during the analysis process to test the external validity of the single coder, and coding was adjusted according to those tests. Open coding was used to allow for developing themes from the data completely through the analysis process (Creswell 2013).

Quantitative data were analyzed using the igraph package in the R programming software (Csardi and Nepusz 2006). Using the spreadsheet data from the interviews, the networks of the stakeholders linked to forests and water quality were visualized by creating sociograms for each watershed (a graphic representation of actor/stakeholder interaction and recognition links). Descriptive statistics were performed on the interaction data for each watershed of each stakeholder on the list: Any stakeholder without a single interaction was dropped from the list. Network statistics were performed on the three watersheds using the local metrics (individual node metrics) of geodesic distance and degree; and using global metrics (network metrics) of degree centrality, closeness centrality, and betweenness centrality (Table 8). Centrality metrics are a measure between 0 and 1 and are reported as a percentage, and a clustering coefficient was applied to the networks to view any clustering of nodes (Rochat 2009; Wasserman and Faust 1994).

Table 8: SNA metric definitions (Csardi and Nepusz 2006; Rochat 2009; Wasserman and Faust 1994).

Measure Level	Metric	Definition	Measure
Local Metrics	Geodesic Distance	The smallest number of ties to connect two nodes	How many ties it takes each node to reach others
	Degree	The number of ties or links a node has	How influential each node is on its neighbors
Global Metrics	Clustering Coefficient	The probability that the adjacent vertices of a vertex are connected (also called transitivity)	Extent clusters of nodes exist in a network
	Degree Centrality	Normalized node degree centrality divided by the theoretical maximum	Node connectivity (finds organizations with great influence on neighbors)
	Closeness Centrality	Normalized node closeness centrality divided by the theoretical maximum	Network connectivity (finds organizations who can contact whole network easily)
	Betweenness Centrality	Normalized node betweenness centrality divided by the theoretical maximum	Network flows (finds organizations whom information likely to pass)

3.2 Results

3.2.1 General Network Overview

Stakeholder interactions in all three watersheds differed by stakeholder type, which dictates their overall function in the network (i.e., watershed). Non-profit Organizations (NPOs) served as the educators and communicators within the network, are project-oriented, and occasionally advocate for specific environmental issues. Local government closely resemble the roles of NPOs (excluding advocacy) with the goal of providing local services. Policy makers/enforcers set the foundation of the network with policies and policy enforcement. Water utilities provide drinking water and treat wastewater. Forest landowners go to NPOs, local government, and forest industry to fulfill their questions and needs. Industry provide specific services throughout the watersheds but are considered natural resource polluters. Consumers are the overall beneficiary of a cohesive network.

3.2.2 Quantitative Results

State agencies had the most frequent average interactions across all three watersheds indicating that contact with state agencies occurs yearly, a few times a year, or monthly (Table 9, 2.4-3.7). In AS, federal government, local government and NPOs had less frequent interactions on average, while industry and academic institutions had almost no interaction. Local government and NPOs had the greatest number of connections to other organizations. Stakeholders within the LGR interacted most frequently with state government, federal government, NPOs, and academic institutions in descending order. Like the AS, local government and NPO stakeholder groups had the greatest number of connections to other organizations in the LGR. Finally, stakeholders within DET interacted most often with state government, water utilities, local government, and federal government in descending order.

When looking at individual interaction data of each listed stakeholder, all watersheds had a regional NPO that was connected to 24-61 other organizations (Appendix B). The LGR and DET interviewees had, on average, monthly interactions with Drain Commissioners (or alternately called Water Resource Commissioners). Uniquely, the DET was the one watershed in which many interviewees had interactions with water providers (indicated as the water utility stakeholder category). Some of the stakeholders with fewer interactions are those that are tied to smaller or less central geographic areas (i.e., NPOs from less central subwatersheds or county government agencies whose counties are only partially within the watershed).

Table 9: Summary statistics of interaction data. "N" is the number of people who answered questions about stakeholder interactions per watershed. "n" is the number of stakeholders in that category multiplied by N. In AS, no one reported any interactions with water utilities (na).

		Watershed								
		AS (N=8)			**LGR (N=15)**			**DET (N=6)**		
Code	**Stakeholder Type**	Interaction (avg.) *	std. dev.	n	Interaction (avg.) *	std. dev.	n	Interaction (avg.) *	std. dev.	n
A	Academic Institution	0.81	0.44	16	1.91	0.47	75	1.75	0.32	24
FG	Federal Government	1.50	1.05	32	2.75	0.66	60	1.96	1.51	24
I	Industry	0.38	0.35	32	1.89	0.47	75	1.70	1.39	30
LG	Local Government	1.26	0.99	80	2.62	1.00	195	2.10	1.41	48
NPO	Non-Profit Organization	1.99	0.75	80	1.96	0.88	255	1.67	1.02	78
SG	State Government	2.44	1.47	32	3.71	1.61	45	2.88	1.49	24
WU	Water Utility	na	na	na	1.80	2.96	15	2.72	1.11	18
	Total	**1.40**	**0.84**	**45**	**2.38**	**1.15**	**103**	**2.11**	**1.18**	**35**

* 0=never, 1=once, 2=yearly, 3=few times/yr, 4=monthly, 5=couple times/mo., 6=weekly, 7=couple times/wk-daily

AS, LGR, and DET stakeholders were connected to one another within each watershed with an average degree of 6, 10, and 6 respectively (Table 10). On average, stakeholders in AS, LGR, and DET were connected to all other stakeholders within the network with an average geodesic distance of 2. The probability that nodes are clustered is highest in the AS (0.37) followed by LGR (0.27) and DET (0.24). The LGR had the highest degree and closeness centralities, while the AS had the highest betweenness centrality. Centrality measures over 50% in all watersheds indicated that there were groups with high influence (Figure 5). Quantitative SNA metrics were also applied to only those nodes of the stakeholders that were interviewed in each watershed: These sociograms and table can be found in Appendix C.

Table 10: SNA local and global metrics of each network (watershed)

	Local Metrics		Global Metrics			
Network	Geodesic Distance (Avg.)	Degree (Avg.)	Clustering Coefficient	Degree Centrality	Closeness Centrality	Betweenness Centrality
AS	2	6	0.37	53%	55%	30%
LGR	2	10	0.27	63%	63%	29%
DET	2	6	0.24	58%	48%	28%

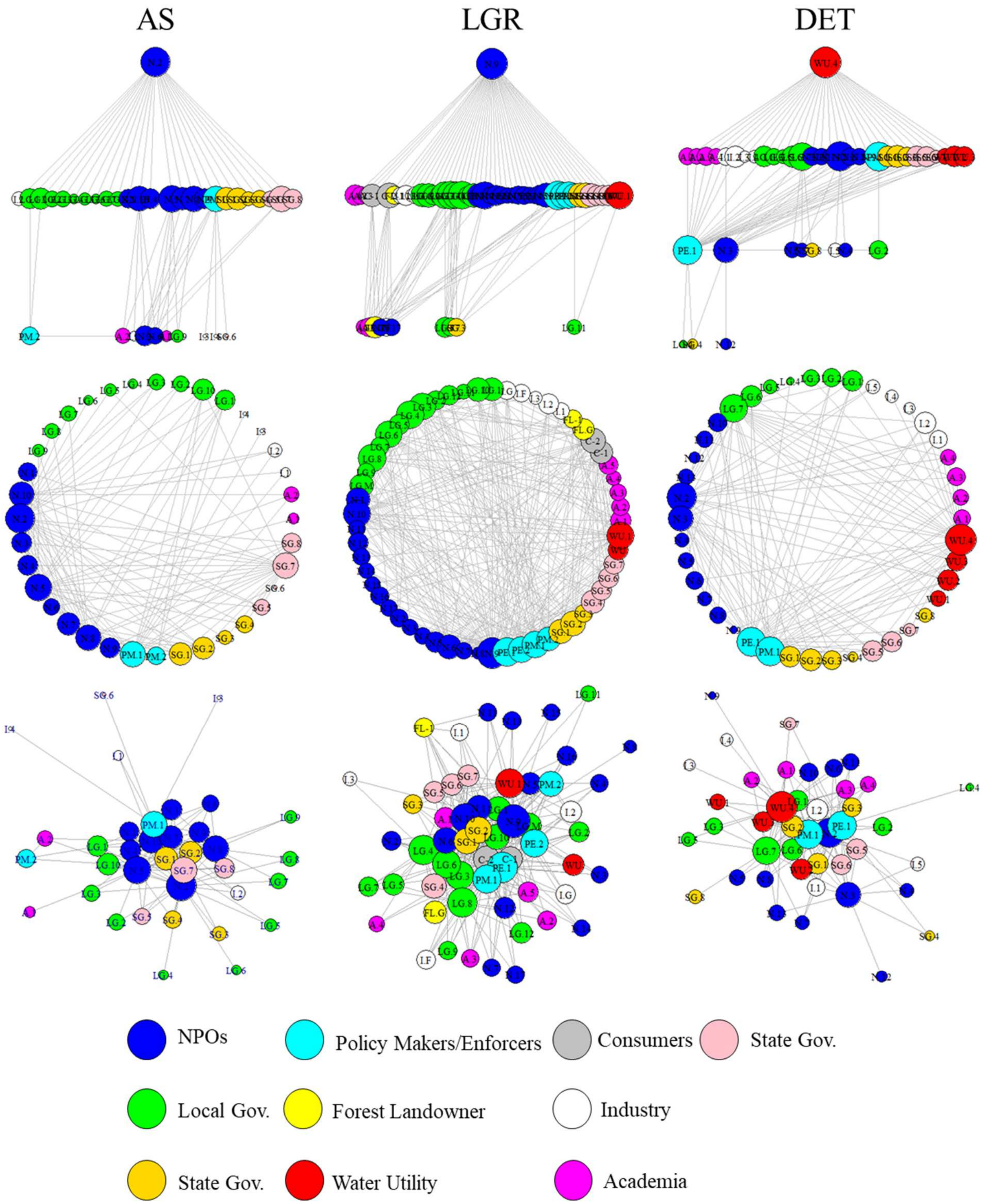

Figure 5: Sociograms of the interactions between stakeholders in each watershed. There are three sociograms of the same network data. The difference visually is from layout structure: Top is tree layout, middle is circle layout, and bottom is random. Nodes are represented by circles in the graphs. Circle size represents the weight of the interactions (i.e., 0-7). Nodes are colored by stakeholder types. Gray lines are edges or connections between stakeholders.

3.2.3 Qualitative Results

During the open coding process of analysis, themes arose from the data that closely followed the theory of social capital (Table 11). Social capital has various definitions within the discipline of sociology: A frequent definition of social capital incorporates aspects that lead to effectively functioning social groups or "networks, norms, and trust" (Putnam 1993, pp 167; Floress et al. 2011).

Social Networks

A common aspect of SNA and social capital is designating “bridger” and “bonder” entities, or those groups that bring people together who do not previously know each other and those that bring people together who already know each other (Floress et al., 2011). Regional NPOs in all three watersheds are the common bridgers that make introductions between groups. In the smaller population of AS, groups know of each other and often sit on each other’s boards. In LGR, groups are all very interconnected, but smaller less influential groups may be forgotten or not included as much as they wish. In the large population of DET, categories are very connected thanks to large regional partnerships of similar stakeholders that are organized by watershed area. NPOs facilitated the sharing of information in each watershed (“disseminators”), with local conservation districts often being sources of information for the general public and forest landowners in LGR and AS. DET had a more complicated information dissemination network which included more actors playing a disseminator role, however, those roles are well-defined (Table 11).

Social Norms

Interviewees perceived a culture of helpfulness, shared values, and proactive action within their watersheds as norms that do (or would) facilitate the functioning of the whole social group. All watersheds showed a general willingness of stakeholder groups to help one another as evidenced by many examples of different stakeholders working together on projects. Also, stakeholders (policy makers, NPOs, and local government) showed a willingness to understand groups by listening to their needs and engaging with them at their level: “One thing I love about this job is I like to hear people, not complain, but to hear the different levels of complaints and how important it is to them and then you put that on a list and go, ‘hey, this is important’” (PM, LGR). Whether helpfulness is consistently achieved or equitably applied is not always clear. However, 13 different stakeholders across the three watersheds mentioned that time and staffing constraints may prevent them from working with other groups or helping when needed. The helpfulness culture exists, but the default is to separate into the functional roles of each stakeholder type. Being helpful is also dependent on effective communication. In LGR, one NPO mentioned that two local government units were not very good partners because of communication failure: “If I ask more than once and they don’t respond I am not going to ask again…I am disappointed they have not been more involved with us.”

Table 11: Social capital by watershed

Aspect of Social Capital	Aspect Measure	Watershed: AS	Watershed: LGR	Watershed: DET
Social Capital: Aspects that lead to effectively functioning social groups or "networks, norms, and trust" (Putnam 1993, pp 167; Floress et al. 2011)				
Social Networks[a]				
A set of social structures made up of social actors (a.k.a. stakeholder categories)	**Bridgers** (bring groups together that do not previously know each other)	Larger regional NPOs do this in all watersheds.		
	Bonders (bring groups together who already know each other)	Structure of network facilitates group bonding; mostly within stakeholder categories.	Groups know each other and work together, but smaller groups can become isolated.	Categories are intra-connected.
	Disseminators (spread information easily throughout network)	CDs and NPOs disseminate information to public and notify influential groups when action is needed.	CDs and NPOs both work on public awareness and communication.	NPOs provide info to public, regional planners provide info to NPOs, and LG provide info to policy makers.
	Powerful Players (have the most influence in the network)	PMs, NPOs, LG, FL (State and Private Industrial), and Army.	PMs, DCs, and NPOs.	Regional planners, PMs, and funders.
	Changers (drive and implement change)	NPOs and CDs. Individual leaders can be driver for change.	NPOs and PMs. Individual leaders can be driver for change.	Collective PMs and NPOs drive change but do it separately of each other.
	Diversifiers (ensure diversity of voices driving decisions)	Regional NPO actively seeks diverse voices.	NPOs are active diversifiers; many groups include diversity in their missions.	NPOs bring diverse groups together with goal of better decision making (decisions may or may not be achieved).

Table 11 (cont'd)

Social Norms[b]				
Unwritten rules of acceptable behavior	**Helpfulness** (how helpful are groups?)	Groups willing to help one another but working together not always desired.	A helpfulness culture persists but working together not always achieved.	Groups tend to separate into their constituent roles but still interact.
	Value Consensus (is there a culture of shared values?)	Groups share the value of keeping the Au Sable pristine.	Shared values differ from urban to rural and within different sub-watersheds.	This is desire. Groups separate into own values when doing projects.
	Proactive vs. Reactive (Do people value long term benefits over short term gains?)	All watersheds have the desire to be more proactive in their projects, goals, and policies. LGR had some concrete examples of doing so, but mainly the watersheds are solely reactive.		
Trust[c]				
Trust is the willingness to be vulnerable/rely on others, and includes a confidence that expectations will be met (Rousseau et al. 1998)	**Risk** (probability of loss from failed expectations)	All watersheds showed the public trusts NPOs and county government (over municipal or SG) to share information. WUs and PMs trust SG overall. LGR COs and NPOs have more trust in their municipal gov. compared to other watersheds.		
	Interdependence (reliance upon other stakeholders)	Stakeholders rely on each other because they are so interconnected.	Stakeholders rely greatly on one another.	Stakeholders rely on one another due to stakeholder function
	Familiarity (knowledge of and experience with other stakeholder groups)	Stakeholders familiar with one another; but PMs, WUs, and municipal separate.	Key stakeholders frequently interact, but subwatershed groups on periphery. Periphery is connected to the whole.	Stakeholders have knowledge of one another and share resources.

Measures partly adapted from a. Buckingham et al. 2018, b. Narayan and Cassidy 2001 c. Mase et al. 2015
CD: Conservation districts; LG: Local Government; PM: Policy Maker; FL: Forest Landowner; DC: Drain Commissioner; CO: Consumer

Not all parts of these watersheds feel equally represented. This was especially present in the AS as explained by an interviewee:

> "The [X] and [Y] have been around a long time. They've been working on conservation projects in our area for years. Nobody picked out or pinpointed our [subwatershed]. The Au Sable watershed is so huge: It almost goes from one side of the state to the other. There's no way that they know what's going on this end. They didn't take particular attention over here, either. It's probably gotten more attention since we've been on board" (NPO, AS).

In the AS, interviewees on the eastern edge of the watershed felt isolated from the broader watershed community. There were examples of stakeholders working together on the eastern and western sides of the watershed but they are less connected as a unit. In DET, there were examples of one county lagging behind other watershed counties in both watershed and environmental management due to budget and resource constraints. One interviewee in the DET said "[X] county is behind the times compared to [the other counties in the watershed] when it comes to watershed management. They're barely trying to make financial ends meet and this piece of it is on the side burner" (WU, DET).

Interviewees consistently mentioned the importance of having a culture of shared values to implement conservation projects. In the AS, there is a strong sense of identity in the sanctity of what many referenced as the "holy waters" of the Au Sable River, and stakeholders share this drive to keep those waters pristine. There is not always agreement on how to achieve this goal, and there are both historic examples of different NPOs at odds with one another and current disagreements, but the AS has a shared value and identity. This shared identity can be leveraged to quickly mobilize stakeholders to collaboratively address river water quality issues. One such instance was a recent pollution loading caused by a fish hatchery: A united front of NPOs and local government collaborated to address and resolve this issue. One AS resident from a local NPO reflected on this sentiment in a current online blog:

> "What did it take to reclaim this river, the Crown jewel of Michigan's trout streams, and what does it take to protect what we have achieved? The answer is a coalition of conservation and environmental interests, setting aside their competing concerns, and working over the years to achieve what we have now: the number one wild trout destination east of the Mississippi. And that's my point: by working closely together, the "hook-and-bullet crowd" and the "tree huggers" can't be beat on issues that affect our natural resources and environment, especially when it comes to water. If we are divided, we are weaker because of it" (Baird 2019).

The shared value in the AS is perceived as eroded by the presence of a large seasonal (summer) population which prioritizes recreation. Full-time residents of AS postulate that these people "are not interested in water quality. They are interested in coming up for the weekend, partying, having a bonfire, going out on a pontoon, waterskiing; and then they go home" (NPO, AS).

Unlike AS, DET does not have this strong shared pride in their river and surrounding land. In fact, there is an opposite perception: The Rouge river is viewed as a historically polluted water body. Many DET stakeholders mentioned this perception of a polluted river as a motivation to clean it (they have made many strides in the past decades in during this). The shared value of restoring a polluted river mimics the AS shared value of keeping a river pristine. One NPO mentioned that while there may not yet be value consensus, "the watershed groups themselves really create shared value, because you have membership from corporations, individuals, businesses, government officials, etc." There may already be a shared value of protecting human health, but it is expressed differently by stakeholder goals. If stakeholders would recognize their shared value, they could foment positive change:

> "[NPO] goal is to improve the watershed and to make it a more beautiful place to live and increase quality of life. The folks at [local government] goal is to get out of debt and to have more people live in [the area] and pay more taxes. We have different ultimate goals, but it's how we both get to that goal. Because I think there's a lot of shared value that happens and we don't really think about that in the broader scale" (NPO, DET)

In the LGR, shared values across a social network may exist in smaller geographic extents like sub-watersheds. In the city of Grand Rapids there is a shared value of the importance of city trees which has led to a stakeholder-wide goal of increasing the urban forest canopy cover by 40% (policy makers, NPOs, water utilities, and consumers all mentioned this). In the more rural areas of LGR there is a shared value of hunting and fishing (LG, LGR). While there may be slightly different values throughout the watershed, one interviewee remarked there is an overarching value called "West Michigan Values" described as a sense of pride in the region and wanting to live, work, and play in this attractive western end of the state. This value is centered in the importance of water for recreation.

Some stakeholders in all watersheds lamented that they could not achieve more proactive actions in their watersheds, and they often default to reactive responses to forest and water quality issues instead of incorporating proactive goals and policies in their visioning of the future. Being proactive requires resources (i.e., staffing and funding) that private and public stakeholders rarely have, however, one of the counties within LGR and one of the counties within the DET had the resources and vision to incorporate many proactive environmental measures into their policies and projects. While being proactive was a desired characteristic of all watersheds there was some frustration shown by stakeholders in humanity's inability to think proactively about the natural environment (including ESs): "There's a value to protecting this area that goes far beyond what people are thinking about especially because it's long term. But most people don't think long term: They don't think of things in terms of an ecosystem, much less ecosystem services" (NPO, AS).

Trust

Trust was an important factor in the frequency of interactions between stakeholders. The AS had examples of public distrust of the federal government. One interviewee explains that this distrust could come from a general dislike of the government, "but it is also probably based on history of experiences: It takes so long to undo one or two bad experiences" (federal government, AS). However, in Northern Michigan and the UP there are also large populations of people who trust both state and federal government because public jobs make up a large portion of the local economy (LG, AS). Being involved in a community with boots on the ground increases trust, but once trust is eroded it is hard to get back. Trust was eroded when stakeholders engaged in bad practices or had bad experiences together. During the social interaction section of the interviews, interviewees would often comment "oh we do not work with them anymore" or "oh we just do not work well together." Trust was also eroded when there was a lack of interaction between stakeholders. One NPO in LGR commented that they had tried to contact an organization many times, but after repeated attempts and not hearing back from this other group, they decided they would not want to work with this other group in the future.

Across all watersheds, interviewees perceive that the public and landowner trust is placed in NPOs and local government like county conservation districts. These groups are the ones that are interacting often with these demographics, thereby increasing familiarity. Water utilities and policy makers generally trust state government to do their part: these groups are also the ones that are very familiar with state government because they have almost daily interactions with them. NPO interviewees mentioned that they are the group that can bridge trust between stakeholder groups. When asked how NPOs build up trust, one interviewee answered, "It takes time. It takes effort and demonstrating through work that you do what you say you're going to do and have results that are meaningful, highly impactful, and reflect the needs of the landowner, the needs of the agency, and the needs of the water or the forest" (NPO, AS).

Miscellaneous Themes

There were some other notable themes that came out of the interview data. Competition between stakeholder groups existed in all watersheds in varying degrees. When limited funding was available, there was an increase in stakeholder competition. One NPO in the AS mentioned that NPOs within the watershed compete for available funds on river projects. In the DET, one NPO mentioned that groups spring up in answer to funding fads (e.g., raingardens), but when the popularity of the fad wanes, funding to keep these programs running decreases making applying for those decreased funds more competitive. Overall, in the DET there is not competition:

> "There's a wide variety of quality and knowledge about ways that you're supposed to do this work…when you're looking at your programs and you're looking at the need in the community and whether or not what you want to do is actually viable, you're not competing at too many levels with others. But when I see other groups that haven't done this kind of work before taking over our

territory, I do feel a little upset about it. I have to constantly remind myself that there's so much work to be done" (NPO, DET).

In the DET, there is this sense that there is so much work to be done, therefore the more groups doing work in the watershed, the better. In the LGR, when asked about implementing a potential payment for ecosystem services (PES) program that incorporates the FESDWQ, a couple interviewees mentioned that the watershed has already reached stakeholder group saturation: "There are so many partners already working here, people get nervous when new partners want to come in" (NPO, LGR).

Interviewees in all watersheds and industry mentioned the importance of individual organization leaders in promoting efficiency and cohesion between stakeholder groups. Leaders with strong values facilitate positive work in the watersheds. In the LGR, one local parks department is "not your typical parks department…I don't know if it is just because of their leadership but [x] has a very strong environmental ethic" (NPO, LGR). On the other hand, a perceived bad leader inhibits the function of an organization: "They are in trouble because they don't have a good leader" (FL, LGR). The industries that were interviewed all had environmental departments that were well established. All three industry interviewees said that their companies (all of which with thousands of employees) have been so effective in sustainability because of leadership. In the AS, a divisive or incompetent leader led to historic examples of different stakeholders being unable to reconcile differences and work together. Contrarily, there are examples of these differences being rectified in the current years because of changes in leaderships.

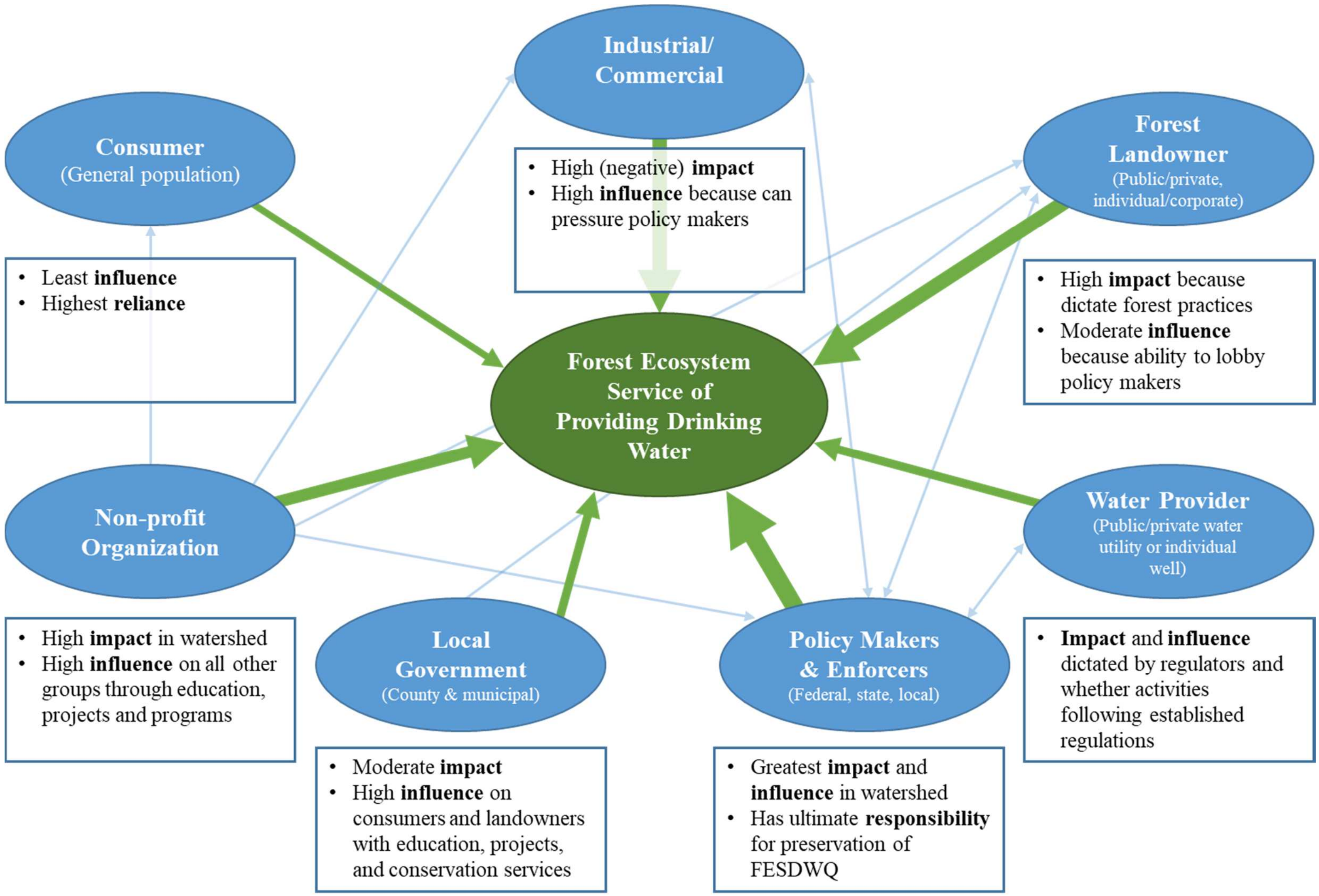

Figure 6: Schematic of stakeholder flow of influence, impact, and reliance on the FESDWQ. Each blue circle is a stakeholder category. Blue arrows (both uni and multi directional) indicate stakeholder influence impressed on each group. Green arrows represent combined influence and impact each stakeholder has on the FESDWQ. Rectangles summarize interviewee data

Network impacts on the FESDWQ

Stakeholder categories have various impact, influence, and reliance on the FESDWQ (Figure 6). This influence (or the ability to make decisions and change behavior regarding the FESDWQ), reliance (or the degree of which a group depends on the FESDWQ), and impact (or activities that effect the FESDWQ) all have various implications to the FESDWQ.

State regulators or any group whose power is backed by regulating practices are perceived as having the most influence over the functioning of the FESDWQ. Whether this power is considered as positive or negative is a different matter. Local government and water utilities respect this relationship between the local to state government because the state regulators are trusted as the ultimate expert on forest and water resources. In that sense, local government see the state as a positive influence on the FESDWQ because they are the only ones ensuring its protection. However, this sentiment is not mirrored by forest landowners and consumers: These groups do not trust regulators to safeguard forest and water resources. One NPO, federal government, and local government interviewee perceived this distrust as a reaction from bad experiences in the past where state regulators failed to protect natural resources or listen to landowner and consumer interests. NPOs in all watersheds understand that the incorporation of ESs into regulation is a difficult thing to do. No one is highlighting this link between forests and drinking water; however, regulators and policy makers are perceived as having the ultimate responsibility for the FESDWQ:

> "I guess the policymakers seem to have disproportionately high influence over everything as opposed to the citizens or the people drinking the water or the landowners. That is a big responsibility to be considered for those types of things like preserving forest land for those ecosystem benefits" (NPO, LGR).

Stakeholders recognized that incorporating ecosystem services into regulatory frameworks is difficult. Overall, NPOs view the state as doing a good job with this given a difficult task, however, they add that more work should be done. Policy maker influence may not always be equitable: “Depending on whether or not they [policy makers] tend to tilt the policy making in favor of one or 2 of these groups at the expense of one or 2 of the others [speaking about stakeholder categories], they can do the most good and they can do the most harm” (AS, NPO). Interviewees in LGR and DET mentioned that the laws, statutes, and ordinances need to be updated to include a better protection of water resources. For example, “The disproportionate impact comes from the legal aspect where our statutes and laws and constitutions have not kept pace with technology, people, processes, and other things going on in our life today…we have a different viewpoint now than when that was written on how to manage water (WU, LGR).”

Influence toward the FESDWQ ended up being measured by whether a group can pressure or influence policy makers. Industry was perceived as having a high impact on the FESDWQ because of the potential of their practices impacting both local forest and water resources, depending on the type of industry. Those that have National Pollution Discharge Elimination System (NPDES) permits under the Clean Water Act directly impact water quality. Forest industry has a very direct impact and some industries of various types may even own substantial forest land (i.e., energy companies own forest land in the AS, DET, and LGR). These impacts are largely dictated by regulation and enforcement of that regulation by policy makers. Interviewees perceived that industry has a strong ability to pressure policy makers to write policy that supports industry desires. Industry is not the only stakeholder with influence: “Industry is the easiest one to target and say ‘you’re the problem, you’re the ones creating all these policies,’ but forest landowners are also really big in influencing how policymakers and enforcers create the rules in which they are supposed to be enacted" (NPO, DET). Landowners were perceived by multiple stakeholders across all watersheds as greatly influencing the FESDWQ because their individual forest practices will impact the FESDWQ, and they have this ability to influence policy maker decision-making. On the other hand, policies and regulations on landowners may not be conducive toward preserving the FESDWQ: "In Michigan, a landowner can clear cut their entire property. There are some laws that prevent them from cutting to the shoreline or river or lake, but enforcement of those laws is sometimes very light. I think landowners have the highest potential of impact" (AS, NPO).

Policy makers have the largest influence because "everyone has to fall in line" (NPO, DET), but not everyone has to comply equally because industry and landowners are able to lobby policy makers against regulations or regulators fail to police regulations (CON, PM; LGR). Industries can have ranging values toward the environment and sustainability (industry interviewees considered themselves as environmentally sustainable) which may motivate them to go above and beyond by investing in conservative practices within their organization and in their communities (none were directly related to the FESDWQ), but ultimately their actions are based in "business value: you have the economic side and you have the regulatory side. When we manage our forests, we are predominantly looking into those two buckets. You can make money from your resources, but you also must follow all regulations" (I, statewide).

Water providers must follow the federal regulations from the Clean Water Act and Safe Drinking Water Act so their influence on the FESDWQ is also largely dictated by policy enforcers. Bigger water utilities have more influence then smaller water utilities, and often enforcers must put a lot of pressure on the bigger utilities "to get them to fall in line" (PM, LGR). The public works affiliates (both drinking water and wastewater service groups) are not actively thinking about this link between forests and drinking water quality because their priority is in providing services, but this apathy toward the FESDWQ does not translate to negatively or positively impacting the FESDWQ because those services are perceived as disconnected from the ES (DET, LG).

NPOs and local government have a high impact on FESDWQ because their projects are focused on conserving natural resources and ecosystems. Interviewees overwhelmingly perceived NPOs as having the highest positive impact in all these watersheds. Local government and NPOs also can influence the behaviors of the landowners and consumers to preserve this FESDWQ, and NPOs can influence policy makers and decision makers by applying pressure. Consumers have influence toward policy makers and other elected officials because they are the constituents that those individuals represent (adequate representation may vary). However, forests and drinking water is not something they ever pressure their elected officials to do something about (refer to section 2.2.3). Consumers can be environmentally minded. They may organize to address water quality and forest resource issues within the watersheds; in fact, this is how many of the NPOs were founded. Many interviewees said that consumers are the group that rely on this FESDWQ the most, but also perceived that this group has the least influence in making decisions regarding this FESDWQ.

Relational Stakeholder Interaction Affecting Value in FESDWQ

While there were no direct examples of value in the FESDWQ being changed by interactions among stakeholders, there is evidence that the actions of one stakeholder can shape how other stakeholders perceive forest and water resources. For example, an NPO and local government showed some frustration with one of the practices of their county drain commissioner because that practice shaped the way that landowners perceived clean water:

“It does not help that the drain commission comes in and bites out a big piece of forestland right along the drain edges, so people think, “Oh they really cleaned it up, and it looks great now, and water can move through there.” It gives people the opposite impression that we want to give people: It gives them the opposite message that we want to give.” (LG)

The drain commissioner practice caused people to perceive an unobstructed flow of a river as a good thing when the opposite is true. Downed trees, meanders and debris in the river leads to a healthy river that supports wildlife and other ecosystem functions.

3.3 Discussion

On average, interviewees in all three watersheds interacted with state government the most frequently. All watersheds had regional NPOs that were influential on watershed networks; and all watersheds had centrality measures that were over 50% suggesting there are stakeholders with high influence over other groups, which the qualitative analysis also corroborates. NPOs often acted as both bridgers and bonders in the three watershed networks, and conservation districts had more influence in the rural AS while Drain Commissioners had more influence in DET and LGR. All watersheds had examples of stakeholders working together and helping one another, of shared values leading to achieved goals, and proactive over reactive behavior (yet reactive behavior overwhelmingly dominates within all three watersheds). While there are examples of these social norms in each watershed, they do not always characterize these watershed networks, but they are all *desired* characterizations.

There are examples of periphery stakeholder groups feeling isolated within the LGR and the AS. Trust in all watersheds was placed in NPOs over any other stakeholder group with examples of familiarity increasing trust and unfamiliarity decreasing trust. Funding and resources are limited for all stakeholder groups, and that limitation can lead to stakeholder competition. On the other hand, niche speciation, or stakeholders organizing into their structural roles, within the watershed networks decreases competition. A watershed network can reach a steady state of stakeholders like the LGR where an addition of a new group would need to be very careful not to disrupt the network and create conflict by slighting those groups working on similar projects. The amount of watershed work that needs to be done in the DET results in an appreciation for any group trying to address watershed issues, however, stakeholders still get frustrated when groups encroach on one another's territory. Finally, policy makers have the ultimate perceived responsibility for the FESDWQ and the ability to do the most good or the most harm. The ability to conserve the FESDWQ was perceived by interviewees by how much influence groups have on policy makers.

In both LGR and AS, there was one example of an NPO on the periphery mentioning a feeling of isolation from watershed governance. The NPO in LGR is comfortable with this isolation, but the NPO in the AS is frustrated with this isolation. In the AS, this isolation was indicated by more watershed projects and stakeholder interactions occurring on the western side of the watershed over the eastern side. The state and federal protection acts of the Au Sable River may have led to this western/eastern disconnect. For example, the federal "Wild and Scenic River" portion covers 23 riverine miles in the eastern middle section of the Au Sable River between the Mio and Alcona Dam Ponds. The "Michigan Natural Rivers Act" protection cuts off right before the western edge of the watershed as the AS flows into Iosco County. The *Natural River Plan* written in 1987 and updated in 2002 to manage the Au Sable in response to these acts explicitly leaves out the eastern edge of the watershed (DNR 2002). Past policies and projects within a watershed can impact the relative influence of stakeholder groups. Recent bridging work in the AS has worked to include diverse voices in watershed goals, but it is important for watershed groups to identify those groups that are on the periphery, why they are on the periphery, and work to actively engage them in the entire watershed decision making process (or be the diversifiers of Table 11) (MacKinnon 2018).

It is not surprising that shared value was a desire of stakeholders in all watersheds. Previous research demonstrates the importance of value consensus in the environmental decision-making process (Pielke 2007; Stanghellini 2010). The AS shared value was conserving the pristine waters of the Au Sable River, but the Rouge River in the DET was perceived as polluted even though it has been dramatically restored from past degraded levels. The perception of a polluted river versus a pristine river impacts the enjoyment of the river (Davenport and Anderson 2005). The previous chapter found that experience within or enjoyment of a river can lead to a higher value placed in that resource which may explain more value consensus in the AS versus the DET. The LGR also has difficulty attaining a culture of shared value because it not only has different values of stakeholder functional types, but also more diverse land cover types within the watershed. As the ecological saying goes, "biodiversity begets biodiversity:" In the case of LGR, diverse land types beget diverse stakeholder values making value consensus, which is important for cohesively working watershed networks and solving challenging regional environmental issues (Batie 2008), trickier to attain. Regional organizers, who organize groups at the watershed level, can be effective in reaching separate stakeholder groups and promoting shared values.

Structuring and scaling political and organizational boundaries can have a marked impact on environmental governance. In fact, "rescaling" governance to smaller local units has become a trend in the last decade (Cohen 2012). Watersheds have been suggested as a comprehensive boundary for re-scaling because "socially constructed" watersheds bring together stakeholders with diverse values and goals into a cohesive unit (Cohen 2012). The three watersheds in this study both adhere to this point and augment it. Governance is not organized by watershed boundaries in any of the watersheds, however, DET has examples of "alliances" or "councils" of municipalities and policy makers that have organized at the watershed level. LGR does not have this but they do have an NPO that functions similarly by organizing resources for all smaller units within the LGR. Existence of these organizations builds a watershed's capacity for solving complex issues, employing rapid responses, and diversifying stakeholder engagement (Cohen 2012). The watershed structure has great potential for employing forest and water conservation in these watersheds by stimulating stakeholders to work more effectively with one another. For example, one NPO in DET mentioned that stakeholders get close to effective collaborations with local government about water quality issues: They could easily unite if they were able to combine the local government goal of increasing public health and the economy with the NPO goal of preserving the watershed. Rescaling governance to the watershed level could be one way to more easily merge seemingly competing goals and values to accomplish a unified vision that includes the preservation of the FESDWQ. In fact, a dozen Interstate River Basin Commissions which acknowledge geographical boundaries of basin-wide watersheds over individual state political boundaries are present in the US with the Delaware River Basin Commission being the original and most successful of these commissions by facilitating trust, cohesiveness, and minimizing disputes between stakeholder groups (Kauffman 2015).

Rescaling environmental governance to watershed boundaries may be an important next step for the watersheds in this study (recognizing the challenging bureaucratic steps required), but a watershed boundary can be subjective and the scaling that is chosen will have implications on environmental governance. For example, LGR is within the Grand River Watershed, which is part of the Great Lakes Basin, and LGR is made up of 31 smaller subwatersheds. Choosing the right scale is important and should include stakeholder input and participation. Also, scales have an impact on ecosystem services, and quantifying that impact is important for protecting them equitably for those who benefit from them (Naeem et al. 2015). Understanding how watersheds at different geographic scales interact politically, economically, and socially is important for these watersheds. Also, all three of these watersheds are within the Great Lakes Compact of 2008 which is an interstate and international commission of the entire Great Lakes Basin (Kauffman 2015). Leveraging membership within Great Lakes Compact boundaries (i.e. basin-wide) and increasing smaller-scaled watershed governance could increase stakeholder collaborations, trust, and facilitate conservation.

The perceived desire for proactive behavior is consistent with environmental ethics literature on the nature of solving environmental issues. In the complex problems that arise in sustainably managing natural resources, environmental action and behavior is often inhibited by the tendency of humans to prioritize or value short term gains over long term benefits (DesJardins 2013). This tendency is problematic when it comes to facilitating a network that protects ecosystems or ESs because most environmental conservation is based on long-term benefits. Tapping into this network desire for proactive behavior will be necessary to adequately incorporate ESs into management goals. In this case, the shorter-term the adoption of proactive behavior the better. One way to build on this network desire is to leverage the trust that is placed in certain stakeholders in the watershed.

Trust is a necessary aspect of social capital which can limit discontent, reduce disorder, facilitate action, and once entrusted must be consistently upkept (Davenport et al. 2007).

Rousseau et al. define trust as the “willingness to be vulnerable” or rely on others which includes a “confidence that expectations will be met” (pp 395). Trust came up during the interviews when participants described watershed networks and stakeholder interactions. In general, people do not trust the federal government, and this mistrust often bleeds into general mistrust of government institutions (state, policy makers, and municipal) (Mase et al. 2015). This research is consistent with stakeholders mistrusting government institutions, however, there was evidence that stakeholders who interact with government agencies increase their familiarity with these institutions increasing their trust in them.

NPOs within the watershed are positioned within all three watersheds to bridge the gap in trust that forest landowners and consumers have of government agencies. NPOs often work with government agencies in some capacity, and while they do not always agree with government methods, they do trust these institutions overall. In fact, NPOs may be uniquely positioned to influence decisions made about the FESDWQ within the watershed networks because they have high social capital: They have stakeholder trust; they have influence on industry and policy makers; they influence consumer and landowner behavior; and they are network disseminators, bridgers, bonders, powerful players, changers, diversifiers; and they even create a culture of shared values. NPOs have a significant potential of fomenting positive influence on the FESDWQ.

There were no direct examples of stakeholder interactions influencing stakeholder value placed on the FESDWQ from any of the interviews; and maybe that is because people are not thinking about this link between forests and drinking water quality; but there is evidence that the actions of one stakeholder can shape how other stakeholders perceive forest and water resources. While the interactional value of the FESDWQ is unknown, Figure 6 provides a potential mechanism for translating stakeholder group values and provides an idea of how to employ that mechanism if there was a watershed goal of preserving the FESDWQ. Value in the FESDWQ is uniquely positioned to be shaped for future conservation, and this research's characterization of the relationships of watershed stakeholders could be an important tool for watershed governance.

3.4 Further Research

A survey-based SNA on all stakeholders that are involved in the FESDWQ would allow a complete view of these social networks. On the other hand, the rich data that this research provided proves this qualitative SNA approach could be employed in other watersheds across the US. Further studies can also explore watershed capacity by investigating whether rescaling governance by watershed will promote better adaptive management or overall regional governance. Regional values should be explored further in Michigan. There is evidence that there is a western to eastern divide in the state. While this western to eastern divide was evident in the AS, the western LGR watershed also mention the importance of "West Michigan Values." How do these large regional values impact governance, environmental management, and ESs? Perhaps both these research questions could be addressed with environmental place-based approaches. Additional research of Michigan watersheds by land use type (mixed, urban, agricultural, forested, etc.) would allow for further comparisons of themes and even include replicates of these conditions increasing research validity.

3.5 Study Limitations

It is important to note that the quantitative SNA was based on a low sample size compared to each of the stakeholder lists that were created (22% in AS, 32% in LGR, and 15% in DET). To get a complete view of the watershed networks related to forests and water quality, a more complete survey of the stakeholders within each watershed is needed. Interpretation of the sociograms are limited by this, however, they are helpful in visualizing parts of each watershed network. Another limitation was that some voices of those stakeholders that were mentioned as key stakeholders were not interviewed due to failed recruitment. This included a watershed NPO in LGR, a federal agency in AS, and a water provider in DET whose perspectives would have enriched the results. Fewer consumers and forest landowners in the AS and DET were interviewed (landowners were interviewed in all watersheds, but consumers were not interviewed in DET or AS). Interviews captured attitudes of these groups, but alternate methods of understanding these values, like comprehensive surveys and multiple focus groups may be a better method of measuring their value.

Feasibility and time constraints led to dropping participant observation as a research method, however this method may have been better suited for observing stakeholder relational or interactional value placed in the FESDWQ. Interviews do not allow for observing value placed in action or observations of social interactions.

3.6 Conclusion

Leveraging trust, incorporating leadership, adapting to changing funding priorities, creating shared value, listening to diverse perspectives, exhibiting proactive goals, and organizing regional planning are just some actions found in this study that increase social capital of watershed networks. High social capital availability within a network provides capacity for effective ES management. This research reveals the complex relationships that stakeholders have with the FESDWQ, provides clarity to those relationships, and begins to explore the necessary ingredients for potential incorporation of the FESDWQ into natural resource management and decision-making. The themes discovered in this research are not limited to only the FESDWQ but can apply to general ESs and other forest and water quality issues. Innovative solutions to complex environmental issues and emerging environmental crises are necessary to increase resiliency of the coupled nature and human environment.

CHAPTER IV: CONCLUSION

As one interviewee from a Detroit non-profit organization explained, a forest is to a watershed as a kidney is to a body: As the kidney filters waste products from the blood, absorbs excess fluids, and regulates fluids; forests filter wastewater, absorb excess water, and regulate the flow of water in a watershed. As the kidney is vital to a healthy body, forests are vital to a healthy watershed. Filtering, absorbing, and regulating water flow are all regulating FESs. While these services are not always perfectly understood, they are highly valued by key stakeholders in the AS, LGR, and DET watersheds. The FESDWQ is a forest provisioning service. Forests provide clean drinking water to over 4.6 billion people (that is over 60% of the world's population) (MEA 2005). Considering the high value people place in drinking water (Olmstead 2009) and forests' critical role in providing that service (Ellison et al. 2017; Postel and Thompson 2005), it is incongruent that the FESDWQ (with the exception of a couple novel cities and provisions of the Safe Drinking Water Act), goes largely unrecognized (Weidner & Todd 2011). Nearly half of the interviewees in this study associated forests with drinking water, but over half mentioned that this connection was not something they typically think about (if at all). This is worrisome because a lack of value place in an ES can lead to its degradation (Meyfroidt et al. 2014). The FESDWQ operates in the unseen and intangible functions of the watershed. When a forest is degraded or clear-cut and the natural filtering systems disappear, the human filtering systems can be overwhelmed.

The positive externalities, or unvalued benefits, of healthily functioning forest ecosystems degrade when managers prioritize tangible goods over intangible ESs (Aguilar et al. 2018). The first step to incorporating ESs into management strategies is to measure stakeholder function of the ES. Costanza et al. (2017) mention that one part of measuring the value stakeholders place in an ES is by making decisions that impacts the ES. In this study, no organizations explicitly incorporated forests and drinking water into any of their watershed priorities, goals, rhetoric, projects, or policies. Another part of measuring the value stakeholders place in an ES is by comparing it to some reference value (Costanza et al. 2017). Stakeholders in all three watersheds placed more value in forests as a regulating service of water quality over the provisioning service of drinking water. Forest and drinking water were perceived as more connected to groundwater resources over surface water, and there was evidence of a disconnect between the natural land and the provision of drinking water (which was more prevalent in urbanized interviewees). In this valuation strategy, forests were essentially removed from one half of the water cycle: Forests are still valued for their functions of capturing rainfall and mitigating stormwater runoff but are not valued for their provision of drinking water (unless it is a forest next to a shallow private well in rural areas).

Humans are social beings; the values that we place on the world around us are tempered, influenced, and constructed by interactions with others. Stakeholder value in the FESDWQ is not static, but dynamically created by interactions between stakeholder categories (Matthies, Kalliokoski, et al. 2016). Characterizing the social capital of each watershed (or aspects that lead to effectively functioning watersheds) allowed for the exploration of networks, norms and trust that may facilitate capacity for the incorporation of the FESDWQ into watershed management. Shared value and history, inter-dialogue, open-mindedness, presence of trust, and regional planning all lead to watershed network cohesion which can build capacity for effectively incorporating the FESDWQ into watershed decision making. While relational value in the FESDWQ was not directly observed between stakeholder groups in these watershed networks; stakeholder impact, influence, and reliance on the FESDWQ was observed. Policy makers were perceived as having the greatest impact and influence on the function of the FESDWQ because their decisions have influence on the way other stakeholders interact with the FESDWQ. They were perceived as having the ultimate responsibility for protecting the service. Non-profit organizations were perceived as being the best positioned to protect the FESDWQ because they have influence on policy makers, industry, and forest landowners; educate and advocate for general consumers, and consistently interact with all other stakeholder categories.

While the value for the FESDWQ in these three watersheds may not be high or presently relevant, the foundations for value are there. All stakeholders strongly link forests and water quality and many interviewees exhibited the belief that nature and its impact on humanity are very interconnected. This belief of the "interconnectedness of nature" may mobilize stakeholders to perceive forests as members of the entire water cycle. While these watersheds were not perfectly functioning and balanced networks, there is clear capacity for support for conservation programs that incorporate this FESDWQ.

4.0 Applying the FESDWQ in Conservation Strategies

Conservation programs that incorporate the valuation that stakeholders place in ESs may include Payment for Ecosystem Services (PES) programs. PES programs, which incorporate the value of an ES by incentivizing landowner behavior and practices to ensure ES service function and provision, are one way of applying the stakeholder value of the FESDWQ into management that bridges the gap between science and policy. As the ES concept has gained traction in natural resource management across the globe, PES programs have emerged as an alternative conservation mechanism over typical command and control conservation approaches (Naeem et al. 2015; Schomers and Matzdorf 2013). In a forest-to-drinking water PES program, program facilitators pay forest landowners to manage their land to preserve or support the forest function of providing clean drinking water to downstream drinking water consumers (i.e., user-financed PES): ES users agree to compensate forest landowners (Salzman et al. 2018). For example, New York City has a program which pays upstream forest landowners for conservation easements or forest restoration activities to protect watershed functioning. Downstream consumers in the city partially fund this program; resulting in the protection of 35% of source water land, $7.5 billion in savings over the course of 10 years, and the treatment of drinking water to a city with a population exceeding 8.5 million without the need of a modern water filtration plant (Postel and Thompson 2005; Weidner and Todd 2011).

PES programs are not novel in Michigan: Agricultural PES programs run by the government have been implement with the state for decades (e.g., Land Reserve Programs, Conservation Reserve Program, Wetland Mitigation Banking) (Claassen et al. 2008), but a lack of understanding and participation by landowners has hampered the success of these programs (MDNR 2010). However, a forestry instead of an agricultural PES would be a novel program for Michigan. Even though forests provide the ESs that are typical for existing PES programs (i.e., water biodiversity, and carbon) (Prokofieva 2016), forest PES programs worldwide have not been institutionalized to the extent of agricultural PES programs (Meyer and Schulz 2017). Recently, Michigan state governments and international institutions of the Great Lakes' region have called for more PES programs and other environmental market approaches to solve water quality issues (OGL 2017).

4.1 Watershed Considerations for a Forest to Drinking Water PES Program

Stakeholders showed general interest in a forest to drinking water PES program across all three watersheds. Stakeholders mentioned five major factors needed for a PES program to be successful and five major barriers that would prevent a program from being successful within their watersheds (Figure 7). All stakeholder types reiterated that adequate incentivization was needed for a successful program. In other words, there must be monetary compensation for any forest landowners (e.g. land tax breaks) and clear benefits for beneficiaries (e.g. lower water bill or clear benefits from protecting forests like increased recreation in water bodies). Finding the appropriate monetary compensation is a common hurdle for many emerging PES programs (Engel et al. 2008). Finding funding for proper incentivization will always be a challenge for a PES program (or any program), especially with local governments and NPOs strapped for cash. A next step for research should be to elicit the exact forest landowner and beneficiary willingness-to-pay or participate in a PES program in each watershed.

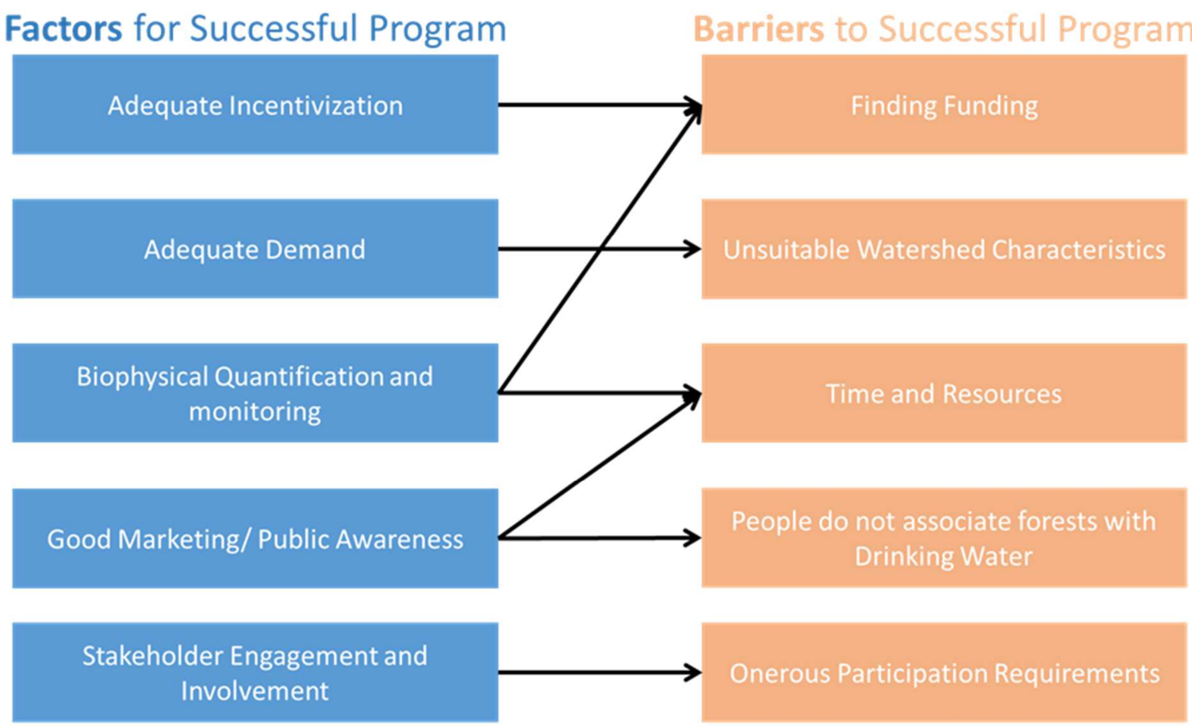

Figure 7: Schematic of stakeholder feedback on PES program. The blue column shows factors required for a successful program. The orange column shows barriers that would prevent a successful program from occurring. Arrows connect which successful factor could potentially be prevented by a corresponding barrier.

All stakeholder types mentioned the importance of involving everyone in the entire process of implementing a PES program. There are copious amounts of literature that state the necessity for the involvement of all stakeholders in watershed management decisions (e.g., Baldwin and Ross 2012; Stanghellini 2010). This means giving all stakeholders, especially the less influential groups, the agency to influence program decisions in beginning stages to completion of a program. Engagement can be stymied before a project begins by a lack of public awareness of the FESDWQ (Meyfroidt et al. 2014). As a PES program gains momentum, program facilitators must ensure that participation requirements are not onerous. FLs mentioned that too many forms to fill out or confusing bureaucratic steps would deter them from participating which is consistent with PES program deterrents in literature (Engel et al. 2008).

Lack of understanding about a PES program and lack of value in the ES of interest can be a barrier to successful PES programs (Pascual et al. 2017). Stakeholders in the three watersheds did not place a high recognized value in the FESDWQ, and there was a perceived disconnect between forests and the provision of drinking water. To counteract this perceived disconnect, program facilitators should create an appropriate "marketing" campaign about the FESDWQ and a resulting PES program. Marketing is especially important to prevent potential stakeholder rejection of a program. Two interviewees mentioned that Michigan is a property-rights state, or residents place identity and value on the autonomy to manage their own land without government intervention which can make social acceptance of conservation programs hard to attain (Isely et al. 2007). In fact, a potential barrier to PES programs can be the existence of property right regimes over common property regimes (Agrawal 2001), however, secure property rights can also be an enabling condition for potential PES programs (Huber-Stearns et al. 2017). For Michigan, “marketing” or rhetoric of a FESDWQ PES program would have to take property rights into account.

A successful PES program requires demand (Salzman et al. 2018), and this demand varies in each watershed. Stakeholders in the heavily forested AS pointed out that forest resources are already adequately conserved and properly managed. Perhaps an 80% forested watershed without many threats to forest resources is not the place to implement a PES program. However, that does not mean that a PES program would never be appropriate in the area: Rapid development could increase the need for forest and drinking water conservation in the future. On the other end of the spectrum, stakeholders within the barely forested DET pointed out the impact the few remaining forested areas have on drinking water quality is probably low. The priority in this watershed is to implement green infrastructure to decrease stormwater runoff and pollution. A forest to drinking water quality PES program would be low priority. In the LGR (which has a blend of forested, urban, and agricultural land), stakeholders readily recognized the potential benefits of a PES program within their watershed but were not sure if another new conservation program is needed in the watershed. Regardless of the differences within these watersheds, stakeholders from all three areas agreed that the biophysical properties of the forests within their watersheds and their corresponding impact on drinking water quality need to be quantified. This quantification would take interdisciplinary scientific research in hydrology, forestry, and collaboration with local water utilities.

4.2 Considerations

Incorporating the FESDWQ into conservation programs hinges on a receptive policy environment. Policy makers at a national scale could incorporate watershed management and source water protection into federal US water policies like the Clean Water Act (CWA) and the

Safe Drinking Water Act (SDWA). Currently, the priority for enforcement is on singular point-source polluters (or identifiable sources of pollution like a discharge pipe into a river) (USEPA 2008). Incorporating watershed management and source water protection as viable options to prevent pollution and increase water quality into these national laws would give these watershed projects the regulated influence necessary to be effective. Policy makers on a local scale can consider combining both wastewater treatment and drinking water treatment governance. While people typically get wastewater and drinking water costs combined in their monthly water bill, the local governance of these two systems are relatively isolated from each other (National Research Council, 2002). One NPO mentioned that "storm water should be connected to our drinking water" (NPO, DET), and a water utility interviewee said that policy of drinking water and stormwater should be more connected:

> "On the drinking water side water folks have to have something called source water protection. Our environmental systems are a part of that. Then, on the storm water side we must have a stormwater pollution prevention initiative. I often think the two should be blended." (WU, LGR)

This separation of the two sides of the water cycle in both national and local policies impacts Public Water System (PWS) management. In fact, "different pieces of legislation tend to regulate each element individually [which] leads to a separate 'tunnel vision' management of each element of this socio-environmental system rather than as a whole" (Garcia et al. 2016 pp 1078; Kiparsky et al. 2013). A restructuring and integration of the legislation of watershed resources would facilitate forest conservation of both the FESDWQ and water regulating FESs. A restructuring and integration of SWP or PES programs could be an adaptive solution toward failing water infrastructure, emerging contaminants, and the other issues water utilities are facing (Bartlett et al. 2017)

The integration of the FESDWQ into watershed management and public drinking water systems (PWSs) will require interdisciplinary cooperation. Integration is contingent on the willingness of PWS to consider water resource management alternatives. Small to medium PWSs are choosing new treatment technologies over SWP to solve water contamination issues (Barnes et al. 2009). On the other hand, there is rising popularity of SWP in ongoing and emergent watershed management programs (Price et al. 2018). There is still much work needed to contextually incorporate SWP into PWS functioning with both single and multisystem PWS studies (Gorzalski et al. 2019). Initial evidence suggests that investing in SWP may only be cost-effective for some PWSs, unless "program costs can be sufficiently distributed across multiple stakeholders" (Price et al. 2018).

The capacity for distributing costs for these kinds of programs depends on the social capital of each watershed. NPOs are situated to educate and disseminate information throughout the watershed networks, influence decision makers, shape the behaviors of landowners and consumers, and have the greatest trust placed in them. NPOs can leverage that trust to bring different stakeholders together in a rescaled watershed governance environment (Cohen 2012) to increase familiarity between stakeholders which ultimately increases trust (Mase et al. 2015). This cascade of increasing trust and influenced behaviors could very easily shoulder the distributed capacity of a forest and drinking water PES program for the benefit of both upstream landowners and downstream beneficiaries.

APPENDICES

APPENDIX A.1: Land Cover of the AS

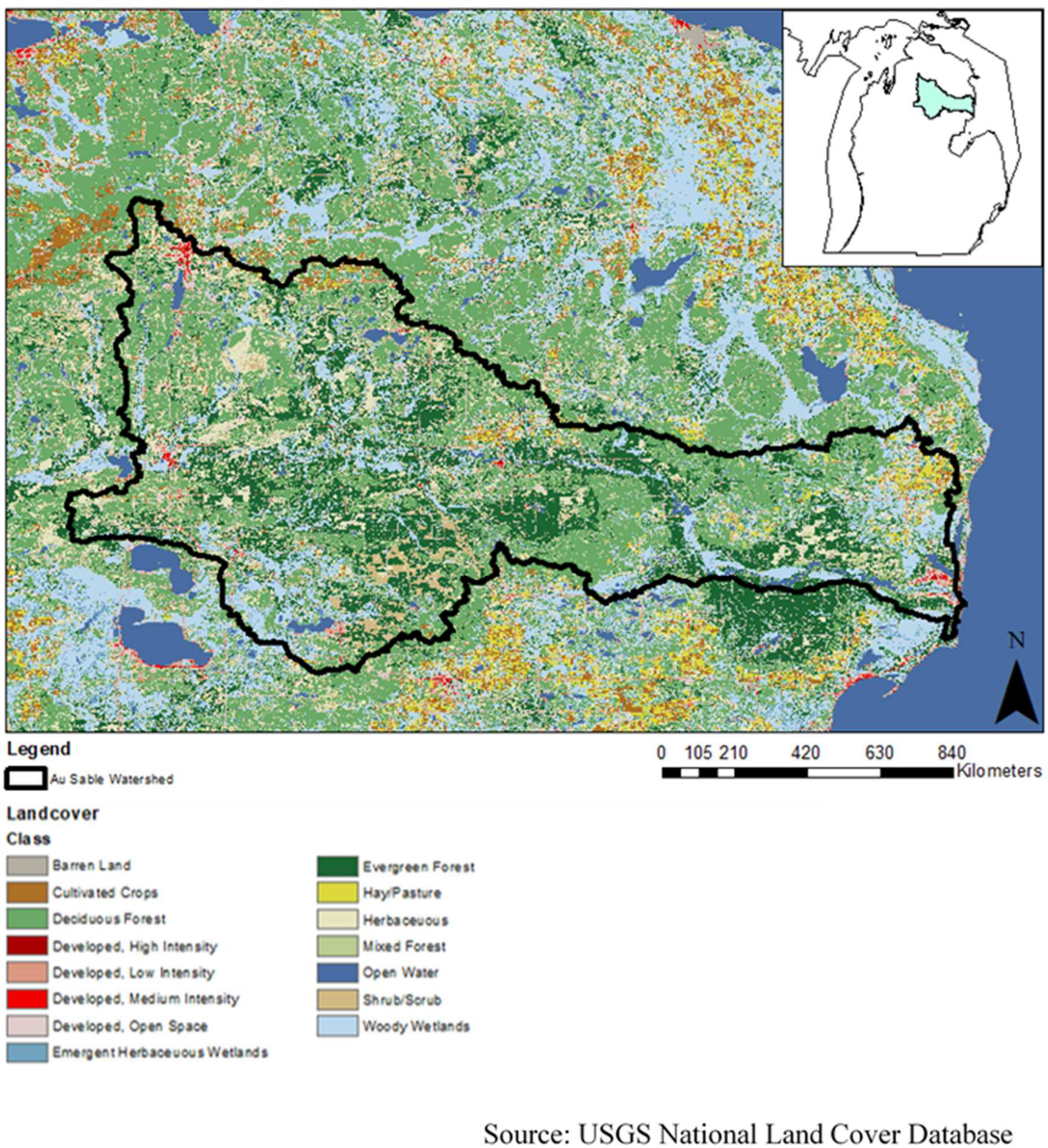

Figure 8: Land cover map of the AS.

APPENDIX A.2: Land Cover of the LGR

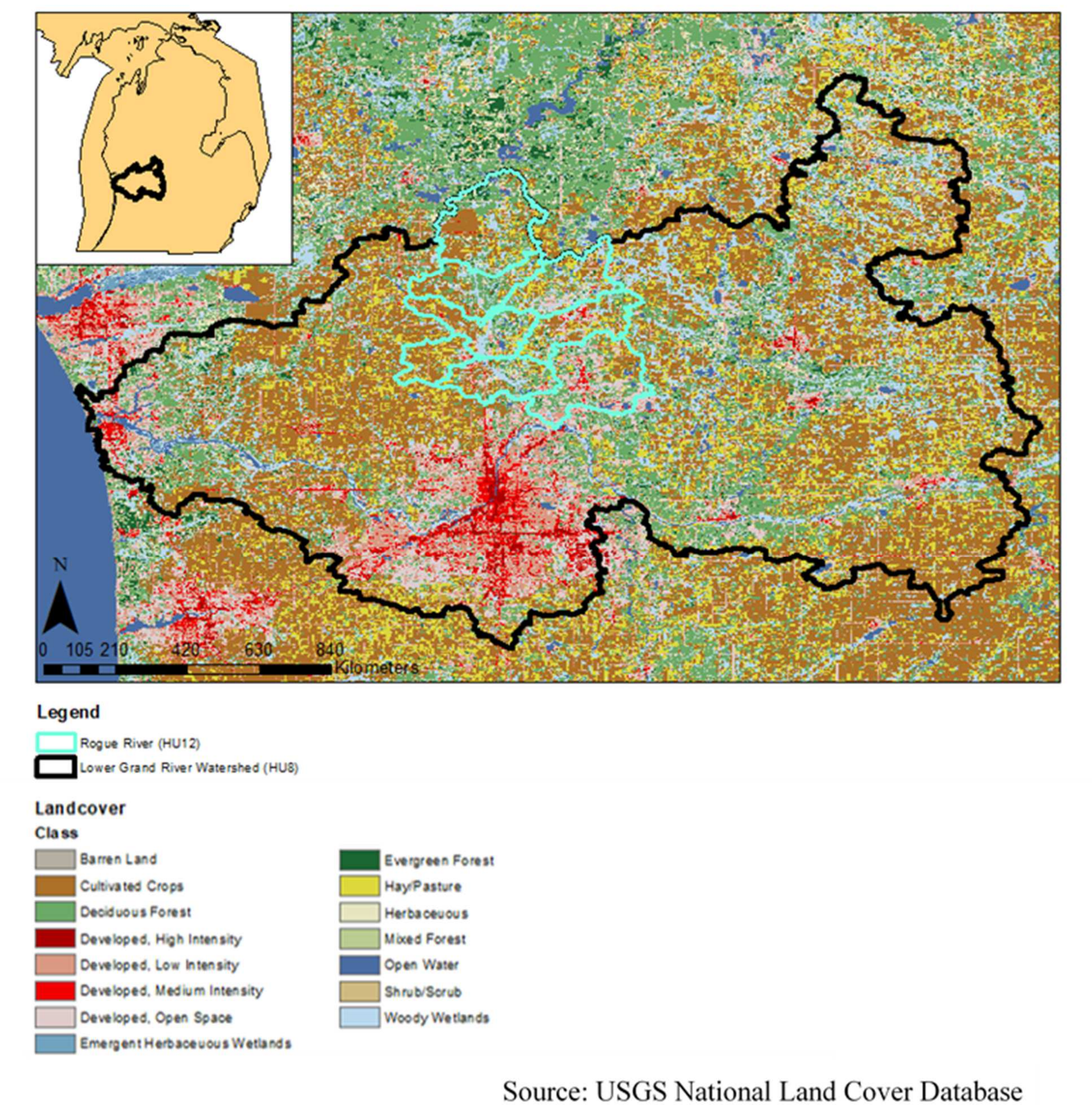

Figure 9: Land cover map of the LGR.

APPENDIX A.3: Land Cover of the DET

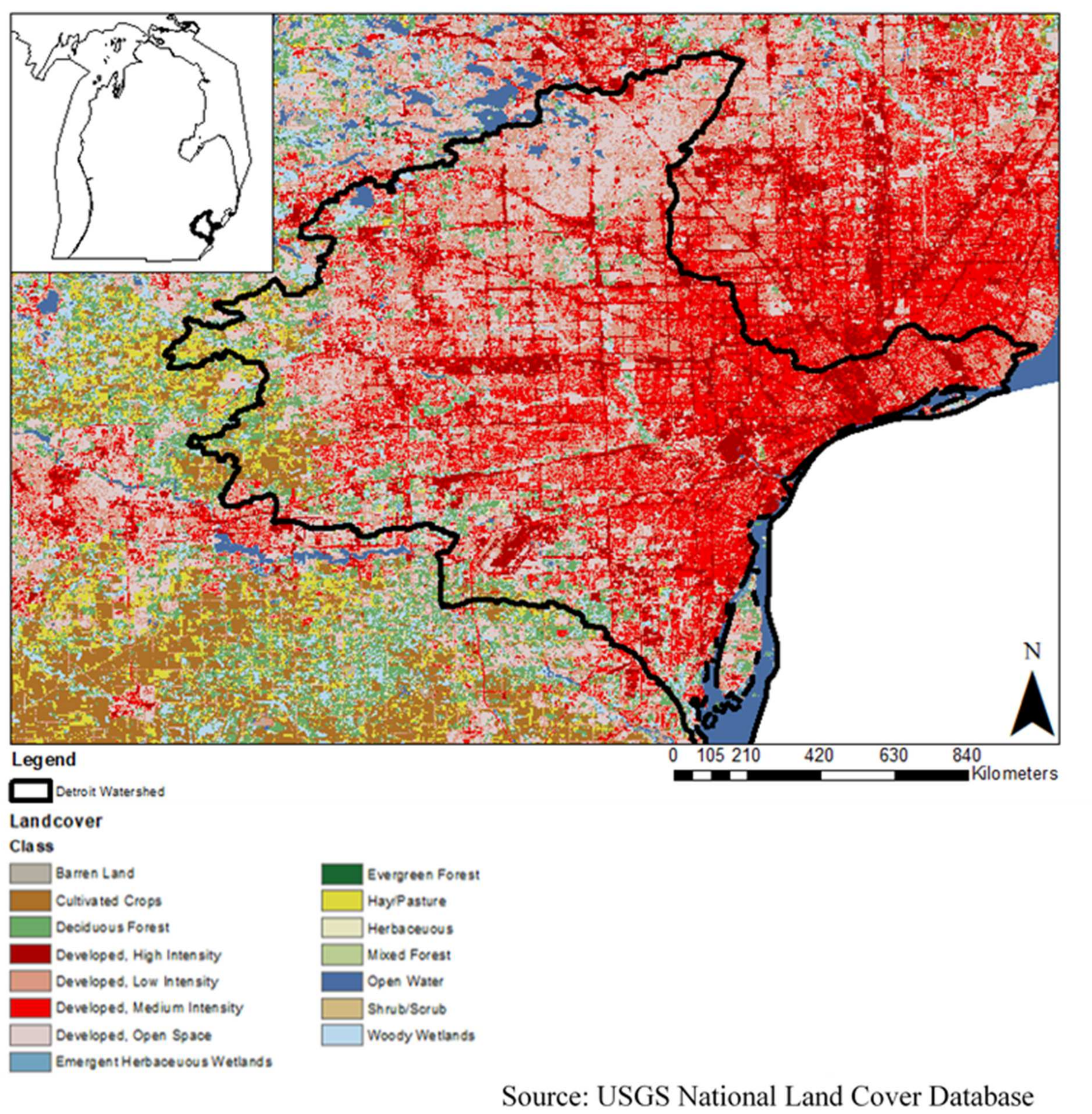

Figure 10: Land cover map of the DET.

APPENDIX B: Interaction Data for Each Listed Stakeholder

Table 12: Summaries of interaction data for each watershed (n=number of interviewees who completed this part of interview). I.D. is the deidentified stakeholder code. Interaction average is the average interaction for each I.D. Total interaction is the summed-up interaction for each I.D. In the summary statistics the "network frequency" refers to the average of all the interaction averages. "Network sum" refers to the average total interaction.

#	Au Sable (n=8)			Lower Grand (n=16)			Detroit (n=6)		
	I.D.	Interaction (avg.) *	Interaction (Total)	I.D.	Interaction (avg.)	Interaction (Total)	I.D.	Interaction (avg.)	Interaction (Total)
1	SG.1	3.9	31	SG.2	4.8	72	SG.2	4.5	27
2	SG.2	3.5	28	SG.1	4.5	67	N.2	4.3	26
3	LG.M	3.4	27	N.1	4.1	61	LG.6	4.0	24
4	N.2	3.0	24	LG.10	4.0	60	I.2	4.0	24
5	N.4	2.6	21	FG.1	3.7	56	WU.2	3.7	22
6	N.9	2.6	21	LG.1	3.7	55	LG.1	3.7	22
7	LG.1	2.6	21	LG.M	4.8	53	SG.1	3.5	21
8	N.3	2.5	20	N.10	3.4	51	FG.2	3.5	21
9	FG.3	2.4	19	N.9	3.0	45	PM.1	3.2	19
10	FG.4	2.3	18	LG.3	3.0	45	WU.3	3.0	18
11	N.1	2.1	17	LG.8	2.7	41	FG.3	3.0	18
12	N.7	2.1	17	A.1	2.6	39	SG.3	2.5	15
13	N.10	1.6	13	N.5	2.5	38	N.10	2.3	14
14	SG.4	1.5	12	FL.G	3.2	38	LG.2	2.3	14
15	N.6	1.4	11	FG.4	2.5	37	A.3	2.2	13
16	N.5	1.3	10	FG.2	2.4	36	N.3	2.0	12
17	LG.2	1.3	10	FG.3	2.4	36	N.6	2.0	12
18	LG.3	1.3	10	LG.5	2.3	35	I.1	2.0	12
19	FG.1	1.3	10	N.12	2.3	34	A.1	1.8	11
20	LG.7	1.1	9	I.2	2.2	33	N.8	1.7	10
21	A.2	1.1	9	LG.6	2.3	32	N.11	1.7	10
22	LG.8	1.0	8	N.6	2.3	32	LG.3	1.7	10
23	SG.3	0.9	7	LG.12	2.3	32	N.5	1.5	9
24	I.2	0.9	7	A.5	2.1	32	N.13	1.5	9
25	N.8	0.6	5	LG.7	2.0	30	WU.1	1.5	9
26	LG.5	0.6	5	LG.2	1.9	29	A.2	1.5	9

Table 12 (cont'd)

#	Au Sable (n=8)			Lower Grand (n=16)			Detroit (n=6)		
	I.D.	Interaction (avg.)	Interaction (Total)	I.D.	Interaction (avg.)	Interaction (Total)	I.D.	Interaction (avg.)	Interaction (Total)
27	LG.9	0.6	5	LG.4	2.0	28	A.4	1.5	9
28	A.1	0.5	4	SG.3	1.9	28	N.4	1.0	6
29	LG.4	0.4	3	N.16	1.9	27	N.7	1.0	6
30	LG.6	0.4	3	A.2	1.8	27	LG.5	1.0	6
31	I.1	0.4	3	WU	3.9	27	I.5	1.0	6
32	FG.2	0.1	1	LG.9	1.7	26	SG.8	1.0	6
33	I.3	0.1	1	I.G	2.4	26	FG.4	0.8	5
34	I.4	0.1	1	N.13	1.7	25	I.4	0.8	5
35	WU.1	0.0	0	I.F	2.1	25	N.12	0.7	4
36	A.3	0.0	0	N.11	1.6	24	I.3	0.7	4
37				N.17	1.6	24	LG.7	0.7	4
38				I.1	1.6	24	FG.1	0.5	3
39				N.2	1.6	24	N.9	0.3	2
40				A.3	1.6	24	LG.4	0.3	2
41				N.3	1.4	21			
42				N.15	1.4	21			
43				A.4	1.4	21			
44				LG.11	1.3	20			
45				N.14	1.4	20			
46				N.7	1.3	20			
47				N.4	1.3	19			
48				I.3	1.2	17			
49				N.8	0.5	8			

Summary Statistics (std. dev.)

Network Frequency	1.4 (1.1)	Network Frequency	2.0 (1.0)	Network Frequency	2.0 (1.2)

SG- State Government
LG- Local Government
FG- Federal Government
I-Industry
A-Academic Association
WU-Water Utility
N-Non-Profit Organization

*0=never, 1=once, 2=yearly, 3=couple times/yr., 4=monthly, 5=couple times/mo., 6=weekly, 7=daily

APPENDIX C.1: Sociograms of Watershed Interviewee Interactions

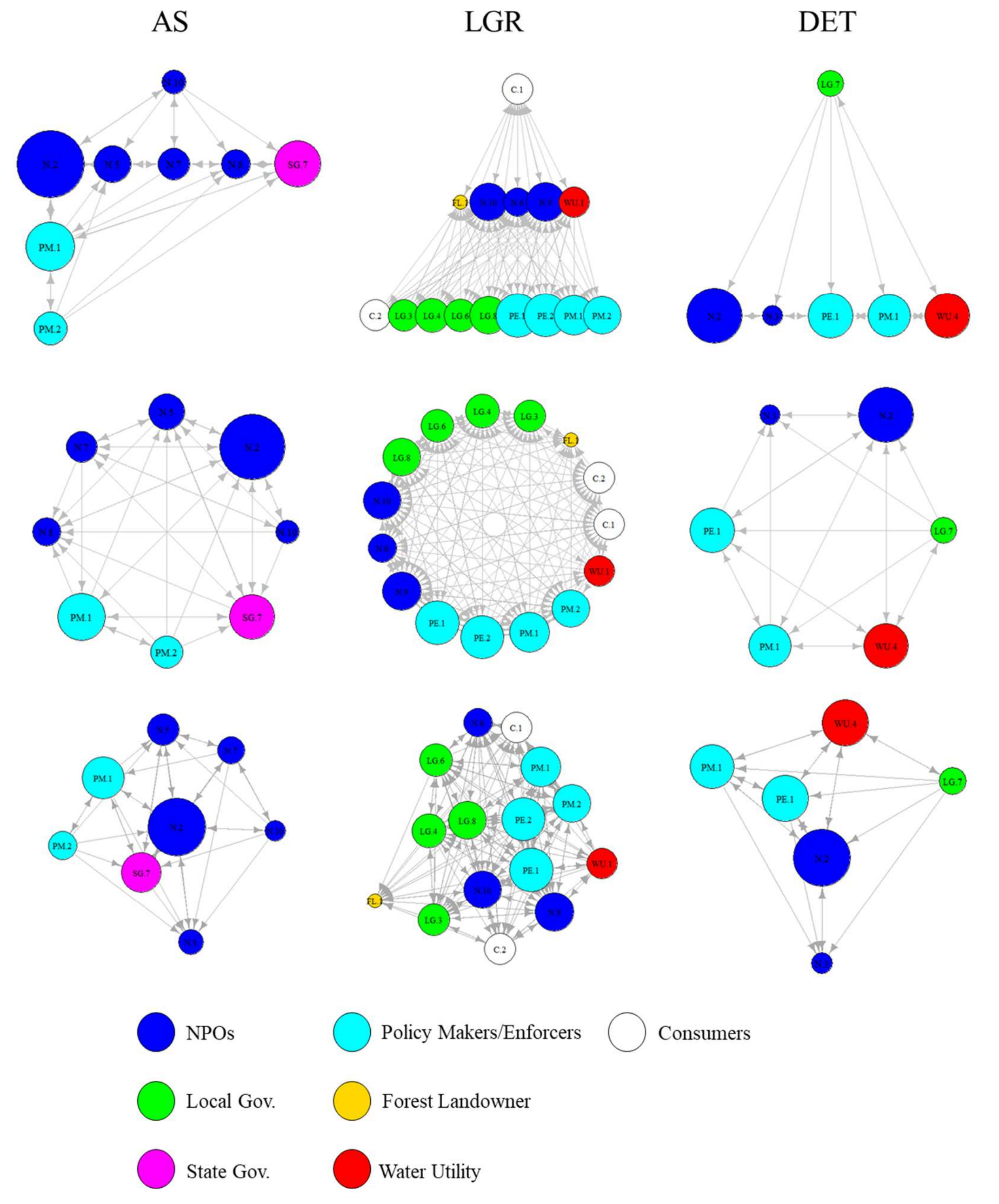

Figure 11: Sociograms of the interactions between stakeholders in each watershed of only those stakeholders who answered SNA questions. Edges are multi or uni directional indicating stakeholder perception of interactional relationship.

APPENDIX C.2: SNA Metrics of Watershed Interactions

Table 13: SNA descriptive summary of three watersheds. Global metrics apply to the whole network and local metrics apply to each individual node (individual stakeholder).

Network	Local Metrics		Global Metrics					
	Average Geodesic Distance	Average Degree	Clustering Coefficient	Degree Centrality			Closeness Centrality	Betweenness Centrality
				In	Out	Total		
AS	3	9	0.90	34%	20%	31%	21%	22%
LGR	2	22	0.97	21%	21%	19%	6%	6%
DET	3	7	0.92	27%	27%	20%	15%	17%

BIBLIOGRAPHY

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Abildtrup, Jens, Serge Garcia, and Anne Stenger. 2013. "The Effect of Forest Land Use on the Cost of Drinking Water Supply: A Spatial Econometric Analysis." *Ecological Economics* 92:126–36.

Agency, U. S. Environmental Protection. 2004. "State of Michigan Source Water Assessment Program." (December).

Agrawal, Arun. 2001. "Common Property Institutions and Sustainable Governance of Resources." *World Development* 29(10):1649–72.

Aguilar, Francisco Xavier, Elizabeth Asantewaa Obeng, and Zhen Cai. 2018. "Water Quality Improvements Elicit Consistent Willingness-to-Pay for the Enhancement of Forested Watershed Ecosystem Services." *Ecosystem Services* 30:158–71.

Ajzen, Icek. 1991. "The Theory of Planned Behavior." *Organizational Behavior and Human Decision Processes* 50:179–211.

Anderson, Henry W., Marvin Hoover, and Kenneth G. Reinhart. 1976. "Forests and Water: Effects of Forest Management on Floods and Water Supply." *USDA Forest Service General Technical Report PSW-18* 18(PSW-18/1976):1–115.

Annin, P. 2013. *The Great Lakes Water Wars*. Island Press.

Anon. 2003. *Common Implementation Strategy for the Water Framework Directive*.

Arriagada, Rodrigo and Charles Perrings. 2009. "Making Payments for Ecosystem Services Work." *Environment* (August).

Arrow, Kenneth J., Maureen L. Cropper, George C. Eads, Robert W. Hahn, B. Lester, Roger G. Noll, Paul R. Portney, Milton Russell, Richard Schmalensee, V. Kerry Smith, Robert N. Stavins, and Lester B. Lave. 1996. "Is There Analysis and Role for in Environmental , Health , Safety Regulation?" *Science* 272(5259):221–22.

AWWA. 2012. "Buried No Longer: Confronting America's Water Infrastructure Challenge." *American Water Works Association* 37.

Baard, Patrik. 2019. "The Goodness of Means: Instrumental and Relational Values, Causation, and Environmental Policies." *Journal of Agricultural and Environmental Ethics* 32(1):183–99.

Baldwin, Claudia and Helen Ross. 2012. "Bridging Troubled Waters: Applying Consensus-Building Techniques to Water Planning." *Society & Natural Resources* 25(3):217–34.

Barnes, Martina C., Albert H. Todd, Rebecca Whitney Lilja, and Paul K. Barten. 2009. "Forests, Water and People: Drinking Water Supply and Forest Lands in the Northeast and Midwest United States Forests." (June):1–71.

Barten, Paul K. and Caryn E. Ernst. 2004. "Land Conservation and Watershed Management for Source Water Protection." *American Water Works Association* 96(4):121–35.

Bartlett, Steve, Henry Cisneros, George Heartwell, Kelly Mcandrew, Sarah Kline, and Andy Winkler. 2017. "Understanding America's Water and Wastewater Challenges." *Bipartisan Policy Center* (May).

Batie, Sandra S. 2008. "Wicked Problems and Applied Economics." *American Journal of Agricultural Economics* 90(5):1176–91.

Bharati, L., K. H. Lee, T. M. Isenhart, and R. C. Schultz. 2002. "Soil-Water Infiltration under Crops, Pasture, and Established Riparian Buffer in Midwestern USA." *Agroforestry Systems* 56(3):249–57.

Biedenweg, Kelly, Ryan P. Scott, and Tyler A. Scott. 2017. "How Does Engaging with Nature Relate to Life Satisfaction? Demonstrating the Link between Environment-Specific Social Experiences and Life Satisfaction." *Journal of Environmental Psychology* 50:112–24.

Bodin, Örjan, Beatrice Crona, and Henrik Ernstson. 2006. "Social Networks in Natural Resource Management: What Is There to Learn from a Structural Perspective?" *Ecology and Society* 11(2).

Calder, Ian R. 2007. "Forests and Water-Ensuring Forest Benefits Outweigh Water Costs." *Forest Ecology and Management* 251:110–20.

Catton, William R. Jr., Dunlap, Riley E. 1978. "Environmental Sociology : A New Paradigm." *The American Sociologist* 13(1):41–49.

Charmaz, K. 2006. "Constructing Grounded Theory: A Practical Guide through Qualitative Analysis." *Sage Publications Ltd.*

Claassen, Roger, Andrea Cattaneo, and Robert Johansson. 2008. "Cost-Effective Design of Agri-Environmental Payment Programs: U.S. Experience in Theory and Practice." *Ecological Economics* 65(4):737–52.

Cohen-Shacham, Emmanuelle, Tamar Dayan, Rudolf de Groot, Coralie Beltrame, Fanny Guillet, and Eran Feitelson. 2015. "Using the Ecosystem Services Concept to Analyse Stakeholder Involvement in Wetland Management." *Wetlands Ecology and Management* 23(2):241–56.

Cohen, Alice. 2012. "Rescaling Environmental Governance: Watersheds as Boundary Objects at the Intersection of Science, Neoliberalism, and Participation." *Environment and Planning A: Economy and Space* 44(9):2207–24.

Communities, Alliance of Rouge. 2012. *Rouge River Watershed Management Plan*.

Costanza, Robert, Ralph D'Arge, Rudolf de Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton, and Marjan van den Belt. 1997. "The Value of the World's Ecosystem Services and Natural Capital." *Nature* 387:253.

Costanza, Robert, Rudolf de Groot, Leon Braat, Ida Kubiszewski, Lorenzo Fioramonti, Paul Sutton, Steve Farber, and Monica Grasso. 2017. "Twenty Years of Ecosystem Services: How Far Have We Come and How Far Do We Still Need to Go?" *Ecosystem Services* 28(Part A):1–16.

Council, National Research. 2005. *Vauling Ecosystem Services: Toward Better Environmental Decision-Making*. Washington, DC.: National Academies Press.

Creswell, John W. 2013. *Qualitative Inquiry and Research Design: Choosing among Five Approaches*. 3rd ed. edited by L. Habib. SAGE Publications Inc.

Csardi, G. and T. Nepusz. 2006. "The Igraph Software Package for Complex Network Research."

Danziger, E. J. 1991. *Survival and Regeneration: Detroit's American Indian Community*. Wayne State University Press.

Darvill, Rachel and Zoë Lindo. 2016. "The Inclusion of Stakeholders and Cultural Ecosystem Services in Land Management Trade-off Decisions Using an Ecosystem Services Approach." *Landscape Ecology* 31(3):533–45.

Davenport, Mae A. and Dorothy H. Anderson. 2005. "Getting From Sense of Place to Place-Based Management: An Interpretive Investigation of Place Meanings and Perceptions of Landscape Change." *Society & Natural Resources* 18(7):625–41.

Davenport, Mae A., Jessica E. Leahy, Dorothy H. Anderson, and Pamela J. Jakes. 2007. "Building Trust in Natural Resource Management Within Local Communities: A Case Study of the Midewin National Tallgrass Prairie." *Environmental Management* 39(3):353–68.

Deal, R., L. Fong, and E. Phelps. 2016. *Integrating Ecosystem Services into National Forest Service Policy and Operations*.

DesJardins, J. R. 2013. *Environmental Ethics: An Introduction to Environmental Philosophy*. Wadsworth.

Desjardins, Jeff. 2017. "The Great Lakes Economy: The Growth Engine of North America." *Virtual Capitalist*. Retrieved (https://www.visualcapitalist.com/great-lakes-economy/).

DNR. 2002. *Au Sable River Natural River Plan*.

Dudley, Nigel and Sue Stolton. 2003. *Running Pure: The Importance of Forest Protected Areas to Drinking Water*. edited by N. Stolton, S and Dudley. 11 New Fetter Lane, London, England: Taylor & Francis Ltd.

Ellison, David, Cindy E. Morris, Bruno Locatelli, Douglas Sheil, Jane Cohen, Daniel Murdiyarso, Victoria Gutierrez, Meine van Noordwijk, Irena F. Creed, Jan Pokorny, David Gaveau, Dominick V. Spracklen, Aida Bargués Tobella, Ulrik Ilstedt, Adriaan J. Teuling, Solomon Gebreyohannis Gebrehiwot, David C. Sands, Bart Muys, Bruno Verbist, Elaine Springgay, Yulia Sugandi, and Caroline A. Sullivan. 2017. "Trees, Forests and Water: Cool Insights for a Hot World." *Global Environmental Change* 43:51–61.

Emerson, R. M., R. I. Fretz, and L. L. Shaw. 2011. *Writing Ethnographic Fieldnotes, Second Edition*. University of Chicago Press.

Engel, Stefanie, Stefano Pagiola, and Sven Wunder. 2008. "Designing Payments for Environmental Services in Theory and Practice: An Overview of the Issues." *Ecological Economics* 65(4):663–74.

Ernst, Caryn, Richard Gullick, Kirk Nixon, and Caryn Ernst. 2004. "Protecting the Source: Conserving Forests to Protect Water." *Opflow* 30(5):2–7.

Farley, Joshua and Robert Costanza. 2010. "Payments for Ecosystem Services: From Local to Global." *Ecological Economics* 69(11):2060–68.

Flyvbjerg, Bent. 2006. "Five Misunderstandings About Case-Study Research." *Qualitative Inquiry* 12(2):219–45.

Freudenburg, William R., Frickel, Scott, Gramling, Robert. 1995. "Beyond the Nature/Society Divide: Learning to Think about a Mountain." *Sociological Forum* 10(3):361–92.

Garcia, X., D. Barceló, J. Comas, Ll. Corominas, A. Hadjimichael, T. J. Page, and V. Acuña. 2016. "Placing Ecosystem Services at the Heart of Urban Water Systems Management." *Science of The Total Environment* 563–564:1078–85.

Genskow, Kenneth D. and Danielle M. Wood. 2009. "Measurement , Learning , and Adaptation in Planning and Implementing Voluntary Nonpoint Source Watershed Programs." *Journal of Planning Literature* 24(2):137–54.

Gorzalski, Alexander S., Anne Spiesman, Priscilla To, and Gregory Prelewicz. 2019. "Broadening the Case for Source Water Protection." *Journal - American Water Works Association* 111(1):86–87.

Granias, Anna, Nicole MartinRogers, Kassira Absar, and Craig Helmstetter. 2018. *How Americans Relate To Water: A Qualitative Study for the Water Main*.

Greider, Thomas and Lorraine Garkovich. 1994. "Landscapes: The Social Construction of Nature and the Environment." *Rural Sociology* 59(1):1–24.

Grese, R. E., R. Kaplan, R. L. Ryan, and J. Buxton. 2000. "Psychological Benefit of Volunteering in Stewardship Programs." Pp. 265–80 in *Restoring nature: Perspectives from the social sciences and humanities*. Washington, D.C.: Island Press.

Guillemin, Marilys and Lynn Gillam. 2004. "Ethics, Reflexivity, and 'Ethically Important Moments' in Research." *Qualitative Inquiry* 10(2):261–80.

Harding, Sandra. 1993. "Rethinking Standpoint Epistemology: What Is 'Strong Objectivity'?" Pp. 49–76 in *Feminist Epistemologies*, edited by E. Alcoff, Linda, Potter. Routledge.

Hauck, Jennifer, Christoph Görg, Riku Varjopuro, Outi Ratamäki, and Kurt Jax. 2013. "Benefits and Limitations of the Ecosystem Services Concept in Environmental Policy and Decision Making: Some Stakeholder Perspectives." *Environmental Science and Policy* 25:13–21.

Heath, Sue, Alison Fuller, and Brenda Johnston. 2009. "Chasing Shadows: Defining Network Boundaries in Qualitative Social Network Analysis." *Qualitative Research* 9(5):645–61.

Van Hecken, Gert and Johan Bastiaensen. 2010. "Payments for Ecosystem Services: Justified or Not? A Political View." *Environmental Science & Policy* 13(8):785–92.

Huber-Stearns, Heidi R., Drew E. Bennett, Stephen Posner, Ryan C. Richards, Jenn Hoyle Fair, Stella J. M. Cousins, and Chelsie L. Romulo. 2017. "Social-Ecological Enabling Conditions for Payments for Ecosystem Services." *Ecology and Society* 22(1).

Hunter, Malcolm L., Kent H. Redford, and David B. Lindenmayer. 2014. "The Complementary Niches of Anthropocentric and Biocentric Conservationists." *Conservation Biology* 28(3):641–45.

Isely, Elaine Sterrett, Carol Griffin, and Richard R. Rediske. 2007. "Michigan's Natural Rivers Act: Conflict and Coordination in Multijurisdictional Natural Resource Management." *Society & Natural Resources* 20(1):85–92.

Ives, Christopher D. and Dave Kendal. 2014. "The Role of Social Values in the Management of Ecological Systems." *Journal of Environmental Management* 144:67–72.

Jarvis, Rebecca M., Barbara Bollard Breen, Christian U. Krägeloh, and D. Rex Billington. 2016. "Identifying Diverse Conservation Values for Place-Based Spatial Planning Using Crowdsourced Voluntary Geographic Information." *Society & Natural Resources* 29(5):603–16.

Kaiser, Florian G. and Heinz Gutscher. 2003. "The Proposition of a General Version of the Theory of Planned Behavior: Predicting Ecological Behavior1." *Journal of Applied Social Psychology* 33(3):586–603.

Kauffman, Gerald J. 2015. "Governance, Policy, and Economics of Intergovernmental River Basin Management." *Water Resources Management* 29(15):5689–5712.

Keeler, B. L., S. Polasky, K. A. Brauman, K. A. Johnson, J. C. Finlay, A. O'Neill, K. Kovacs, and B. Dalzell. 2012. "Linking Water Quality and Well-Being for Improved Assessment and Valuation of Ecosystem Services." *Proceedings of the National Academy of Sciences* 109(45):18619–24.

Kiparsky, Michael, David L. Sedlak, Barton H. Thompson, and Bernhard Truffer. 2013. "The Innovation Deficit in Urban Water: The Need for an Integrated Perspective on Institutions, Organizations, and Technology." *Environmental Engineering Science* 30(8):395–408.

Kuhn, T. S. and I. Hacking. 2012. *The Structure of Scientific Revolutions: 50th Anniversary Edition*. University of Chicago Press.

Kumar, Manasi and Pushpam Kumar. 2008. "Valuation of the Ecosystem Services: A Psycho-Cultural Perspective." *Ecological Economics* 64(4):808–19.

de Laat, Maarten, Vic Lally, Lasse Lipponen, and Robert-Jan Simons. 2007. "Investigating Patterns of Interaction in Networked Learning and Computer-Supported Collaborative Learning: A Role for Social Network Analysis." *International Journal of Computer-Supported Collaborative Learning* 2(1):87–103.

Lapointe, Marie, Graeme S. Cumming, and Georgina G. Gurney. 2019. "Comparing Ecosystem Service Preferences between Urban and Rural Dwellers." *BioScience* 69(2):108–16.

Larson, Silva, Kim S. Alexander, Riyanti Djalante, and Dewi G. C. Kirono. 2013. "The Added Value of Understanding Informal Social Networks in an Adaptive Capacity Assessment: Explorations of an Urban Water Management System in Indonesia." *Water Resources Management* 27(13):4425–41.

López-Mosquera, Natalia and Mercedes Sánchez. 2012. "Theory of Planned Behavior and the Value-Belief-Norm Theory Explaining Willingness to Pay for a Suburban Park." *Journal of Environmental Management* 113:251–62.

Ma, Shan, Scott M. Swinton, Frank Lupi, and Christina Jolejole-Foreman. 2012. "Farmers' Willingness to Participate in Payment-for-Environmental-Services Programmes." *Journal of Agricultural Economics* 63(3):604–26.

Mace, Georgina M., Ken Norris, and Alastair H. Fitter. 2012. "Biodiversity and Ecosystem Services: A Multilayered Relationship." *Trends in Ecology & Evolution* 27(1):19–26.

Mack, Elizabeth A. and Sarah Wrase. 2017. "A Burgeoning Crisis? A Nationwide Assessment of the Geography of Water Affordability in the United States." *PLoS ONE* 12(1):1–19.

MacKinnon, S. 2018. *Practising Community-Based Participatory Research: Stories of*

Engagement, Empowerment, and Mobilization. UBC Press.

Malekian, Atefe, Dariush Hayati, and Noelle Aarts. 2017. "Conceptualizations of Water Security in the Agricultural Sector: Perceptions, Practices, and Paradigms." *Journal of Hydrology* 544:224–32.

Martín-López, Berta, Irene Iniesta-Arandia, Marina García-Llorente, Ignacio Palomo, Izaskun Casado-Arzuaga, David García Del Amo, Erik Gómez-Baggethun, Elisa Oteros-Rozas, Igone Palacios-Agundez, Bárbara Willaarts, José A. González, Fernando Santos-Martín, Miren Onaindia, Cesar López-Santiago, and Carlos Montes. 2012. "Uncovering Ecosystem Service Bundles through Social Preferences." *PLoS ONE* 7(6):1–11.

Mase, Amber Saylor, Nicholas L. Babin, Linda Stalker Prokopy, and Kenneth D. Genskow. 2015. "Trust in Sources of Soil and Water Quality Information: Implications for Environmental Outreach and Education." *JAWRA Journal of the American Water Resources Association* 51(6):1656–66.

Matthies, Brent D., Dalia D'Amato, Sami Berghall, Tommi Ekholm, Hans Fredrik Hoen, Jani Holopainen, Jaana E. Korhonen, Katja Lahtinen, Osmo Mattila, Anne Toppinen, Lauri Valsta, Lei Wang, and Rasoul Yousefpour. 2016. "An Ecosystem Service-Dominant Logic? - Integrating the Ecosystem Service Approach and the Service-Dominant Logic." *Journal Of Cleaner Production* 124:51–64.

Matthies, Brent D., Tuomo Kalliokoski, Kyle Eyvindson, Nina Honkela, Janne I. Hukkinen, Nea J. Kuusinen, Petri Räisänen, and Lauri T. Valsta. 2016. "Nudging Service Providers and Assessing Service Trade-Offs to Reduce the Social Inefficiencies of Payments for Ecosystem Services Schemes." *Environmental Science & Policy* 55(Part 1):228–37.

MDNR. 2010. *Michigan Forest Resource Assessment and Strategy*.

Meyer, Markus A. and Christoph Schulz. 2017. "Do Ecosystem Services Provide an Added Value Compared to Existing Forest Planning Approaches in Central Europe?" *Ecology and Society* 22(3):art6.

Meyfroidt, Patrick, Baptiste Nettier, and Sandra Lavorel. 2014. "How Ecosystem Services Knowledge and Values Influence Farmers ' Decision-Making." *PLoS ONE* 9(9).

Michigan Department of Environmental Quality. 2017. *Water Quality and Pollution Control in Michigan*.

Michigan Department of Health and Human Services. 2016. "Tribal Service Area Matrix."

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-Being: Synthesis*. edited by A. Sarukhan, Jose, Whyte. Washington, DC.: Island Press.

Mol, Arthur P. J. 2006. "From Environmental Sociologies to Environmental Sociology? A

Comparison of U.S. and European Environmental Sociology." *Organization and Environment* 19(1):5–27.

Münch, Richard. 2001. *International Encyclopedia of the Social & Behavioral Sciences*. Elsevier.

Naeem, S., J. C. Ingram, A. Varga, T. Agardy, P. Barten, G. Bennett, E. Bloomgarden, L. L. Bremer, P. Burkill, M. Cattau, C. Ching, M. Colby, D. C. Cook, R. Costanza, F. DeClerck, C. Freund, T. Gartner, R. Goldman-Benner, J. Gunderson, D. Jarrett, A. P. Kinzig, A. Kiss, A. Koontz, P. Kumar, J. R. Lasky, M. Masozera, D. Meyers, F. Milano, L. Naughton-Treves, E. Nichols, L. Olander, P. Olmsted, E. Perge, C. Perrings, S. Polasky, J. Potent, C. Prager, F. Quetier, K. Redford, K. Saterson, G. Thoumi, M. T. Vargas, S. Vickerman, W. Weisser, D. Wilkie, and S. Wunder. 2015. "Get the Science Right When Paying for Nature's Services." *Science* 347(6227):1206–7.

Napieralski, Jacob, Ryan Keeling, Mitchell Dziekan, Chad Rhodes, Andrew Kelly, and Kelly Kobberstad. 2015. "Urban Stream Deserts as a Consequence of Excess Stream Burial in Urban Watersheds." *Annals of the Association of American Geographers* 105(4):649–64.

Neary, Daniel G., George G. Ice, and C. Rhett Jackson. 2009. "Linkages between Forest Soils and Water Quality and Quantity." *Forest Ecology and Management* 258(10):2269–81.

Nisbet, Elizabeth K., John M. Zelenski, and Steven A. Murphy. 2009. "The Nature Relatedness Scale." *Environment And Behavior* 41(5):715–40.

Obeng, Elizabeth Asantewaa and Francisco Xavier Aguilar. 2018. "Value Orientation and Payment for Ecosystem Services: Perceived Detrimental Consequences Lead to Willingness-to-Pay for Ecosystem Services." *Journal of Environmental Management* 206:458–71.

OGL. 2017. *Sustaining Michgan's Water Heritage*. Lansing.

Olander, Lydia P., Robert J. Johnston, Heather Tallis, James Kagan, Lynn A. Maguire, Stephen Polasky, Dean Urban, James Boyd, Lisa Wainger, and Margaret Palmer. 2018. "Benefit Relevant Indicators: Ecosystem Services Measures That Link Ecological and Social Outcomes." *Ecological Indicators* 85:1262–72.

Olander, Lydia, Stephen Polasky, James S. Kagan, Robert J. Johnston, Lisa Wainger, David Saah, Lynn Maguire, James Boyd, and David Yoskowitz. 2017. "So You Want Your Research to Be Relevant? Building the Bridge between Ecosystem Services Research and Practice." *Ecosystem Services* 26:170–82.

Olmstead, Sheila M. 2009. "The Economics of Water Quality." *Review of Environmental Economics and Policy* 4(1):44–62.

Pascal, U. and F. Muradian, Roldan, Brander, L., Gomez-Baggethun, E., Martin-Lopez, B., Verna, M., Armsworth, P., Cornelissen, H., Eppink. 2010. "The Economics of Valuing Ecosystem Services and Biodiversity." in *TEEB-Ecological and Economic Foundation: Ecological and Economic Foundations*, edited by P. Kumar. London: Earthscan.

Pascual, Unai, Patricia Balvanera, Sandra Díaz, György Pataki, Eva Roth, Marie Stenseke, Robert T. Watson, Esra Başak Dessane, Mine Islar, Eszter Kelemen, Virginie Maris, Martin Quaas, Suneetha M. Subramanian, Heidi Wittmer, Asia Adlan, SoEun Ahn, Yousef S. Al-Hafedh, Edward Amankwah, Stanley T. Asah, Pam Berry, Adem Bilgin, Sara J. Breslow, Craig Bullock, Daniel Cáceres, Hamed Daly-Hassen, Eugenio Figueroa, Christopher D. Golden, Erik Gómez-Baggethun, David González-Jiménez, Joël Houdet, Hans Keune, Ritesh Kumar, Keping Ma, Peter H. May, Aroha Mead, Patrick O'Farrell, Ram Pandit, Walter Pengue, Ramón Pichis-Madruga, Florin Popa, Susan Preston, Diego Pacheco-Balanza, Heli Saarikoski, Bernardo B. Strassburg, Marjan van den Belt, Madhu Verma, Fern Wickson, and Noboyuki Yagi. 2017. "Valuing Nature's Contributions to People: The IPBES Approach." *Current Opinion in Environmental Sustainability* 26–27:7–16.

Pielke, R. A. 2007. *The Honest Broker: Making Sense of Science in Policy and Politics*. Cambridge University Press.

Pines, Huron. 2001. *Upper Au Sable River Watershed Management Plan*.

Postel, Sandra L. and Barton H. Thompson. 2005. "Watershed Protection: Capturing the Benefits of Nature's Water Supply Services." *Natural Resources Forum* 29(2):98–108.

Price, James I., Matthew T. Heberling, and Christopher T. Nietch. 2018. "Economic Support for Decisions on Source Water Protection." *Journal - American Water Works Association* 110(9):56–61.

Prokofieva, Irina. 2016. "Payments for Ecosystem Services—the Case of Forests." *Current Forestry Reports* 2(2):130–42.

Pugh, Scott A., Charles Paulson, and Brett J. Butler. 2016. *Forests of Michigan, 2015*. Newton Square.

Redford, Kent H. and William M. Adams. 2009. "Payment for Ecosystem Services and the Challenge of Saving Nature: Editorial." *Conservation Biology* 23(4):785–87.

Reed, M.S., Allen, K., Attlee, A., Dougill, A.J., Evans, K.L., Kenter, J.O., Hoy, J., McNab, D., Stead, S.M., Twyman, C., Scott, A.S., Smyth, M.A., Sstringer, L.C., Whittingham, M. J. 2017. "A Place-Based Approach to Payments for Ecosystem Services." *Global Environmental Change* 43:92–106.

Rochat, Yannick. 2009. "Closeness Centrality Extended To Unconnected Graphs : The Harmonic Centrality Index." *Application of Social Network Analysis (ASNA)* 117.

Roesch-McNally, Gabrielle E. and Sergey S. Rabotyagov. 2016. "Paying for Forest Ecosystem

Services: Voluntary Versus Mandatory Payments." *Environmental Management* 57(3):585–600.

Roobavannan, Mahendran, Tim H. M. Van Emmerik, Yasmina Elshafei, and Jaya Kandasamy. 2018. "Norms and Values in Sociohydrological Models." *Hydrology and Earth System Sciences* 22:1337–49.

Salzman, James, Genevieve Bennett, Nathaniel Carroll, Allie Goldstein, and Michael Jenkins. 2018. "The Global Status and Trends of Payments for Ecosystem Services." *Nature Sustainability* 1(3):136–44.

Scholte, S. S., A. J. van Teeffelen, and P. H. Verburg. 2015. "Integrating Socio-Cultural Perspectives into Ecosystem Service Valuation: A Review of Concepts and Methods." *Ecological Economics* 114:67–78.

Schomers, Sarah and Bettina Matzdorf. 2013. "Payments for Ecosystem Services: A Review and Comparison of Developing and Industrialized Countries." *Ecosystem Services* 6:16–30.

Schwartz, S. H. 1973. "Normative Explanations of Helping Behavior: A Critique, Proposal, and Empirical Test." *Journal of Experimental Social Psychology* 9:349–64.

Schwartz, S. H. 1977. "Normative Influences on Alturism." Pp. 221–79 in *Advances in experimental social psychology*, edited by L. Berkowitz. New York: Academic Press.

SEMCOG. 2014. "Green Infrastructure Vision for Southeast Michigan."

Small, Robert A., Lewis, David J. 2009. *Forest Land Conversion, Ecosystem Services, and Economic Issues for Policy: A Review*.

Stanghellini, Paola Sabina Lupo. 2010. "Stakeholder Involvement in Water Management: The Role of the Stakeholder Analysis within Participatory Processes." *Water Policy* 12(5):675.

Steg, Linda and Charles Vlek. 2009. "Encouraging Pro-Environmental Behaviour: An Integrative Review and Research Agenda." *Journal of Environmental Psychology* 29(3):309–17.

Stern, Paul C. 2000. "New Environmental Theories: Toward a Coherent Theory of Environmentally Significant Behavior." *Journal of Social Issues* 56(3):407–24.

Symstad, A. J., F. S. Chapin, D. H. Wall, K. L. Gross, L. F. Huenneke, G. G. Mittelbach, D. P. C. Peters, and D. Tilman. 2003. "Long-Term and Large-Scale Perspectives on the Relationship between Biodiversity and Ecosystem Functioning." *Bioscience* 53(1):89–98.

Syrbe, Ralf-Uwe and Ulrich Walz. 2012. "Spatial Indicators for the Assessment of Ecosystem Services: Providing, Benefiting and Connecting Areas and Landscape Metrics." *Ecological Indicators* 21:80–88.

Teasdale, Guillaume. 2012. “Old Friends and New Foes: French Settlers and Indians in the Detroit River Border Region.” *Michigan Historical Review* 38(2):35.

Thompson, Ian D., Kimiko Okabe, Jason M. Tylianakis, Pushpam Kumar, Eckehard G. Brockerhoff, Nancy A. Schellhorn, John A. Parrotta, and Robert Nasi. 2011. “Forest Biodiversity and the Delivery of Ecosystem Goods and Services: Translating Science into Policy.” *BioScience* 61(12):972–81.

Todd, Albert H. and Emily Weidner. 2010. “Valuing Drinking Water as an Ecosystem Service.” *The Pinchot Letter* 10–13.

USEPA. 2008. *Water Quality Trading Evaluation: Final Report*.

USFSW. n.d. “National Wild and Scenic Rivers System: AuSable River, Michigan.” *2019*. Retrieved May 20, 2019 (https://www.rivers.gov/rivers/ausable.php).

Vayda, Andrew P. and Bradley B. Walters. 1999. “Against Political Ecology.” *Human Ecology* 27(1):167–79.

Warziniack, Travis, Chi Ho Sham, Robert Morgan, and Yasha Feferholtz. 2017. “Effect of Forest Cover on Water Treatment Costs.” *Water Economics and Policy* 03(04):1750006.

Wasserman, S. and K. Faust. 1994. *Centrality and Prestige*. New York City: Cambridge University Press.

Watersheds, Lower Grand River Organization of. 2011. *Lower Grand River Watershed Management Plan*.

Weidner, Emily and Al Todd. 2011a. *From the Forest to the Faucet: Drinking Water and Forests in the US*.

Weidner, Emily and Al Todd. 2011b. “From the Forest to the Faucet: Drinking Water and Forests in the US.” *United States Forest Service, Ecosystem Services and Markets Program Area, State and Private Forestry* (October):1–34.

Weigel, Lori and David Metz. 2018. *The Language of Conservation: Updated Recommendations on How to Communicate Effectively to Build Support for Conservation*.

Wolcott, H. F. 2008. *Ethnography: A Way of Seeing*. 2nd ed. Walnut Creek, CA: Altamira.

Zorn, Troy G. and Steven P. Sendek. 2001. “Au Sable River Assessment Au Sable River Assessment.” *Mchigan Department of Natural Resources*.