5-2011

Investigation of the Use of Multi-Criteria Decision-Making Tools For Management of an Urbanizing Watershed

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Colton, Reed C., "Investigation of the Use of Multi-Criteria Decision-Making Tools For Management of an Urbanizing Watershed" (2011). *Civil Engineering Theses, Dissertations, and Student Research*. 19.
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INVESTIGATION OF THE USE OF MULTI-CRITERIA DECISION-MAKING TOOLS FOR MANAGEMENT OF AN URBANIZING WATERSHED

By

Reed C. Colton

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Civil Engineering

Under the Supervision of Professor John Stansbury

Lincoln, Nebraska

May, 2011

Investigation of the Use of Multi-Criteria Decision-Making Tools For Management of an Urbanizing Watershed

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University of Nebraska, 2011

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The regulation of non-point pollution sources (e.g. agricultural runoff and stormwater discharges) as mandated by the 1972 Clean Water Act, forced a fundamental paradigm shift from “end of the pipe” pollution control to a watershed management approach. Multiple jurisdictions and often conflicting objectives make it difficult to reach stakeholder consensus and execute watershed management decisions. To facilitate decision making when multiple and/or conflicting objectives exist, Multi-Criteria Decision-Making (MCDM) tools were developed for diverse applications, and potentially could be used to facilitate watershed management.

The overall objective of this thesis was to evaluate MCDM tool use to facilitate community-based management of an urbanizing watershed. The study methodology was to recruit representative stakeholders from the community; identify critical issues/goals, decision criteria, and applicable technologies, considering ecological, human health, social, and economic factors; establish historical and current watershed conditions; determine management alternatives for stakeholder review; evaluate management alternatives by having stakeholders apply MCDM tools; and have stakeholders evaluate the effectiveness of MCDM tool use for watershed management.

Based on the study, four primary conclusions were made. First, MCDM tools can be used effectively for community-based watershed management and could be used

effectively for watershed management under differing conditions. MCDM tools can encourage stakeholder input, and facilitate determination of watershed issues/goals, stakeholder education, and decision-making process transparency. Second, stakeholder input/participation is essential for watershed management plans to have broad community support. Third, sustained stakeholder involvement is difficult to obtain and maintain, but is more likely if valued resources are at stake and/or controversial alternatives are considered. Fourth, effective, representative stakeholder participation requires adequate resources to recruit stakeholders, consistent efforts to engage them, and early establishment of clear goals.

Dedication

A Sonya, por todo
No hay palabras adecuadas ni suficientes para expresar mis sentimientos
Simplemente, sos mi amor, mi vida, y mi todo
Yo te amo.

Y

A mi mamá
Siempre tenías fe en mí, siempre me apoyabas, siempre me guiabas con
tus consejos y tu ejemplo. Siento en mi corazón
que estarías contenta y orgullosa. Si pudieras estar aquí . . .
Te quiero, mamá.

Author's Acknowledgements

I express my immense gratitude and deepest appreciation to Dr. John Stansbury, my Master's thesis advisor, for giving me the opportunity to pursue this research and supporting me to the end. The invaluable knowledge and experience that I gained under his tutelage have enriched my understanding, contributed significantly to my civil engineering career, and will continue to do so throughout my life. It goes without saying that without his knowledge, guidance, support, and persistent encouragement, this thesis would not have been possible.

I consider it an honor to have worked with Dr. Renee Irvin, who, through her knowledge and expertise, contributed immensely to my understanding of community-based decision making and the socio-political constructs of watershed management. I would like to thank her and express my appreciation for her insights and guidance.

To Dr. Duane Schulte and Dr. David Admiraal I express my sincere and heart-felt gratitude for their willingness to serve on my committee. I cannot thank them enough for the time they took from their busy schedules, under less than ideal circumstances, to review my thesis and participate in my final thesis examination. I truly appreciate their invaluable insights and contributions to the completed work.

I owe an immense debt of gratitude to Dr. Bruce Dvorak for his willingness to help, his persistence, and his support. Without his support, completion of my graduate studies would not have been possible.

Words are not adequate to express my gratitude, appreciation, and so much more, to Terri Eastin, Graduate Programs Specialist for Masters Degrees in the Office of Graduate Studies. She has always been in my corner, has always been supportive, and always found a way. Without her, these acknowledgements may have never been written,

this thesis and my Master's Degree may not have been completed, and I would have always asked myself "What if?" I cannot thank her enough.

I would like to thank EPA Region VII for supporting this project. In addition, I thank the City of Omaha, the Papio-Missouri River Natural Resources District, the U.S. Army Corps of Engineers, and the Metropolitan Area Planning Authority for providing data and advice in support of the project.

Finally, I would like to thank my village who supported me through this process and saw me through to the end (Clinton 2009). I am especially grateful to Sonya for all the years; there are not words enough to express the totality of the acknowledgement she deserves. I express special thanks to my family, but especially to my dad for his example, to Mark for being there and providing refuge during the stormy week of my thesis defense, and to Annette for never doubting and always having an encouraging word. I feel heart-felt gratitude for Linda who stood in for mom. Special thanks to Nolan for insight, perspectives and views, and support. I especially thank Jason for *everything*, my brother Davey, who has been with me through thick and thin through the years, and to his family Tamie, Maddie, and Emma for sharing. I thank Tyler for his ride, Erin C. who has been a true friend and always has faith in me, and my friend Steve C., professor of philosophy, for his guidance, friendship, and meditations. For friendship and support, I thank Nancy T., Nancy S., Marlon and Lisa, Guille, Christie, Brooke and John, Barbara and Michael, Kat, Evita and Ramiro, Steve and Erin, Jeff and Natalie, Kelli and Joel, Amber and Jeremy, and Marin and Brian. I thank Andrea, Dr. Susan, Dr. Ann, and Dr. Eric for their significant contributions to my life, and to Dr. Gary, Dr. Peter, Dr. Paul, Yvonne, and Lina for my life.

Grant Information

This research was supported in part by the United States Environmental Protection Agency, Region VII, under EPA Grant Number CP997759-01 to Dr. John Stansbury and Dr. Renee Irvin at the University of Nebraska – Omaha.

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Acronyms and Abbreviations

BMP	Best Management Practice
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
CSO	Combined Sewer Overflow
CtP	Composite Programming
MAR	Management Alternative Report
MAUT	Multiattribute Utility Theory
MCDM	Multi-Criteria Decision Making
NGO	Non-Governmental Organization
PMRNRD	Papio-Missouri River Natural Resources District
TMDL	Total Maximum Daily Load
USACE	United States Army Corp of Engineers
EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WAP	Weighted Average Programming

Chapter 1
Introduction

1.1 Investigators

Investigation of the Use of Multi-Criteria Decision-Making Tools for Management of an Urbanizing Watershed studies the decision-making process for management of watersheds with multiple land uses, including agricultural and urban. The study was funded by a grant from Region VII of the U. S. Environmental Protection Agency (EPA), EPA Grant No. CP997759-01. This report is a collaborative effort between two principal investigators, John Stansbury and Renee Irvin, primarily assisted by Reed Colton and Chris Swanson. Dr. Stansbury is a professor in the Department of Civil Engineering at the University of Nebraska with experience in ecological and human health risk assessment, Multi-Criteria Decision-Making (MCDM) tools, and MCDM studies considering environmental and economic impacts. Dr. Irvin is an economist and a former faculty member in the Department of Public Administration at the University of Nebraska-Omaha (UNO) specializing in environmental and health economics, applied microeconomics, and the development of multivariate regression models utilized in quantitative analysis of consumer benefits from environmental remediation.

1.2 Project Rationale

The 1972 Amendment to the Clean Water Act mandated the Federal Government to regulate water quality in the waterways of the United States. While the legislation applied to point and non-point sources of pollution, for many years the primary regulatory focus was on point source pollution. In spite of the significant improvement in water quality in the nation’s streams and lakes, water quality in many water bodies is still not satisfactory. This has prompted the EPA to address non-point pollution sources such as agricultural and storm water discharges. As part of non-point pollution management, the EPA assigns and enforces Total Maximum Daily Loads (TMDLs) for impaired waterways, with daily contaminant allotments assigned to both point and non-point sources of pollution. Non-point pollution management and TMDLs force a fundamental paradigm shift from “end of the pipe” pollution management to a watershed management approach.

Due to the multi-jurisdictional nature of watersheds, the watershed management approach is often difficult. Watersheds may span state and county boundaries. States may have one entity governing recreational use and wildlife, another governing flood control, and yet another regulating water quality. This is further complicated by the oversight of Federal agencies, such as the EPA and the United States Army Corp of Engineers (USACE).

In addition, management decisions frequently have long-reaching impacts on people living and working within the watershed. For example, limiting flood plain use may decrease the amount of valuable commercial property available within city limits, and the installation of riparian buffer strips in agricultural areas may take land out of productive use. Lack of public participation at the decision-making level may result in litigation and costly delays or cancellation of projects, such as the 1975 lawsuit in the Papillion Creek (often referred to as the Papio Creek) Watershed which halted construction of an Army Corps of Engineers flood control dam (United States. Army Corps of Engineers, 1982). For this reason, there is growing recognition of the need for public participation in watershed management decision making (United States. Environmental Protection Agency, 1996).

With multiple, often conflicting, objectives for the management of a watershed, it may be difficult to reach a decision or consensus among stakeholders regarding a watershed management plan. MCDM tools were designed to facilitate decision making when multiple and conflicting objectives exist. This study evaluates the use of MCDM tools as a facilitator for watershed management.

Chapter 2
Study Objectives

The overall project objective was to evaluate the use of MCDM tools to facilitate community-based management of an urbanizing watershed, selecting among competing management alternatives while considering ecological, human health, social, and economic factors. Secondary objectives of the project were:

1. To identify critical environmental, social, public health, and economic issues and goals related to the development of management policies and alternatives for a degraded urban stream;
2. To evaluate how different management policies impact critical issues and goals by quantifying the condition of these parameters for possible management alternatives.

Five interim steps were used to achieve the objectives. First, a group of stakeholders was recruited. Second, critical watershed issues and goals were identified. Third, reasonable management alternatives for the watershed were developed. Fourth, impacts to environmental, social, public health, and economic conditions were assessed for each identified management alternatives. Finally, a forum of stakeholders met to use MCDM tools to trade of the impacts of the management alternatives, select the “best” management alternative, and to evaluate MCDM use for community-based watershed management.

Chapter 3
Literature Review

3.1 Legislation and Regulatory Agencies

Watershed management in the United States has historically been administered by local, state and federal agencies, as mandated by both state and federal legislation. Key federal legislation impacting watersheds includes the following:

1. Swamp Land Acts of 1849, 1850, and 1860;
2. Rivers and Harbors Act of 1899 and subsequent amendments;
3. Flood Control Act of 1936;
4. Federal Water Pollution Control Act of 1956;
5. Water Resources Planning Act of 1962;
6. Water Quality Act of 1965;
7. Clean Water Act of 1972 and subsequent amendments;
8. Safe Drinking Water Act of 1974 and subsequent amendments.

The main thrust of these acts, through about 1950, was public safety from floods and disease, navigation, and power production. During this time, Congress authorized the Army Corps of Engineers to construct structural solutions to navigation, flooding, and power; authorized the formation of the Tennessee Valley Authority, and authorized the Bureau of Reclamation to construct dams in the western part of the United States (Burby, 1985). In the latter part of the twentieth century, there was a growing emphasis placed on maintaining high water quality in the rivers and streams within watersheds. Publicly owned treatment plants were financed and regulated, water quality standards were developed for interstate waters, and finally, physical, chemical and biological standards were established which included surface and ground water (U. S. Environmental Protection Agency, 1995).

Several federal agencies and departments have authority under the Acts listed above, including, among others, the USACE, Department of the Interior, Department of Agriculture, and the EPA. In addition to these are various state agencies, including state departments of environmental quality/protection, agriculture, and natural resources, and local municipal and county governments.

3.2 Rationale for a Watershed Approach

In the past, watersheds were managed indirectly, generally by falling within different jurisdictional and geographical boundaries. The Papillion Creek watershed, for example, fell under the jurisdiction of the U. S. Army Corps of Engineers and the Papio-Missouri River Natural Resources District (State of Nebraska), the United States Environmental Protection Agency through the Nebraska Department of Environmental Quality (NDEQ), three counties, the City of Omaha, and several smaller community governments. Most regulatory decision making was done by each agency, with little or no collaboration between agencies or between the agencies and the public. As a result, there may not be a clear vision or mission for the watersheds or a clearly identifiable economic, social, or ecological resource to be protected. Decision making may, by default, be left primarily to land owners and developers. In the case of floodplain management, a strong federal presence led to a false sense of security in local communities (Burby, 1985; Farber, 1996). “ . . Believing themselves to be adequately protected from floods through federal intervention, [they] took little interest in the use of land within their own floodplains” (Platt, 1979).

Past management activity has addressed, with some success, the tasks of economic development and improvement of quality of life (Lant, 1999). However, several complex watershed related problems have not been fully addressed, meriting a reevaluation of how watershed management has been done to this point (Faber, 1996; Lant, 1999; United States. Environmental Protection Agency, 1995; United States. Environmental Protection Agency, 1996). For example, the 1972 Clean Water Act (CWA) mainly addressed point source discharges into streams, but many streams were still classified as impaired under Section 303d. This impairment has been attributed to non-point source pollution and habitat degradation (EPA, 1994). The 1987 amendments to the CWA mandated states to address non-point sources of contamination, among other issues. The EPA has defined a "watershed approach" as:

> . . . a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined geographic areas, taking into consideration both ground and surface water flow.

Further, the EPA has suggested that the "watershed approach" may be an effective tool for addressing those issues (EPA, 1996).

3.3 Cooperative Watershed Decision Making

In order for the "watershed approach" to be successful, a cooperative approach to watershed management is necessary. Cooperative watershed management may involve inter-governmental agency interaction, interaction between federal, state and local authorities, and/or interaction between federal, state, and local authorities, and citizen stakeholders (Center, 1999; United States. Environmental Protection Agency, 1995).

Because of the number of regulatory agencies, with differing mandates, and the number and variety of conflicting issues, cooperative watershed management was not widely practiced until recently.

The authoritative model for decision making is still the predominant form of management impacting watersheds. Within the authoritative paradigm, agencies assume the responsibility for conception and execution of the watershed plan. The watershed management team may be chosen by legislative or regulatory authority. Consistent funding and legal authority are two advantages, among others, to authoritative decision making. The largest disadvantage may be disenfranchisement of the stakeholder public. To be successful, an authoritative watershed management team must include representatives from the various jurisdictions that have a stake in the watershed and have a clear vision with specific goals (Center, 1999).

Watershed decision making may also be community-based. Watershed decisions are made with significant input from community members, including a range of stakeholders in the community. The advantage of community-based decision making is that the community becomes vested in a process that has previously excluded it. Stakeholder involvement may be at a "grass-roots" level, funded by grants and with voluntary cooperation of government agencies; or, it may be formed as a collaborative effort between local and state governments, funded by government entities.

Lant (1999) reports that there are over 1,500 locally-led watershed management initiatives in the United States, most established in the 1990s. Often, community based decision making is inspired by some notable economic, ecological, or social resource associated with a watershed that is not be adequately protected by the management processes in place. For example, the Puget Sound watershed in Washington State was experiencing significant environmental degradation caused by urban and agricultural discharges. When it became apparent that the degradation was seriously impacting the fish and shellfish, and therefore the health of the community, a citizen-led effort ensued to implement management systems to protect the watershed (Gordon, 1989). Similarly, in the Chesapeake Bay watershed, when water quality degraded to the degree that it seriously impacted fish and shellfish in the watershed, community-led efforts forced new management initiatives for the watershed (Hodges, 1996). In both of these and similar cases, the decision making process that evolved has a strong community-based component (Robinson, 1997).

3.4 Community Participation

Top-down command and control regulation works best for point source pollution, where sites can be measured, monitored, and enforced. However, most of the problems within watersheds result from “diffuse human activities” and “a multitude of small sources” and may be difficult to control with traditional (authoritative) approaches to management (United States. Environmental Protection Agency, 1996a; United States. Environmental Protection Agency, 1996b).

Collaborative, multi-jurisdictional watershed planning groups may be necessary due to the nonpoint nature of the source of the water quality degradation and to the political and geographical realities of watersheds (Kenney, 2000). According to the EPA (1996b), community participation through watershed planning groups and partnerships “ensures that environmental objectives are well integrated with those for economic stability and other social and cultural goals. It also provides that the people who depend upon the natural resources within the watersheds are well informed of and participate in planning and implementation activities." The EPA further asserts that, "Community Based Environmental Protection is designed to maximize the use of scarce resources, encourage local support, and consider the economic well-being of communities (United States. Environmental Protection Agency, 1996a)."

3.4.1 *Participatory democracy*

Barber (1984) describes 9 functions of "democratic talk" – 1) articulation of interests; 2) persuasion; 3) agenda-setting; 4) exploring mutuality; 5) affiliation and affection; 6) maintaining autonomy; 7) witness and self-expression; 8) reformulation and reconceptualization; and 9) community-building as the creation of public interests, common goods, and active citizens (as reported in Weeks, 2000). Citizen participation in the watershed management process potentially completes these 9 functions, and may also help strengthen democracy, becoming an investment in social capital (Mansbridge, 1980; Dryzek, 1990; Reich, 1988). Gutmann and Thompson (1996) state that open discussion facilitates deliberation by increasing available information, expanding the range of considered arguments, and widening the moral frame of reference. Maier (2001) praises citizen participation as a sort of a step up along the evolutionary ladder of democracy, quoting Putnam (1995) "Scholars from the West 'have lamented the absence or obliteration of traditions of independent civic engagement and a widespread tendency toward passive reliance on the state.'" On the other hand, finding volunteers to participate may be difficult. Nickelsberg (1998) states:

> Community members may lack the time to devote to an exhausting, collaborative effort. Moreover, professional and scientific assistance

> may not be available or may be prohibitively expensive. The probability that citizens will undertake such long-term collective action varies widely from community to community, most likely in correlation with the economic prosperity of the inhabitants.

There may be a perception among non-participating community members that a few vocal members of the community are making decisions on behalf of the general public (Weeks, 2000). Further, “If participation is small, but representative, the results may accurately reflect the policy preferences of the community, but the larger goals of civic engagement will be sacrificed (Weeks, 2000).” Community participation practices may also be considered to be un-democratic (Abrahams, 1996, Curry, 1996). For example, Curry (2001) states that several of the groups in his study “were clearly not acting in a representative capacity, or even perceiving themselves to be, and some had an openly declared intent to pursue vested interests, sometimes working against decisions of the state.” Benson (1998) objects to watershed councils having “real” authority. He fears local groups will be dominated by a pro-development agenda at the expense of larger resource issues, and the regulatory agency or agencies might find it politically inexpedient to oppose the watershed council’s actions once the decisions are announced. This is supported by Weeks’ study (2000), where the decisions made by the public via surveys were reluctantly followed by the City Council in Eugene, Oregon.

Some groups may be underrepresented by the community participation process (McCloskey, 1996). Survey research conducted by the Natural Resources Law Center suggests “. . . that about half of the watershed initiatives in the Interior West do not include environmental representatives; furthermore, in about two-fifths of those groups, membership is not completely open (Kenney, 2000).” As a result, stakeholders with underrepresented views may choose not to collaborate and may use litigation. Litigation, if successful, results in “wins”, whereas collaborative decision making often results in compromise and negotiated arrangements.

3.4.2 *Public education*

There is an inherent public education value to collaborative groups (Blackburn, 1995; Kenney, 2000; Pateman, 1970; Sabatier, 1988). “We envision that these relationships established with regional and community organizations will bring about a better understanding of environmental problems as well as more effective solutions.” (United States. Environmental Protection Agency, 1996a). Margerum (2002) notes that engaging stakeholders in a learning process about the system they are addressing, and how different problems are interrelated, may help engage narrow-interest stakeholders who might otherwise become disinterested in collaborative planning because their specific interest is not being addressed enough. Kenney (2000), states, “…it is unrealistic to expect people to care about those things they do not understand, to combat problems they do not recognize, or to implement solutions they have not considered.” Yankelovich (1991) argues that the process of working through problems can be accelerated by structured activities that present citizens with options, provide information about their characteristics and consequences, encourages reasoned discussion among peers, and elicits reflective judgment (as reported by Weeks, 2000).

3.4.3 *Stakeholder group composition and dynamics*

The stakeholder selection process and composition of the group will have an impact on the success of management planning and execution. Margerum (2002) found, that the importance of stakeholder selection and composition confirmed "well-established principles in the literature on clear process, inclusion, and flexibility (Gray, 1989; Innes et al., 1994; Carlson, 1999)." Efforts should be made to be inclusive, but to limit the group to a manageable size (Margerum, 2002; Gray, 1989, Susskind, 1987). Weeks (2000) admits that his deliberative democracy project works well in Eugene, Oregon, a medium-sized city with a well-educated homogenous population and a tradition of civic engagement, but may not work well elsewhere. Several studies endeavored to obtain statistically representative samples for their citizen-involvement processes (Fishkin, 1991; Fishkin, 1995; Crosby, 1986; and Dahl, 1989).

Group dynamics may be a major stumbling block to the success of the collaborative process. For example, in Fort Collins, Colorado, workshops were "well attended and group discussions were enthusiastic but generally unproductive. Community activists aligned with specific groups or causes were able to sometimes "hijack" their group to advance their cause and favored solution. More often, the group members lacked sufficient knowledge about the underlying issue to fruitfully engage in developing preventive or corrective strategies. Solutions tended to be the conventional wisdom as reflected by recent newspaper headlines (Weeks, 2000)." It may also be difficult for consensus based groups to reach a compromise on truly divisive issues (Coglianese, 1999). From Margerum (2002), "Some authors suggest that when there are basic ideological or value differences, collaborative forums may need to give way to political or legal forums (Amy, 1987; Whetten and Bozeman, 1984)." There is some evidence that the collaborative process may create divisiveness (Curry, 2000; Sherwood & Lewis, 1994; and Owen, 1998). Although it is commonly assumed that stakeholders with extreme viewpoints will come together in collaborative groups and arrive at average (negotiated to the middle) results, several researchers have found the opposite, that is, stakeholders sometimes arrive at extreme viewpoints (Kenney, 2000; Moscovici & Zavalloni, 1969). Over-reliance on consensus is feared to squelch or discredit diverse and minority opinions (Kenney, 2000; Rescher, 1993).

Roberts (2000) explains:

> Experience in Leicester suggests that multi-sector partnership meetings can be very difficult to facilitate. Often, influential and energetic individuals with widely differing paradigms and agendas will sit around the same table. Such meetings can be chaotic, are often dominated by the most vocal and can be inconclusive in terms of specific commitments and actions arising.

Frequently, the whole process may take longer than necessary, and it is extremely difficult to include under-represented groups (Roberts, 2000). Community participation in collaborative decision making works best when the group is small and homogenous (Ostrom, 1990). Objectives must be clear and mutually agreed on, the process should be voluntary and inclusive, there must be adequate funds for participation and information collection, the parties must keep their constituencies informed, and reasonable deadlines must exist (Bingham, 1997).

Chapter 4
Methodology

4.1 General Description of the Watershed Evaluated for this Study

The Papillion Creek watershed is located in eastern Nebraska, draining parts of Washington, Douglas and Sarpy Counties before flowing into the Missouri River, just north of the mouth of the Platte River. There are three major branches of the Papillion Creek: the Big Papillion Creek forms the central and major branch and the main trunk that flows into the Missouri River, the Little Papillion Creek is located on the eastern edge of the watershed; the West Branch is located on the southwest corner of the watershed. *Figure 4.1* indicates the general location of the Papillion Creek watershed and the general configuration of the Big Papillion Creek and tributaries.

The basin is approximately 41 miles long, generally from north to south, from mouth to headwaters. The widest east-to-west dimension is approximately 17 miles, extending from Gretna to Bellevue. Total drainage area is approximately 400 square miles. The land use is mixed urban and agricultural; the stream runs through portions of Omaha, Papillion, La Vista and Bellevue, as well as through other small towns.

4.2 Overview of the Methodology Used for this Study

As mentioned in *Section 3.1*, the EPA outlines the basic method for a “watershed approach” in “Watershed Approach Framework”, the key points being partnership (stakeholder participation), geographic focus, and sound management techniques based on strong science and data (United States. Environmental Protection Agency, 1996). While the use MCDM tools, in general, follows a similar framework, the multi-criteria decision-making process is more than simple application of multiple criteria algorithms.

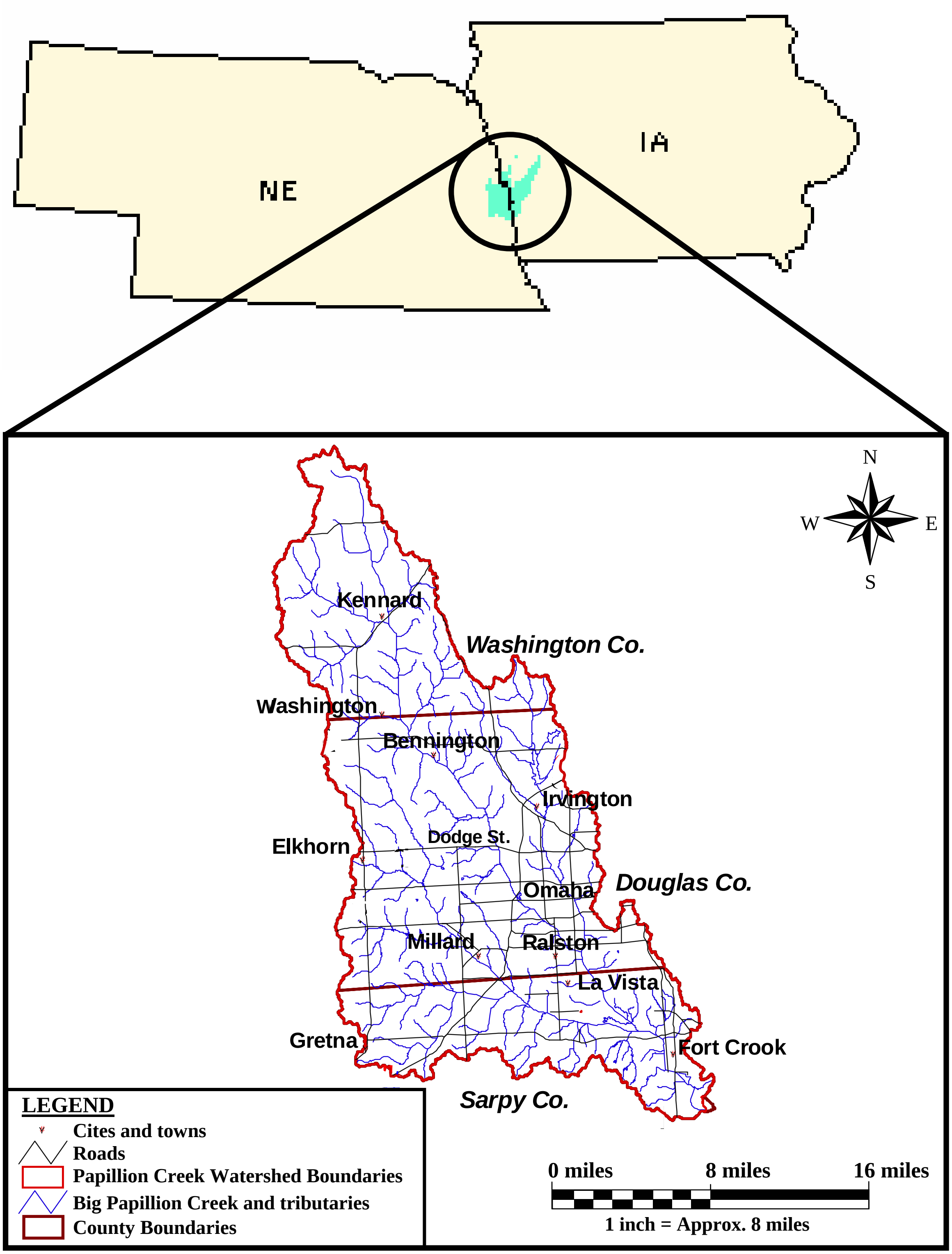


Figure 4-1. Papillion Creek watershed map (source: EPA: Surf Your Watershed).

To incorporate MCDM into the management process, stakeholders and agency administrators must have access to both historic and current information about the watershed. This structured approach to MCDM includes gathering information about the watershed, establishing critical watershed issues and goals, identifying management alternatives, determining management alternative impacts on the watershed, and disseminating data to the stakeholders. The overall methodology for this project is outlined below:

1. Recruit stakeholders for study;
2. Identify critical issues and goals for management of watershed;
3. Identify the decision criteria;
4. Identify technologies to achieve the watershed goals;
5. Establish historical and current watershed conditions;
6. Identify potential management alternatives;
7. Determine the condition (value) of each decision criteria under each management alternative;
8. Normalize the values of the decision criteria;
9. Evaluate and select MCDM tools;
10. Use the chosen tools to evaluate the management alternatives;
11. Evaluate the usefulness of MCDM tools for watershed management;
12. Disseminate results regarding Papillion Creek watershed stakeholder decision making.

4.3 Stakeholder Recruitment

Community representatives were contacted to solicit participation in a watershed-wide study of MCDM processes. In the fall of 1999, a brochure entitled “Papio Creek Watershed Restoration Study” (see *Appendix A*) was produced to recruit community stakeholders. Approximately one hundred letters with accompanying brochures were sent to:

1. Neighborhood associations near the Papillion Creek system;
2. Plant and tree nurseries;
3. Key rural property owners;
4. Newspaper media contacts;
5. High schools;
6. Environmental organizations;
7. Businesses near the Papillion Creek system;
8. City managers.

By the winter of 2000, replies were received regarding interest in signing up as a community respondent for the project. Preliminary thank-you phone calls were made, and then a letter thanking them for their interest and outlining the 2-year participation process was sent. Respondent names were placed on a list of stakeholders.

In addition to contacts made by mail, the following people from the media, agencies, and non-governmental organizations (NGOs) were contacted:

1. Phone interview with Julie Anderson, Omaha World Herald environmental editor;
2. Met with four managers at the NRD office. The NRD is the primary stakeholder agency involved in watershed planning for the Papillion Creek system;
3. Met with George Cunningham, Adopt-a-Stream Coordinator for the National Wildlife Federation;
4. Met with biologists Tom Bragg, Richard Stasiak, and graduate student Pamela Peters at UNO;
5. Phone interview with Brad Simmons of the Papillion Times;
6. Met with Kent Holm, Douglas County Environmental Services Director;

7. Met with Milton Fricke, Papillion landowner and soil conservation pioneer.

As a result of these contacts, newspaper articles regarding the project were published in February, 2000, in the Omaha World Herald and the Papillion Times (Anderson, 2000).

During the summer of 2000, a survey titled *Papio Creek Community Benefit Survey* was being prepared for distribution. Prior to distribution, additional brochures were mailed directly to neighborhood association in an effort to recruit more urban stakeholders. At this point, the stakeholder mailing list appeared to have a wide geographical distribution of respondents, including Washington and Sarpy county landowners and farmers. The stakeholder mailing list had a total of 45 names, with the following distribution:

Landowners & Farmers (including 2 out-of-state owners)	14
Agency personnel	10
Environmental group representatives	4
Other nonprofit group representatives	2
Environmental Professionals (teachers, engineers, etc.)	5
Individuals	8
Businesses	2

By summer 2001, the stakeholder mailing list contained approximately 60 people representing a wide cross-section of stakeholder interests and geographical locations.

4.4 Identification of Critical Issues and Goals

A preliminary list of critical issues and goals for the Papillion Creek watershed was identified using a variety of sources. Under the Clean Water Act 303d List, portions of the Big Papillion Creek are listed as impaired. The Big Papillion Creek is designated for contact recreation, and the NDEQ has listed these portions of the creek as being impaired due to coliform bacteria. The source of bacteria has not yet been determined. However, there are several possible sources, including combined sewer overflows (CSOs), urban runoff, cattle feedlots and livestock in the creek, and agricultural runoff. Watershed goals were designed to bring the Creek into compliance with current and future regulation.

A March 1999 study, *A Community-Based Watershed Management Plan for Zorinsky Lake* identified several other water quality issues, including sediment accumulation, high bacteria levels, high turbidity, low dissolved oxygen, and nutrients (“Community-Based”, 1999). Other issues, such as flood control, recreational needs, economic development, and wildlife habitat were identified through contact with the United States Army Corps of Engineers (USACE), Papio-Missouri River Natural Resources District (PMR NRD), University of Nebraska faculty, Nebraska Game and Parks Commission, and various departments for the city of Omaha.

Several watershed goals for this study were also developed from *Community-Based Watershed Management Plan for Zorinsky Lake* (“Community-Based,” 1999). These goals included restoration of fish and wildlife habitat and communities, aesthetics, water quality, and development of recreational opportunities (“Community-Based,” 1999).

Other goals, specifically flood protection and economic development, are long standing goals of the USACE, PMR NRD, and the City of Omaha. Flood protection and control has been the primary watershed management issue and the principle driving force behind the majority of modifications to the creek. These modifications include reservoirs, channel modifications, and grade control structures. From a policy perspective, flood control management plans have caused serious conflict in the watershed between upstream rural and downstream urban residences. Original plans made by the USACE after the floods of 1964 called for the construction of 21 dams, primarily in the upstream rural areas to protect the downstream urban areas (Omaha-Council Bluffs, 1980). In 1975, the Papio Valley Preservation Society, a private citizen group formed of primarily rural landowners, filed suit, resulting in a court injunction that blocked the construction of Dam 10, and suspended plans for several other dams pending reevaluation. Currently, six dams are in operation: dam sites 11 (Glenn Cunningham Lake), 16 (Standing Bear), 18 (Zorinsky Lake), 20 (Wehrspann), 21 (Walnut Creek), and 17 (Lake Candlewood, private).

In the summer of 2000, a document titled *Preliminary List of Papio Creek Watershed Management Alternatives* and accompanying survey was sent to the “recruited” stakeholders. A portion of the survey requested that the surveys respond to the preliminary list of critical issues and goals. A copy of the *Preliminary List of Papio Creek Watershed Management Alternatives* and survey responses are provided in *Appendix B.*

From the sources discussed previously and stakeholder input, the following goals and issues were developed for the Papillion Creek Watershed:

1. Provide good water quality:
    a. Adequate dissolved oxygen for native aquatic species;
    b. Low levels of nutrients to avoid eutrophication;
    c. Low levels of pesticides and other chemicals to avoid health hazard upon water contact and upon fish consumption;
    d. Low levels of bacteria to avoid health hazard upon water contact;

2. Provide good wildlife habitat:
    a. Riparian (stream-side and bank): stream-side areas of vegetation including grasses and trees to provide habitat for birds and small animals;
    b. Aquatic: Stream structure (e.g., meanders, bottom substrate) and cover (e.g., vegetation) to provide habitat for native fish and aquatic species;
3. Provide recreational opportunities:
    a. Hiking, biking (etc.) trails along streams;
    b. Water sports (e.g., boating in lakes);
    c. Fishing;
    d. Watershed-related park space;
4. Provide opportunity/climate for economic development:
    a. Agriculture;
    b. Real estate development;
    c. Other businesses;
5. Provide flood control;
6. Provide high quality of life:
    d. Aesthetically pleasing creek;
    e. Green space.

4.5 Decision Criteria

Decision criteria are measures of the degree of attainment of a watershed goal. Each criterion is a quantifiable representation of a goal. For example, flood control is a watershed goal; annual expected flood damage is the decision criterion selected to measure how well the goal of flood control is met given a management alternative. These criteria included water quality changes, wildlife habitat changes, and economic costs and benefits brought about by the management alternatives (discussed in *Section 4.6*). The following is a complete list of decision criteria:

1. Water quality:
    1. Dissolved oxygen (August average, mg/L);
    2. Nitrogen (total) (discharge index, fraction);
    3. Phosphorous (total) (discharge index, fraction);
    4. Coliform bacteria (discharge index, fraction);
    5. Sediment Load (discharge index, fraction);
    6. Regulatory compliance (index, scale 1 to 3);
2. Habitat:
    1. Riparian quantity (area in watershed, acres);
    2. Riparian connectivity (connected length/total, fraction);
    3. Substrate/cover (*Habitat Assessment*, index 0 to 1);
    4. Water velocity (velocity at watershed outlet, ft/sec);
3. Recreation:
    1. Fishing/boating (total annual, user days);
    2. Picnicking/other (total annual, user days);
    3. Hiking/biking (total annual, user days);
    4. Lake habitat (lake area in watershed, acres);
4. Economic development:
    1. Business disruption (index, 0 to 1);
    2. Real estate costs (half of stormwater retention costs, dollars);
    3. Implementation cost (total cost, dollars);
    4. Creek-side economic activity (index, 0 to 1;
5. Flood control;
    1. Flood protection (expected annual damage, dollars);

6. High quality of life:
    a. Aesthetics (willingness to pay, dollars);
    b. Green space (area in watershed, acres).

Decision criteria and criteria values are discussed in more detail in *Section 4.9*.

4.6 Determination of Applicable Technologies and Best Management Practices

To achieve the Papillion Creek watershed goals discussed in *Section 4.4*, applicable technologies and Best Management Practices (BMPS) were selected based, in general, on the standard of practice and a wide-range of government agency and academic sources (see Gupta, 2001 and Novotny, 1994). In practice, the following technologies and/or BMPs could be incorporated alone or in combination into watershed management alternatives:

1. Water quality:
    a. Implement CSO (sanitary and storm sewers) outflow separation;
    b. Construct CSO storage;
    c. Implement CSO disinfection;
    d. BMPs for agricultural land:
        i. Install fence to keep livestock from entering creek and water bodies;
        ii. Construct upland runoff catchments (e.g., ponds, constructed wetlands) for fields and feedlots;
    e. BMPs for urban and suburban land:
        i. Implement and/or continue street/parking lot cleaning;
        ii. Implement education/management programs for fertilizers and pesticides;
        iii. Implement and enforce pet manure control;

        iv. Construct improvements such as terracing and grassed waterways;
        v. Install buffer strips (grass and trees) along waterways and creeks;
        vi. Use pervious surfaces and retention ponds for stormwater;

2. Habitat:
    a. Riparian:
        i. Install linear parks along creeks;
        ii. Install forested or grass buffer strips along creeks and waterways;
        iii. Allow/encourage stream banks to develop natural structure and vegetation rather than having a “bare” levee or cropped land next to stream;
    b. Aquatic:
        i. Restore meanders where stream has been straightened;
        ii. Increase plant cover for aquatic species (both in stream and bank);
        iii. Restore bottom substrate to natural conditions by reducing sediment load;
        iv. Restore hydrology by controlling runoff from agricultural and urban areas;

3. Recreation:
    a. Create reservoirs at appropriate locations;
    b. Improve water quality:
        i. Reduce sediment load;
        ii. Reduce nutrient load;
        iii. Reduce bacteria load (agricultural, suburban, CSO);

    c. Provide fishing facilities in parks:
    d. Provide canoeing/boating facilities;
    e. Create parks near creeks;

4. Economic development:
    a. Foster agricultural production use of watershed;
    b. Foster real estate development in watershed;
    c. Provide recreational opportunities and related businesses;
    d. Provide nice community for workforce to live (aesthetics, parks, water recreation);

5. Flood control:
    a. Provide bank stabilization to improve flood flow;
    b. Develop higher levees to increase flood protection in low areas;
    c. Build previously planned flood control dams;
    d. Build storage basins (i.e., low areas that will be intentionally flooded during flood events. These basins could be used for other purposes such as parks at other times);
    e. Build storm water retention facilities for developed areas;
    f. Build storm water retention facilities for new developments;
    g. Install buffer strips to reduce runoff and increase infiltration;
    h. Keep development (urban and agricultural) out of natural flood plains – move development from flood plains;
    i. Build farm ponds and constructed wetland areas to collect runoff;

6. High quality of life:
    a. Maintain and enhance property values by providing parks, trails, water access;
    b. Maintain flood control;

c. Provide aesthetically pleasing creek areas;
d. Provide green space;
e. Maintain economic development;

4.7 Assessment of Watershed Conditions

4.7.1 *Pre-development Conditions*

Pre-development conditions were estimated to derive a “base-line” to which subsequent alterations to this watershed could be compared. For example, the slope of the Papillion Creek has increased due to stream channelization. The change in slope and its effects caused by new management alternatives is more properly assessed by comparison to natural conditions than to current conditions. Attempts were made to establish pre-development conditions, including flora and fauna, aquatic habitat and species, and channel morphology. Lewis and Clarks’ journals, dated 1804, were consulted (Moulton, 1986). Library research found reports from the late nineteenth century that reported on conditions found across Nebraska, including the Papillion Creek region (Aughey, 1880; Hayden, 1873; Hayden, 1876).

Early stream morphology was estimated from maps found at the Nebraska State Historical Society, both hard copy and microfiche, and from CD versions of land survey maps created by the Nebraska State Land Surveyors office. In addition, Dr. Vince Dreeszen, a hydrogeologist at the University of Nebraska Conservation and Survey Division provided two United States Geological Survey (USGS) maps, dated 1897, that covered the Papillion Creek watershed area.

Attempts were made to incorporate early aerial photographs to evaluate morphology and land use. The photos were not used due to the lack of aerial photos from pre-development years. Stream flow data and other records from the USGS are very limited. The USACE had information mostly in the form of HEC-RAS data files. Unfortunately, the validity and reliability of the USACE data was questionable due to inconsistent monitoring and the flashy nature of the Big Papillion Creek and tributaries.

Government and agency intervention in the watershed, primarily for flood control and channelization, was documented using reports published by the Papio-Missouri River NRD, USACE, and Soil and Water Conservation Districts (Sarpy Soil, 1964; Sarpy Soil, 1966; U.S. Army Corps. of Engineers, 1975; Omaha-Council Bluffs, 1980; Papio Natural, 1981).

4.7.2 *Topography and Land Use*

The northern region of the watershed consists of rolling hills with moderate to steep slopes. The southern region has more gentle slopes, with a widening flood plain. The bluffs bordering the Elkhorn River and Missouri River form the western and eastern edges of the watershed, respectively.

The surface elevation at the mouth of Big Papillion Creek is approximately 950 feet above mean sea level (MSL). The highest surface elevation is approximately 1,335 feet above MSL near the headwaters of Big Papillion Creek, for a total relief of 385 feet. The surface elevation at the upper reach of Little Papillion Creek is approximately 1,340 feet above MSL, for a total relief of 390 feet. Within the urban area, the topography has been modified from historical conditions by construction and development, both commercial and residential.

Figure 4.2 shows the land use distribution across the watershed, generated with EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) software using EPA land use data provided with the BASINS package (see *Section 4.9.2* for further discussion of BASINS). Land use classifications follow Level Two Classification after Anderson, et al. (1972) (United States. Environmental Protection Agency, 1997; United States Environmental Protection Agency, 1998).

4.7.3 *Climate*

Average annual precipitation at Omaha is about 30.00 inches (National Climatic Data Center, 2002). Maximum-recorded annual precipitation was 48.90 inches in 1883. The minimum was 14.90 inches in 1934. Most precipitation is from high intensity and short duration thunderstorms. Average growing season length is about 170 days, with 75 percent of the precipitation occurring during this time (Sarpy Soil and Water Conservation District, 1964).

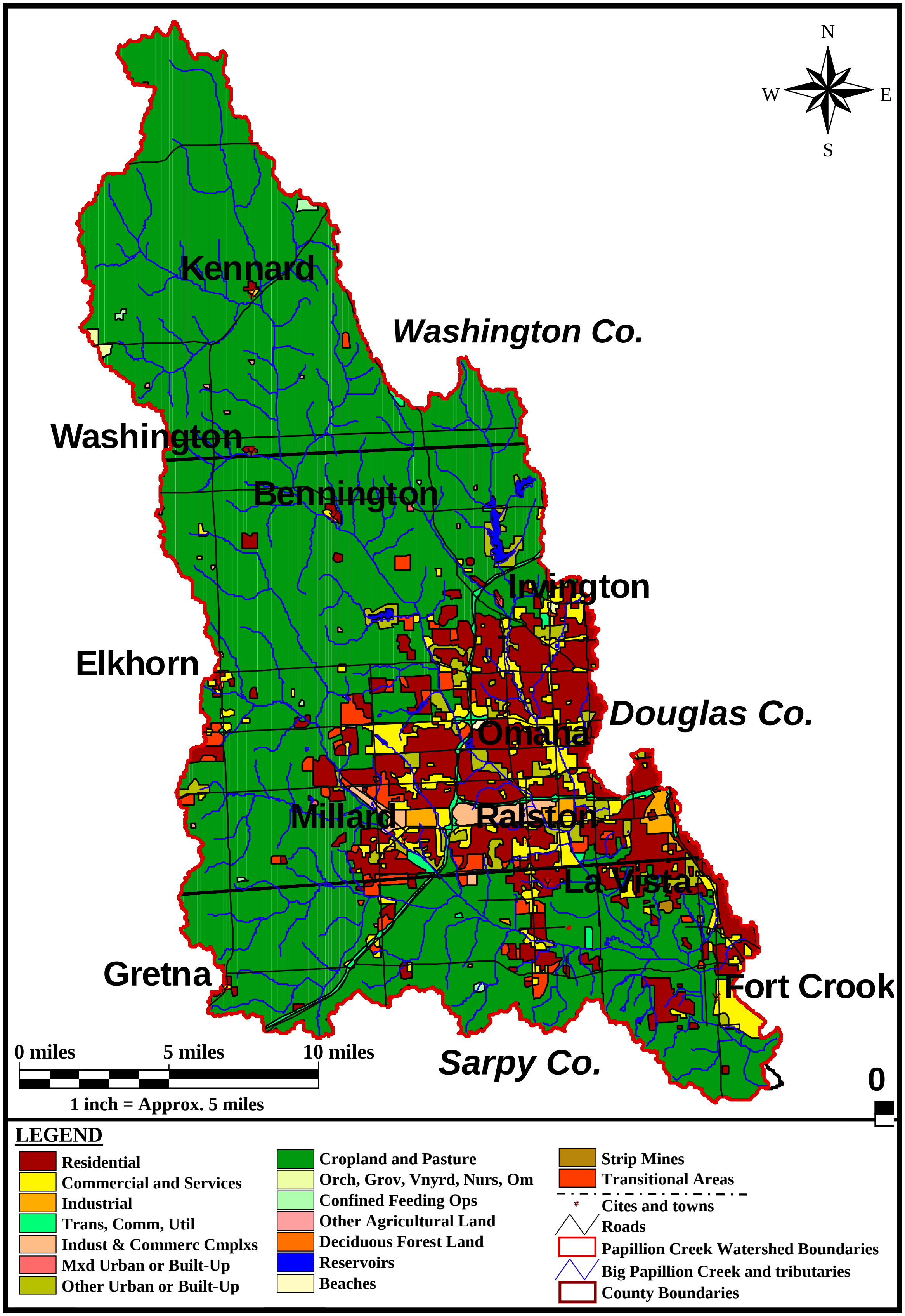


Figure 4-2. Land-use distribution map.

4.7.4 *Stream Characteristics*

4.7.4.1 Slope

Historical stream slopes were determined from USGS maps dated from 1893. The average slope from Big Papillion Creek at Kennard to the confluence with Little Papillion Creek was estimated at approximately 0.001 ft/ft. The average slope of the Little Papillion Creek from approximately one mile south of the Washington and Douglas County line to the confluence with the Big Papillion Creek was estimated at approximately 0.002 ft/ft. Current slopes appear to be greater than the historical slopes indicated by the 1893 map. Slopes measured from 1997 EPA R3 stream data with the global information system (GIS) program ArcView™, ranged from approximately 0.002 ft/ft to 0.003 ft/ft for the upper Big Papillion Creek, and averaged approximately 0.0034 ft/ft for the Little Papillion Creek.

4.7.4.2 Morphology

From early maps, it appears that Papillion Creek meandered, following a typical stream path in deep alluvium/colluvium. Over the last century, much of the Papillion Creek has been channelized, primarily for flood control and to increase available agricultural land. The shape of the channel has also been modified from overhanging banks to straight-sided banks designed to move flood waters. The result is higher stream velocity and increased bank erosion and bed scouring.

Historical flow regimes in the prairie had high infiltration rates, leading to a high baseflow and low runoff. Current flow regimes have low infiltration due to a higher amount of impervious area, leading to lower baseflow and higher runoff. Current flow regimes have lead to more influence of precipitation events, higher sediment and contaminant loads in the stream, and increased potential for floods.

4.7.4.3 Stream Bed Substrate

Throughout the Papillion Creek watershed, the stream bed substrate generally consists of silty clay alluvium/colluvium deposited at the base of the loess slopes. In some localized areas, the alluvium/colluvium soil may contain varying amounts of sand and fine gravel. In some areas of the northern watershed, it may be possible to find substrate consisting of Kansan till, with sand, assorted size gravel and rock.

4.7.5 *Aquatic Biota*

4.7.5.1 Macro-Invertebrates

As is common in most watersheds, historical records of macro-invertebrates have not been maintained for this watershed. Some historical perspective may be gained from the literature (see Cross, 1987, and Matthews, 1988).

At the time of this investigation, preliminary results of a study conducted by Richard Staziak at the University of Nebraska-Omaha results showed a degraded macro invertebrate population. The degradation was likely caused by a combination of stream bed siltation and water quality changes.

4.7.5.2 Fish

Due to insufficient historical records, a comprehensive list of historical fish populations is most likely not available. Aughey (1880) records several species and their habitat from 1880. Although the reviewed records did not directly list the Papillion Creek, inferences can be made from the nearby Elkhorn River. These fish include several species of catfish, pond fish (pomotis vulgaris), minnow, and gar pike (Aughey, 1880). Aughey's list is not comprehensive enough to establish a baseline for comparison to current conditions.

Shallow conditions, likely caused by decreased baseflow in the modern-day Big Papillion Creek system, do not support significant game fish populations, except in the southern reaches near the mouth of Big Papillion Creek. At the time of this study, the Nebraska Game and Parks Commission stocked rainbow trout in Standing Bear Lake and walleye in Wehrspann Lake. Other species identified in the reservoirs of the Papillion Creek basin included black bullhead, black crappie, bluegill, channel catfish, common carp, freshwater drum, largemouth bass, rainbow trout, redear sunfish, walleye, white bass, white crappie, and yellow perch.

4.7.6 *Habitat Assessment*

A *Habitat Assessment* was designed and performed to establish a baseline for habitat conditions in the watershed at the time of the study. Data from the *Habitat Assessment* was to be used to model the watershed and provide riparian and aquatic habitat information to evaluate the management alternatives. The *Habitat Assessment* was designed to quickly assess and collect data from each location, including weather conditions, channel information, structures at the site, and biological communities, including riparian and aquatic habitat. A six-page *Field Observation Sampling Sheet* was developed to facilitate data collection for the *Habitat Assessment*, and included an adapted bioassessment protocol described in *Section 4.7.6.1*. A blank *Field Observation Sampling Sheet* and examples of completed field sheets are provided in *Appendix D*.

4.7.6.1 *Bioassessment*

To assess riparian and aquatic habitat, a bioassessment protocol and forms were developed. Bioassessment protocols (*Bioassessment*) were adapted, with some modifications, from *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (RBP), developed and published by the EPA (1999). From the RBP, the following ten "Habitat Parameters" were selected for this study.

1. Epifaunal substrate/available cover:
2. Pool substrate characterization;
3. Pool variability;
4. Sediment deposition;
5. Channel flow status;
6. Channel alteration;
7. Channel sinuosity;
8. Bank stability;
9. Vegetative protection;
10. Riparian vegetative zone width.

To estimate relative conditions for the Big Papillion Creek, tributaries, and watershed, four "Condition Categories," designated *Optimal, Suboptimal, Marginal,* and *Poor*, along with corresponding, parameter-specific descriptions were adapted from the RBP and included in the *Bioassessment* for each "Habitat Parameter" (United States. Environmental Protection Agency, 1999). Each "Condition Category" was assigned numerical values, ranging from one (1) to 20 or zero (0) to ten (10), depending on the "Habitat Parameter." The purpose of assigning numerical values to the "Condition Categories" was to facilitate refinement of relative condition estimates and determine numerical "scores" for individual "Habitat Parameter" conditions and overall score for each location to be used for data analysis.

Specifically, the ranges of numerical values for each “Condition Category” were assigned to the listed “Habitat Parameters” as follows:

1. Epifaunal substrate/available cover; Pool substrate characterization; Pool variability; Sediment deposition; Channel flow status; Channel alteration; and Channel sinuosity:
    a. *Optimal*: 20 to 16;
    b. *Suboptimal*: 15 to 11;
    c. *Marginal*: 10 to 6;
    d. *Poor*: 1 to 5.
2. Bank stability (left and right banks assessed); Vegetative protection (left and right banks assessed); and Riparian zone width (left and right banks assessed):
    a. *Optimal*: 10 to 9;
    b. *Suboptimal*: 8 to 6;
    c. *Marginal*: 5 to 3;
    d. *Poor*: 3 to 0.

The final *Bioassessment*, including “Habitat Parameters,” corresponding “Condition Categories” and descriptions, were included in the *Habitat Assessment* and incorporated into the previously discussed *Field Observation Sampling Sheet*.

To estimate Manning’s frictional coefficient *n* (Manning’s *n*) to calibrate proposed computerized watershed model, a method was developed to correlate Cowan’s (1956) estimation of hydraulic roughness coefficients to *Bioassessment* data. The method adapted four channel parameters (character of channel, degree of irregularity, relative effect of obstructions, and degree of meander), corresponding conditions, and condition values defined by Cowan to correlate with four “Habitat Parameters” (channel substrate, bank stability, epifaunal substrate, and channel sinuosity), and the corresponding “Condition Categories” previously discussed in this *Section*. Based on Cowan, a parameter designated “channel vegetation height,” and corresponding “Condition Categories,” and descriptions was incorporated into the *Habitat Assessment*. Adapted from Cowan, individual parameters were assigned a variable, and “Condition Categories” were assigned a range of values. After determining values for individual parameter variables, Manning’s *n* was calculated using an equation developed by Cowan (1956). A table used to estimate Manning’s *n* and containing parameters, conditions, variables, values, and Cowan’s equation, is included in the *Field Observation Sampling Sheet* provided in *Appendix D.*

4.7.6.2 Habitat Assessment: Field Work and Results

Field work for the *Habitat Assessment* was performed in June 2000 by Reed Colton and Pam , using the previously discussed *Field Observation Sampling Sheet.* The field work consisted of assessing more than ninety sites throughout the Papillion Creek watershed, generally located where Big Papillion Creek and tributaries crossed section lines and that were accessible by paved or unpaved roads, which included back roads, county roads, city streets, and highways. Each location was photographed to document site conditions for future reference.

Some bias may have been introduced by performing the assessments at bridges, given channel modifications necessary for bridge construction; however, though the potential for bias was evaluated, the amount of bias was considered negligible for the purposes of this study. A compilation of the data collected during the *Habitat Assessment*, including, location specific information (e.g. weather, structures, surrounding land uses), *Bioassessment* data and numerical scores for “Habitat Parameters,” and Manning’s *n* estimations is provided in *Appendix D*. Selected photographs of the Papillion Creek watershed are included with slides from a stakeholder forum presentation provided in *Appendix F*.

4.7.6.3 Riparian and Aquatic Habitat

Numerical "scores" from "Condition Categories" and other *Habitat Assessment* data were used to generate maps using BASINS software. The maps, provided as *Figures 4.3* (*Estimated aquatic habitat conditions for the Papillion Creek watershed*), and *4.4* (*Estimated riparian zone widths for selected Papillion Creek reaches*), indicate general riparian and aquatic habitat conditions at the time of the *Habitat Assessment*. Based on *Habitat Assessment* data, it appears that the majority of the channels in the Papillion Creek basin have been modified and/or straightened, resulting in riparian and aquatic habitat conditions that were estimated to have "Condition Categories" of *Marginal* to *Poor* in most areas. Conversely, it should be noted that areas of wilderness preserve located north of Cunningham Lake were estimated to be in the *Optimal* range, and an undeveloped area along the West Branch of the Papillion Creek that was estimated to be in the *Suboptimal* range.

4.8 Development of Potential Management Alternatives

Alternatives were developed to meet the identified watershed goals. Since the watershed goals are sometimes in conflict, each alternative satisfies different goals to various levels. The alternatives consist of combinations of technologies (see *Section 4.5*) designed to satisfy specific watershed goals. The alternatives were based, in part, on current watershed plans developed by various agencies in the watershed. (Papio-Missouri, 1999; HDR, 1999; American Public, 1998; Papio Natural, 1977).

As discussed in *Section 4.6*, technologies for the various alternatives were selected by the investigation team to meet the watershed goals. Four alternatives were developed to provide a small workable number of alternatives that covered the spectrum of watershed issues and goals (i.e., environmental, development, recreational, and flood control issues). The cost details included with the management alternatives are rough estimates, for comparison only. Alternatives and details are outlined in the sections that follow.

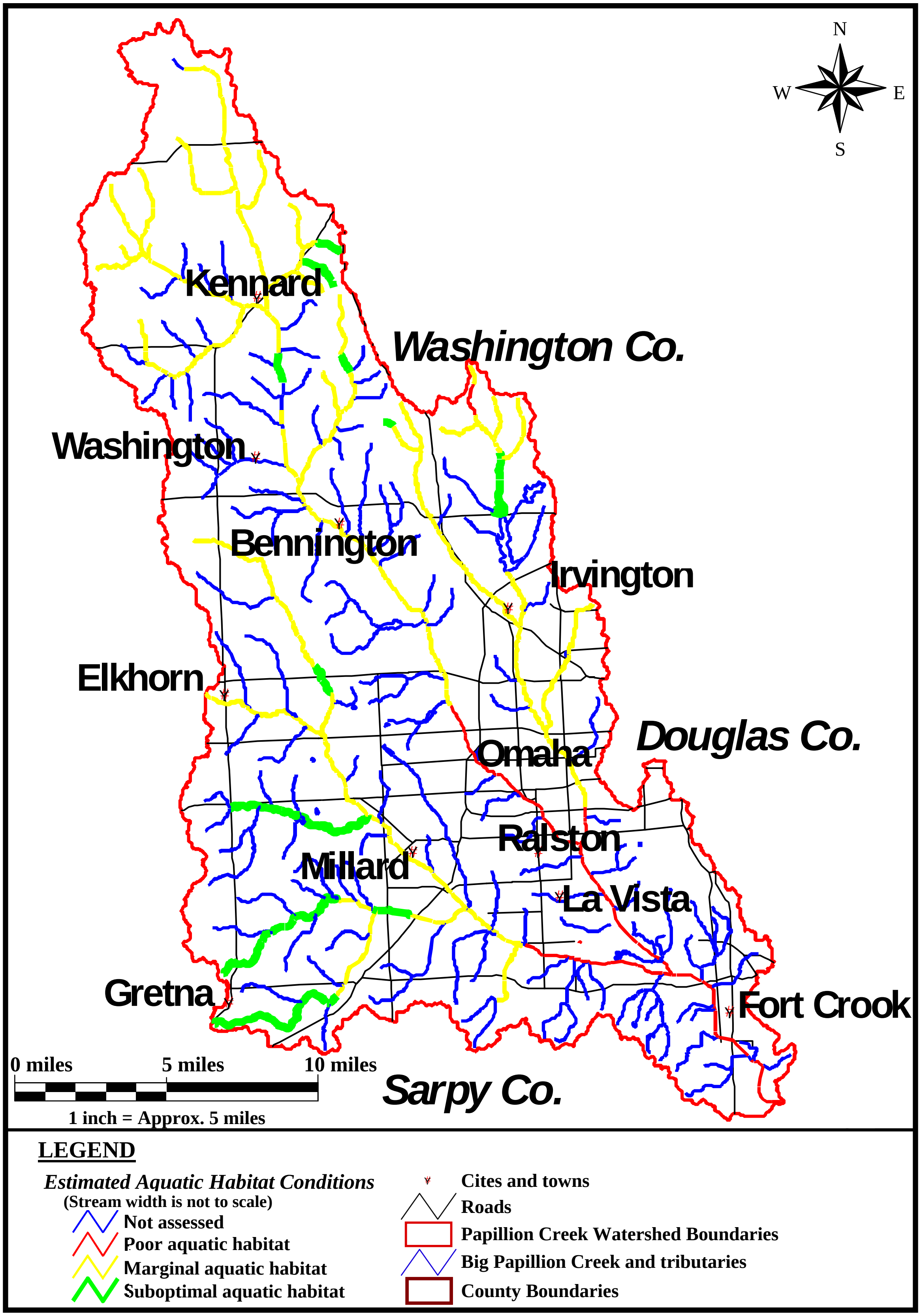


Figure 4-3. Estimated aquatic habitat conditions for the Papillion Creek watershed.

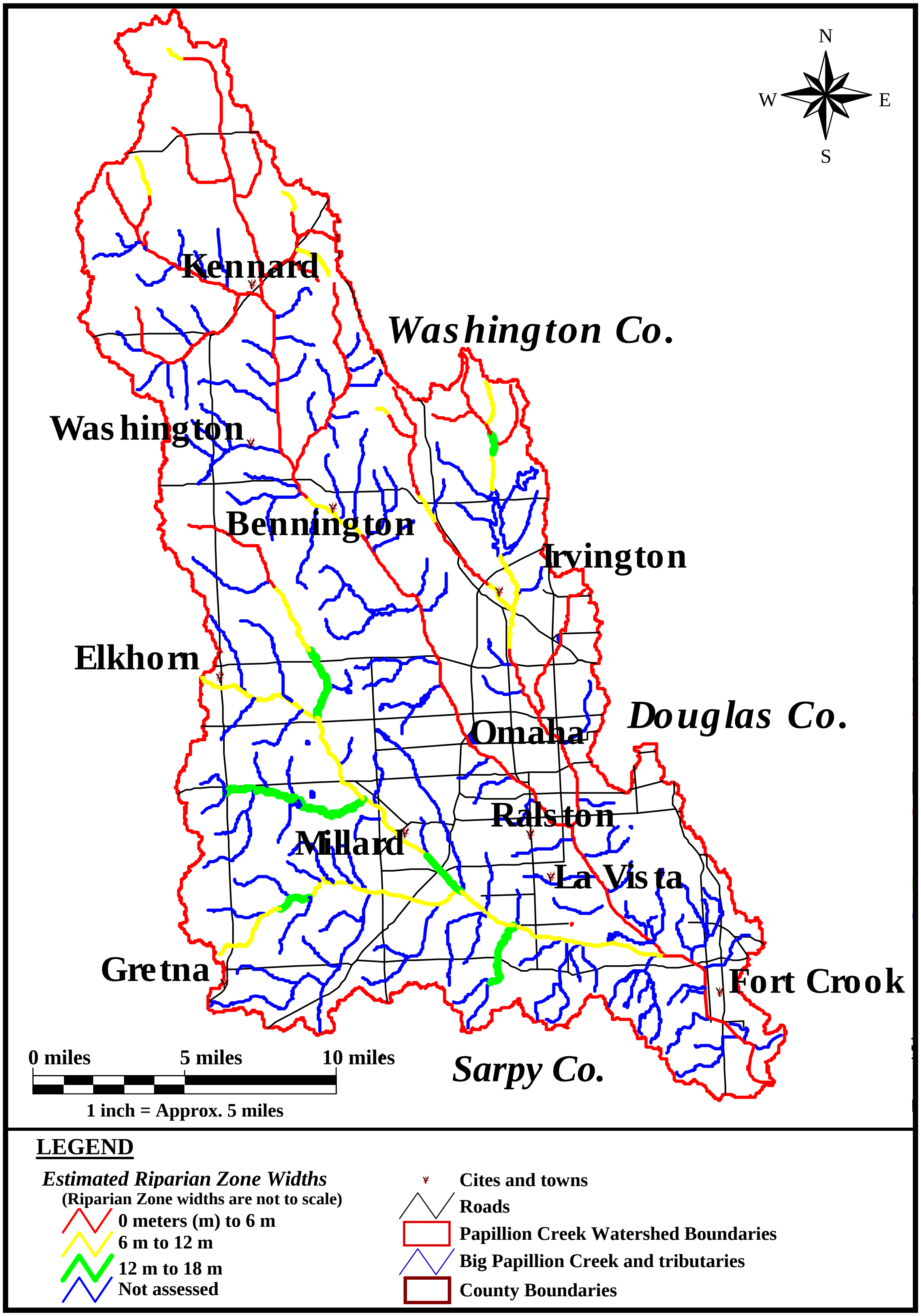


Figure 4-4. Estimated riparian zone widths for selected Papillion Creek reaches.

4.8.1 *Alternative 1: Environmental Focus*

This **Alternative** is designed to restore “natural” ecological and hydrological conditions in and near the creek. The technologies are designed to improve water quality, provide wildlife habitat, and reduce peak flows in the creek. Cost information was included for later comparison of the management alternatives. More discussion on costs can be found in *Sections 4.9.4.12* and *4.9.4.13*.

1. Install buffer strips (grass and trees) on perennial and intermittent streams. Buffer strips provide land and water habitat and filter sediments, excess nutrients and bacteria from runoff before it reaches the stream:
    a. 100 feet per side for perennial streams:
        i. 132 linear miles of stream at 100 feet wide per side (6,273 acres);
        ii. Cost:
            1. Land acquisition and/or easement:
               6,273 acres @ $3,000/acre = $18,819,000;
            2. Buffer installation:
               6,273 acres @ $3,000/acre = $1,881,900;
    b. 75 feet per side for intermittent streams:
        i. 169 linear miles of stream at 75 feet wide per side = 3,072 acres;
        ii. Cost:
            1. Land acquisition and/or easement:
               3,072 acres @ $3000/acre = $9,216,000;
            2. Buffer installation:
               3072 acres @ $300/acre = $921,600;
2. Install planned parks along creek. The parks will provide green space, recreation opportunities, and function as buffer strips:
    a. Tranquility Nature Preserve:

      i. 120th and Fort to 156th and Bennington Road;
      ii. Cost: no additional cost; project is currently planned by city;
   b. Cunningham Nature Preserve:
      i. 96th and Bennington Road to 96th and Dutch Hall Road;
      ii. Cost: no additional cost; project is currently planned by city;
   c. Nature preserve:
      i. Near Kennard at confluence of the NW Branch and Big Papillion Creek;
      ii. Cost:
         1. Land: 320 acres @ $4000/acre = 1,280,000;
         2. Development: assume $3000/acre = $960,000;

3. Install grade control structures to restore hydraulic gradient where natural meanders have been removed (i.e., where streams have been channelized and straightened). Restoring the natural hydraulic gradient will slow water in the stream, improving aquatic habitat and decreasing stream-bank erosion:
   a. Assume 20 grade control structures will be installed throughout the watershed;
   b. Cost: $30,000 per structure = $600,000;

4. Install bank stabilization structures to manage lateral stream migration and reduce sediment load to stream from bank erosion:
   a. Assume 20 bank stabilization structures will be installed throughout the watershed;
   b. Cost: $30,000 per structure = $600,000;

5. Move levees back to 500 feet per side where development allows. This will provide terrestrial (land) habitat, improve aquatic habitat, and improve flood control by allowing flood water storage:

  a. Assume seven linear miles of stream treated: four miles on the Big Papillion Creek between Harrison Street and Highway 370, and three miles from 72nd Street to 36th Street on the West Branch;
  b. Cost:
    i. Land acquisition and/or easement:
      848 acres @ $5000/acre = $4,240,000;
    ii. Construction:
      7 miles @ $1,000,000 per mile = $7,000,000;

6. Implement BMPs for agricultural land. Currently, approximately 40% of the agricultural land is in need of further conservation management treatment. BMPs for the watershed land include fencing livestock out of waterways, terracing steep cultivated land, planting waterways to grass, implementing conservation tillage, installing farm ponds to trap runoff and sediment and to increase infiltration, and installing livestock waste control facilities for feedlot operations. These BMPs reduce runoff and reduce loadings of sediment, excess nutrients, and bacteria to the streams:
  a. Fence livestock from perennial and intermittent streams:
    i. Assume 50 miles of fencing along streams;
    ii. Cost: 50 miles @ $10,000/mile = $500,000;
  b. Install contour terracing:
    i. Assume 3,000,000 feet;
    ii. Cost: 3,000,000 feet @ $1.00/foot = $3,000,000;
  c. Install grassed waterways:
    i. Assume 700 acres;
    ii. Cost: 700 acres @ $2,000/acre = $1,400,000;
  d. Implement conservation tillage practices:
    i. Assume 50,000 acres;
    ii. Cost: 50,000 acres @ $30/acre = $1,500,000;

    e. Install farm ponds:
        i. Assume 20 ponds;
        ii. Cost: $80,000 per pond = $1,600,000;
    f. Install livestock waste control facilities:
        i. Assume four facilities;
        ii. Cost: four facilities @ $10,000/facility = $40,000;

7. Implement BMPs for urban and suburban land. These BMPs reduce runoff and reduce loadings of sediment, excess nutrients, and bacteria to the streams:
    a. Implement street and parking lot cleaning:
        i. Assume already planned and/or implemented by the city;
        ii. Cost: no additional cost;
    b. Implement chemical application education:
        i. Public service announcements, elementary school presentations;
        ii. Cost: $10,000/year;
    c. Install stormwater retention systems for established developments:
        i. Current development in watershed = 90 square miles;
        ii. Install stormwater retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of approximately 153,000 ft^3 will be required;
        iii. Cost: assume $50,000 each; 45 square miles x 4 x $50,000 = $9,000,000;

8. Install storage/disinfection facilities for CSOs in the Papillion Creek watershed:

a. Decrease loadings of excess nutrients, organic matter and bacteria to the creek;
b. Cost: $10,000,000.

4.8.2 *Alternative 2: Development Focus*

This **Alternative** represents the prevalent current function of the watershed. The creek system is used primarily as a conduit to remove runoff and flood waters. The use of the land for agriculture and urban development is emphasized.

1. Foster real estate development (no new controls):
    a. Assume additional urban development of 45 square miles, primarily in Douglas county west and northwest of Omaha;
    b. Cost: no additional cost;
2. Foster agricultural land use (no new controls):
    a. Assume current agricultural land use on land not converted to urban developments;
    b. No additional cost;
3. Make channel improvements to improve flood control:
    a. Channelize, stabilize, and add levees:
        i. Big Papillion Creek from Center Street to Fort Street. Cost: $7,900,000;
        ii. West Branch from 90th Street to Lake Zorinsky outlet. Cost: $4,800,000;
    b. Raise established levees to restore 100 year flood protection:
        i. Established levees are: L Street to confluence with Missouri River for the Big Papillion Creek and 90th Street to confluence with the Big Papillion Creek for the West Branch;
        ii. Assume 24 miles @ $400,000/mile Cost: $9,600,000.

4.8.3 *Alternative 3: Recreational Focus*

This **Alternative** is designed to maximize recreational opportunities in the watershed.

1. Build Dam 3:
    a. Big Papillion Creek, near 180th Street and Washington, Douglas County line);
    b. Cost: $20,000,000;
2. Build Dam 12:
    a. West Branch, near 216th Street and West Maple Road);
    b. Cost: $3,000,000;
3. Build Dam 13:
    a. West Branch, near 192nd Street and Blondo Street;
    b. Cost: $3,000,000;
4. Install linear park system. The linear parks planned by Douglas County plus similar parks in Sarpy and Washington (linear parks and trails for perennial streams):
    a. Tranquility Nature Preserve:
        i. 120th Street and Fort Street to 156th Street and Bennington Road;
        ii. Cost: no additional cost; project is currently planned by city;
    b. Cunningham Nature Preserve:
        i. 96th Street and Bennington Road to 96th and Dutch Hall Road;
        ii. Cost: no additional cost; project is currently planned by city;

- c. Nature preserve near Kennard:
    - i. At confluence of the NW Branch and Big Papillion Creek;
    - ii. Cost:

      Land: 320 acres @$4,000/acre = $1,280,000

      Construction cost: assume $1,500/acre = $480,000;
- d. Hiker/biker paths along creeks (assume 50 miles of additional trails):
    - i. Hiker/biker paths to headwaters of : Little Papillion Creek, Thomas Creek, Big Papillion Creek, West Branch, and North Branch of West Branch;
    - ii. Assume 50 miles of additional trails;
    - iii. Cost: $150,000/mile x 50 miles = $7,500,000;

5. Implement BMPs for agricultural land. Currently, approximately 40% of the agricultural land is in need of further conservation management treatment. BMPs for the watershed land include fencing livestock out of waterways, terracing steep cultivated land, planting waterways to grass, implementing conservation tillage, installing farm ponds to trap runoff and sediment and to increase infiltration, and installing livestock waste control facilities for feedlot operations:
    - a. Fence livestock from perennial and intermittent streams:
        - i. Assume 50 miles of fencing along streams;
        - ii. Cost: 50 miles @ $10,000/mile = $500,000;
    - b. Install contour terracing:
        - i. Assume 3,000,000 feet of contour terracing;
        - ii. Cost: 3,000,000 feet @ $1.00/foot = $3,000,000;
    - c. Install grassed waterways:
        - i. Assume 700 acres of grassed waterways;
        - ii. Cost: 700 acres @ $2,000/acre = $1,400,000;

  d. Implement conservation tillage practices:
    i. Assume 50,000 acres;
    ii. Cost: 50,000 acres @ $30/acre = $1,500,000;
  e. Install farm ponds:
    i. Assume 20 ponds;
    ii. Cost: $80,000 per pond = $1,600,000;
  f. Install livestock waste control facilities:
    i. Assume four facilities;
    ii. Cost: four facilities @ $10,000/facility = $40,000;

6. Implement BMPs for urban and suburban land. These BMPs reduce runoff and reduce loadings of sediment, excess nutrients, and bacteria to the streams:
  a. Implement street and parking lot cleaning:
    i. Already planned or implemented by the city;
    ii. Cost: no additional cost;
  b. Implement chemical application education:
    i. Public service announcements, school presentations;
    ii. Cost: $10,000/year;
  c. Install stormwater retention systems for established developments:
    i. Current development in watershed = 90 square miles;
    ii. Install stormwater retention systems to store increased runoff caused by development for the 10-year flood;
    iii. For each quarter section developed, a retention volume of approximately 153,000 cubic feet will be required;
    iv. Cost: assume $50,000 each; 45 square miles x 4 x $50,000 = $9,000,000;

4.8.4 *Alternative 4: Flood Protection Focus*

This **Alternative** is designed to provide a high level of flood control for the watershed. It uses conventional flood control methods such as dams, levees, and channel improvements.

1. Build Dam 1, near Kennard:
   Cost = $20,000,000;
2. Build Dam 2, near Kennard:
   Cost = $20,000,000;
3. Build Dam 3, near 180th and Washington, Douglas county line:
   Cost = $20,000,000;
4. Build Dam 4, near 168th Street and Washington, Douglas county line:
   Cost $15,000,000;
5. Build Dam 12, near 216th and West Maple Road:
   Cost = $3,000,000;
6. Build Dam 13, near 192nd and Blondo:
   Cost = $3,000,000;
7. Make channel improvements to improve flood control:
   a. Channelize, stabilize, and add levees:
      i. Big Papillion Creek from Center Street to Fort Street:
         Cost = $7,900,000;
      ii. West Branch from 90th Street to Lake Zorinsky outlet:
         Cost = $4,800,000;
   b. Raise established levees to restore 100-year flood protection:
      i. Established levees are: L Street to confluence with Missouri River for the Big Papillion Creek and 90th Street to confluence with the Big Papillion Creek for the West Branch;
      ii. Assume 24 miles @ $400,000/mile = $9,600,000.

In the spring of 2000, a preliminary list of *Papio Creek Watershed Management Alternatives* (see *Appendix B*) was sent to stakeholders for review and comment. Twelve detailed replies were received, and the results were evaluated and tabulated. Stakeholder reviews and comments are found in *Appendix C, Papio Creek Community Benefit Survey and Results*. Stakeholder input was considered in the final revision of the management alternatives found in this section.

4.9 Determination of Decision Criteria Values for Management Alternatives

Several methods were used to determine the criteria values for different alternatives. Criteria related to public perception and benefits (real estate costs, creek-side economic activity, business disruption, fishing/boating, picnicking, hiking/biking, green space, and aesthetics) were determined from the literature and from a stakeholder survey titled *Papio Creek Community Benefit Survey*, which is discussed in detail in *Section 4.9.1* and provided in *Appendix C.*

In order to determine the remaining criteria values, an attempt was made to model the watershed and alternatives using HSPF through BASINS. However, the amount of data available for the watershed was determined to be inadequate to support the HSPF model through BASINS Therefore, simpler deterministic relationships were used with the available data and literature values to predict criteria values (see *Section 4.9.2*).

4.9.1 *Papillion Creek Community Benefit Survey*

The *Papio Creek Community Benefit Survey* was designed to gather information from stakeholders to determine, or provide a basis for, criteria values including real estate costs, creek-side economic activity, business disruption, fishing/boating, picnicking, hiking/biking, green space, and aesthetics.

Five hundred copies of the survey (along with pre-paid business return envelopes) were distributed throughout the watershed area. The survey (see *Appendix C*) was designed to incorporate travel cost questions regarding the complementary costs of visiting the Papillion Creek streams and lakes (driving distance and frequency, gear costs, etc.). In addition, the survey mimicked a hedonic valuation study with questions regarding housing and rental prices, attempting to correlate housing price to Papillion Creek proximity, and a contingent valuation study using "willingness to pay" questions to relate water quality improvements to "willingness to pay". The objective was to link travel cost survey responses with housing value and willingness to pay values to cross-verify responses and to construct more meaningful estimates of public value of the watershed.

The survey was field tested prior to distribution, and found to elicit sensible responses from respondents, with some minor adjustments. Survey response was far lower than anticipated, with 48 total responses returned. Surveys distributed personally at Papillion Creek sites were observed to have higher response rates than surveys delivered at stores and parking lots. Since response rates were highest for surveys distributed at Papillion Creek recreation sites, responses were most likely be biased toward high estimates of recreational usage. The survey was designed to ask valuation questions from both recreational and housing price perspectives, which aided to reduce response bias from frequent recreational users by providing additional information to verify valuation data. Severe weather during the entire survey distribution period was a major unanticipated problem. Omaha experienced its fifth coldest winter on record, from early in the fall, 2000, to the late spring 2001. The low response rate may be due, in part, to the weather. Because of the low response rate, survey results were used only as a guideline, along with other data, for estimating decision criteria values.

4.9.2 *BASINS*

BASINS is a suite of GIS tools and watershed related computer models designed and distributed by the EPA for compiling and evaluating watershed data. BASINS is also used to evaluate watershed management alternatives, once the current conditions have been modeled.

BASINS was originally proposed for use in this study to model the management alternatives. The GIS tools within BASINS were used to create pertinent maps and compile geographical information and other data for the watershed. The investigative team for this study chose, however, not to use the BASINS watershed related models to evaluate management alternatives due to the small amount of available data for the Papillion Creek watershed. It should be noted that the amount of available watershed data may inhibit proper watershed model calibration.

4.9.3 *Literature Values*

Literature values were used to determine loading factors, discharge indices, and indices for the decision criteria values. Due to the nature of the study, it was decided that extrapolating decision criteria values from the literature would adequately provide information to the stakeholders. In actual application, comparison of management alternatives would likely require the use of computer models and GIS to provide a more accurate assessment of watershed conditions for analysis. This would, in turn, require a significant data collection effort for watersheds like Papillion Creek.

4.9.4 *Justification of Decision Criteria Values*

4.9.4.1 Lake Habitat

The lake habitat criterion represents the available habitat for aquatic species that rely on non-running water. The lake habitat criterion values are represented by the total surface area (in acres) of lakes in each proposed alternative. Currently, there are approximately 1,000 acres of lake surface area in the watershed. The lake surface areas for the four potential alternatives range from 1,000 to 3,000 acres.

4.9.4.2 Water Velocity

The water velocity in the creek is an important factor for aquatic habitat and hydraulic issues. Relatively higher water velocities may wash juvenile aquatic species out of their environment, destroy aquatic habitat cover structures, and cause increased stream-bank erosion. Conversely, if water velocities are too low, re-aeration will be limited resulting in low dissolved oxygen concentrations and deposition of fine particulates, which could affect bed substrate conditions and aquatic habitat.

The water velocity criterion is represented by the calculated velocity near the mouth of the watershed for a 2-year storm. The 2-year storm was considered likely to be the “channel-forming” flow at the time of this study, meaning the corresponding water velocity could potentially cause moderate to significant changes in the channel.

The water velocity near the mouth of the watershed for the 2-year flood was estimated as follows. The runoff from the 2-year storm (2.75 inches) was estimated using the Soil Conservation Service (now Natural Resources Conservation Service) runoff method (Gupta, 2001). A spatially weighted average curve number was used based on the relative agricultural and urban areas for each given alternative. For the alternatives that mandate storm water detention, the curve number for urban land was set equal to that for agricultural land (i.e., increased runoff from developed land would be detained, and peak flows would be similar to those expected from agricultural land).

The peak flow near the outlet of the watershed was estimated using the SCS peak-flow equation:

$$q_p = \frac{484 \cdot A \cdot Q}{0.5 \cdot D + 0.6 \cdot T_c} \qquad (4\text{-}1)$$

where:

q_p = peak flow (cfs)
A = watershed area (square miles)
Q = runoff from watershed (in)
D = duration of the rainfall (12 hours)
T_c = time of concentration (h), determined by the equation:

$$T_c = \frac{L^{1.1.5}}{7{,}700 \cdot H^{0.38}} \qquad (4\text{-}2)$$

where:

L = length of longest tributary (ft)
H = elevation drop from ridge to outlet of watershed (ft)

The depth of flow was calculated from the peak flow using Manning’s equation in an iterative manner. Manning’s n values were used to account for differences in stream parameters, such as bank treatments and epifaunal substrate, for the alternatives. For alternatives that did not specify the implementation of BMPs or other applicable technologies, Manning’s n was set to 0.03. For alternatives that specified BMPs or other technologies, such as bank stabilization, Manning’s n was set to 0.1.

The water velocity was then calculated by the continuity equation using the depth of flow and the cross-sectional flow area using the continuity equation:

$$V = \frac{Q}{A} \tag{4-3}$$

where:

V = average water velocity (ft/sec)
Q = flow (cfs)
A = cross-sectional area of flow (ft^2)

4.9.4.3 Substrate Cover

The substrate cover criterion represents the amount and quality of aquatic habitat cover structures in the stream. This is an important variable for aquatic habitat. The *Habitat Assessment* (discussed in *Section 4.7*) was used to establish a baseline for the substrate structure criterion for Aquatic Habitats. The assessment resulted in a range from 0 to 1 where a value of 1.0 represents an excellent aquatic habitat and a value of 0.0 represents “very” poor aquatic habitat compared with historical conditions. Values for each of the management alternatives were estimated based on the baseline, with **Alternatives 1** and **3** increasing substrate cover, and **Alternatives 2** and **4** having no change.

4.9.4.4 Riparian Quantity

The riparian quantity criterion represents the amount of habitat available for riparian species (terrestrial and avian species living along the stream). The riparian quantity criterion is a measure of the area of buffer or woodland along the streams for the various alternatives. Currently, there are approximately 2,560 acres of woodland and grassland along the creeks in the watershed. Buffer strips along the entire creek system (as in **Alternatives 1** and **3**) would cover 13,185 acres.

4.9.4.5 Riparian Connectivity

The connectivity of the riparian habitat is important to riparian species because it allows migration along the stream. Discontinuities in the riparian zone significantly reduce the ability of these species to utilize the habitat. The riparian connectivity criterion is represented as the ratio of length of buffer to total stream length resulting in possible criterion values from 0.0 to 1.0 where 0.0 indicates no connectivity (no riparian zone), and 1.0 represents a completely continuous riparian zone along the creeks in the watershed.

4.9.4.6 Coliform Bacteria

Coliform bacteria concentrations are an important measure of the water quality in a watershed. Coliform bacteria concentrations represent the degree to which a stream is impacted by animal manure and/or human sewage. Since pathogenic organisms (bacteria and viruses) may also be present where coliform bacteria are present, coliform bacteria concentrations are important indicators of the potential for a water body to pose health hazards to those who come into contact with the water.

The coliform bacteria criterion is represented by a discharge index. The discharge index represents the fraction of coliform bacteria that are likely to be discharged to the Papillion Creek given the management practices for the various alternatives compared to the amount that are being discharged without those management practices. That is, the current discharge rate of coliform bacteria to the creek is considered 1.0, and an alternative with management practices that would reduce the discharge by 25% would have a discharge index of 0.75. The discharge index is calculated as:

$$DI = (1 - r_1) \cdot (1 - r_2) \cdot (1 - r_3) \cdot \ldots \cdot (1 - r_n) \qquad (4\text{-}4)$$

where:

DI = Discharge Index (fraction)

r_n = removal factor for technology n (fraction)

The removal factor, r_n, is the fraction bacteria removed by the technology. These factors, estimated from literature values, are provided in *Table 4-1*.

Table 4-1. Removal factors for bacteria.

Applicable Technology for Decision Criteria	Removal Factors	Alternative 1 Environment	Alternative 2 Development	Alternative 3 Recreation	Alternative 4 Flood Control
Buffer strips	0.2	0.2	0	0	0
Parks	0	0	0	0	0
Grade control/sediment traps	0	0	0	0	0
Bank stabilization	0	0	0	0	0
Move levees back	0	0	0	0	0
Livestock fencing	0.1	0.1	0	0.1	0
Terraces	0	0	0	0	0
Grassed waterways	0.01	0.01	0	0.01	0
Conservation tillage	0.01	0.01	0	0.01	0
Farm ponds	0	0	0	0	0
Livestock waste containment	0.3	0.3	0	0.3	0
Street cleaning	0.05	0.05	0	0.05	0
Chemical education	0.01	0.01	0	0	0
Storm retention – established	0.05	0.05	0	0.05	0
Storm retention – new	0.05	0.05	0	0.05	0
CSO separation	0.3	0.3	0	0.3	0
Channel stabilization	0	0	0	0	0
Raise levees	0	0	0	0	0
Dams	0.05/dam	0	0	0.15	0.3
Discharge Factor		0.29	1	0.31	0.7

4.9.4.7 Nitrogen

Nitrogen, in its several forms, is a nutrient that causes increased plant growth in aquatic systems. When these aquatic plants die and decay, they can significantly reduce the dissolved oxygen in the water that can in turn kill the aquatic animal life. Nitrogen in the Papillion Creek typically comes from fertilizers (agricultural and urban), and animal and human wastes. The nitrogen criterion is represented by a discharge index. The discharge index method is described in *Section 4.9.4.6*. Removal factors for nitrogen are given in *Table 4-2*.

Table 4-2. Removal factors for nitrogen.

	Removal Factors	**Alternative 1 Environment**	**Alternative 2 Development**	**Alternative 3 Recreation**	**Alternative 4 Flood Control**
Buffer strips	0.01	0.01	0	0	0
Parks	0	0	0	0	0
Grade control/sediment traps	0	0	0	0	0
Bank stabilization	0	0	0	0	0
Move levees back	0	0	0	0	0
Livestock fencing	0.05	0.05	0	0.05	0
Terraces	0.01	0.01	0	0.01	0
Grassed waterways	0.01	0.01	0	0.01	0
Conservation tillage	0.01	0.01	0	0.01	0
Farm ponds	0.01	0.01	0	0.01	0
Livestock waste containment	0.3	0.3	0	0.3	0
Street cleaning	0.01	0.01	0	0.01	0
Chemical education	0.01	0.01	0	0.1	0
Storm retention – established	0.05	0.05	0	0.05	0
Storm retention – new	0.05	0.05	0	0.05	0
CSO separation	0.1	0.1	0	0.1	0
Channel stabilization	0	0	0	0	0
Raise levees	0	0	0	0	0
Dams	0	0	0	0	0
Discharge Factor		0.50	1	0.51	1

4.9.4.8 Phosphorus

Phosphorus in its several forms is a nutrient that causes increased plant growth in aquatic systems. When these aquatic plants die and decay, the can significantly reduce the dissolved oxygen in the water which can in turn harm the aquatic animal life. Phosphorus in the Papillion Creek typically comes from fertilizers (agricultural and urban), and animal and human wastes.

The phosphorus criterion is represented by a discharge index, determined by the same method described in *Section 4.9.4.6*. Removal factors for phosphorous are listed in *Table 4-3*.

Table 4-3. Removal factors for phosphorous.

	Removal Factors	Alternative 1 Environment	Alternative 2 Development	Alternative 3 Recreation	Alternative 4 Flood Control
Buffer strips	0.2	0.01	0	0	0
Parks	0.01	0	0	0	0
Grade control/sediment traps	0.01/struct	0	0	0	0
Bank stabilization	0.01/struct	0	0	0	0
Move levees back	0	0	0	0	0
Livestock fencing	0.01	0.05	0	0.05	0
Terraces	0.4	0.01	0	0.01	0
Grassed waterways	0.01	0.01	0	0.01	0
Conservation tillage	0.4	0.01	0	0.01	0
Farm ponds	0.01	0.01	0	0.01	0
Livestock waste containment	0.3	0.3	0	0.3	0
Street cleaning	0.01	0.01	0	0.01	0
Chemical education	0.01	0.01	0	0.1	0
Storm retention – established	0.2	0.05	0	0.05	0
Storm retention – new	0.2	0.05	0	0.05	0
CSO separation	0.1	0.1	0	0.1	0
Channel stabilization	0.01	0	0	0	0
Raise levees	0	0	0	0	0
Dams	0.05/struct	0	0	0	0
Discharge Factor		0.50	1	0.51	1

4.9.4.9 Sediment Load

A high concentration of sediment (suspended particles) in the stream water is an indicator of erosion in the watershed. It can cause damage to aquatic species by covering habitat structures in the stream bottom and by decreasing the ability of aquatic species to visually find food (and avoid becoming food). In addition, high concentrations of sediment cause an accelerated rate of sedimentation in reservoirs thus shortening their effective life span. The sediment load criterion is represented by a discharge index. The discharge index method is described in the Coliform Bacteria criterion section. Removal factors for each alternative are listed in *Table 4-4*.

Table 4-4. Removal factors for sediment.

	Removal Factors	Alternative 1 Environment	Alternative 2 Development	Alternative 3 Recreation	Alternative 4 Flood Control
Buffer strips	0.2	0.2	0	0	0
Parks	0.01	0.01	0	0.01	0
Grade control/sediment traps	0.01/struct	0.2	0	0	0
Bank stabilization	0.01/struct	0.2	0	0	0
Move levees back	0	0	0	0	0
Livestock fencing	0.01	0.01	0	0.01	0
Terraces	0.4	0.4	0	0.4	0
Grassed waterways	0.01	0.01	0	0.01	0
Conservation tillage	0.4	0.4	0	0.4	0
Farm ponds	0.01	0.01	0	0.01	0
Livestock waste containment	0	0	0	0	0
Street cleaning	0.1	0.1	0	0.1	0
Chemical education	0	0	0	0.2	0
Storm retention – established	0.2	0.2	0	0.2	0
Storm retention – new	0.2	0.2	0	0	0
CSO separation	0	0	0	0	0
Channel stabilization	0.01	0	0.01	0	0.01
Raise levees	0	0	0	0	0
Dams	0.05/dam	0	0	0.15	0.3
Discharge Factor		0.10	0.99	0.20	0.69

4.9.4.10 Dissolved Oxygen

The dissolved oxygen concentration in the stream water is important for the health of aquatic species. The dissolved oxygen concentration depends on several factors such as temperature, turbulence of the stream, plants in the water, and chemical constituents in the water (e.g., organic matter and nutrients) that remove dissolved oxygen. The dissolved oxygen in a stream will typically be between 0.0 mg/L and the oxygen solubility of around 10 mg/L. Recent water quality sampling in the Papillion Creek indicates that the dissolved oxygen concentration in the creek in August, critical period for this watershed, is approximately 2.5 mg/L.

The value of the dissolved oxygen criterion was estimated to be 1.0 mg/L for the alternatives that allow further development of the watershed with no concurrent management practices designed to increase dissolved oxygen. The dissolved oxygen criterion was estimated to be 6 mg/L for alternatives that mandate management practices designed to increase dissolve oxygen concentrations (e.g., keeping animal and human wastes and nutrients from the stream).

4.9.4.11 Flood Protection

The flood protection criterion represents the expected annual damage due to flooding in the Papillion Creek watershed. Differences in the values between alternatives account for factors such as increased development (increased impervious area), channel improvements and levee improvements, flood control reservoirs, and storm water detention basins. The values used for this report, which range from $100,000/year for **Alternative 4** to $900,000/year for **Alternative 2**, are only estimates designed to provide a relative range of values and have not been verified.

4.9.4.12 Implementation Costs

Implementation costs are the total costs of the management practices mandated by each alternative. Costs include estimates for land acquisition and construction of the management practices. Operation and maintenance costs were not included. Impacts to land owners (e.g., for converting agricultural land to buffer strips) were not included as a "cost" because these impacts were assumed to be accounted for in the purchase price.

Only one-half of the estimated cost of storm water detention basins is included in this criterion because it was assumed that half of this cost would be borne by the developer; that cost is included in the "Real Estate Cost criterion". The costs of the management practices as they are applied to the watershed are given in the descriptions of the potential management alternatives and summarized in *Table 4-5*.

Table 4-5. Estimated implementation costs for each management alternative.

	Alternative 1 Environment	Alternative 2 Development	Alternative 3 Recreation	Alternative 4 Flood Control
Buffer strips – 100 feet				
Land	$7,530,000	$0	$0	$0
Installation	$9,400,000	$0	$0	$0
Buffer strips – 75 feet				
Land	$3,700,00	$0	$0	$0
Installation	$4,600,000	$0	$0	$0
Parks				
Land	$768,000	$0	$768,000	$0
Development	$960,000	$0	$8,430,000	$0
Grade control/sediment traps	$600,000	$0	$0	$0
Bank stabilization	$600,000	$0	$0	$0
Levees				
Land	$1,018,000	$0	$0	$0
Construction	$7,000,000	$0	$0	$0
Livestock fencing	$500,000	$0	$500,000	$0
Terraces	$3,000,000	$0	$3,000,000	$0
Grassed waterways	$1,400,000	$0	$1,400,000	$0
Conservation tillage	$1,500,000	$0	$1,500,000	$0
Farm ponds	$1,600,000	$0	$1,600,000	$0
Livestock waste containment	$40,000	$0	$40,000	$0
Street cleaning	$0	$0	$0	$0
Chemical education	$10,000	$0	$10,000	$0
Stormwater retention				
Established	$36,000,000	$0	$36,000,000	$0
New	$9,000,000	$0	$9,000,000	$0
CSO separation	$10,000,000	$0	$0	$0
Channel stabilization	$0	$12,700,000	$0	$12,700,000
Raise levees	$0	$9,600,000	$0	$9,600,000
Dams	$0	$0	$26,000,000	$81,000,000
Subtotal of Costs	$99,226,000	$22,300,000	$88,248,000	$103,300,000
50% of Total Stormwater Retention Costs	$22,500,000	$0	22,500,000	$0
Total Cost (Total Cost - 50% Total Stormwater Retention Costs)	$76,726,000	$22,300,00	$65,748,000	$103,300,000

4.9.4.13 Real Estate Development Costs

The real estate development cost criterion represents the costs to developers for installing storm water detention basins; in other words, this cost reduces developer profits through higher construction costs and loss of developable land. It was assumed that one-half of the cost for these basins would be borne by the developer, and one-half would be borne by the “public”. Detention basins are mandated for **Alternatives 1** and **3** (Environmental and Recreational Alternatives). The total costs of the detention basins for the entire watershed (including new developments and established developments is $45 million.

4.9.4.14 Creekside Activity Index

Creekside activity refers to business activity such as retail and dining establishments orienting toward the water. In some cities (for example, San Antonio TX, Estes Park, CO), after enhancement of the urban watershed, businesses began to orient themselves toward the river or creek. For example, restaurants can have picture windows and decks overlooking the water. In this way, the businesses can increase their revenues by capitalizing on scenic views.

Alternatives 1 and **3** could potentially improve aesthetics in the Papillion Creek Watershed enough that some Omaha area businesses could benefit from increased pedestrian traffic and retail activity. One possibility, for example, is increased creek-orientation of businesses near 78th and Cass Streets. A modest increase in business activity for those alternatives (for **Alternative 1**, a 10% increase, and for the **Alternative 3**, a 5% increase) was assumed. The baseline business activity index is zero for **Alternatives 1** and **4**. This is based on the current, observed low level of creek-orientation of businesses and an assumed low level of potential positive economic impact on businesses after implementation of the two **Alternatives**.

4.9.4.15 Business Disruption Index

Construction of physical structures and landscaping to improve water quality or flood control efforts has a temporary effect on businesses due to traffic rerouting. However, much of the land immediately adjacent to the creek is far enough away from arterial streets that much environmental and flood remediation can be accomplished with little traffic reduction. Also, construction of dams as proposed in **Alternative 4** occurs primarily in low-traffic, non-urban areas. Thus, the effects on business disruption are predicted to be minimal. Using **Alternative 2** as a baseline, with a business disruption index of 0.00, the disruption index for **Alternatives 1** and **4** is 0.05, with a slightly lower disruption level of 0.04 for **Alternative 3**.

4.9.4.16 Fishing/Boating

To gauge the frequency of recreational use and economic value of the Papillion Creek watershed, a survey was administered. One of the survey questions addressed frequency of annual fishing or boating. Survey responses came disproportionately from avid fishermen, since many of the surveys were distributed at Papillion Creek system lakes. The survey responses indicate that, among those who fish, fishing is a very frequent activity (an average of twenty times per year); however, a rather small proportion of area residents fish. Boating, on the other hand, can be a less frequent activity. Even those who own a boat may not actually go out on an area lake more than 5 or 10 times per year. Based on this information, the estimate for current annual total fishing and boating visits for the Papillion Creek watershed area is 200,000, and this value is used for **Alternative 2**.

For **Alternative 1**, the expected increase in number of fish and also numbers of species available raises the fishing/boating estimate to 300,000. **Alternative 4** is expected to increase boating visits due to the construction of dams, resulting in an estimated value for fishing/boating of 250,000. **Alternative 3** is expected to result in the largest increase in fishing/boating, with a fishing/boating estimate of 350,000.

4.9.4.17 Hiking/Biking/Skating/Running

Survey responses were difficult to obtain from bicyclists because it was difficult to intercept them when they were en route along a Creekside trail. However, it was clear from survey responses that some bicyclists travel along portions of the Papillion Creek trail system “every day” (some allowance was given for poor weather conditions). Similarly, many walkers who use the trail system walk several times per week. Thus, numbers of visits are estimated to be much larger for this category than for fishing/boating. However, recreational use in this category is likely to be enhanced by improvements in what the creek looks like after restoration, rather than the actual quality of the water.

Dividing the population of 400,000 people linearly into groups of recreational users of the trail and lake system, the following profile of use was developed:

Number of People in Each Category:	**Visits per Year per Person**	**Total Visits per Year**
200,000	never	0
100,000	once every 2 years	50,000
50,000	2 times/year	100,000
25,000	5 times/year	125,000
12,500	20 times/year	250,000
6,250	40 times/year	250,000
3,125	80 times/year	250,000
1,562	160 times/year	250,000
781	320 times/year (“daily”)	250,000
400,000		1,525,000

The baseline recreational criterion value for the watershed was determined to be 1,500,000 visits per year, which was assigned to **Alternative 2**. A recent study done by Greer (2000) was also consulted to develop criteria values.

4.9.4.18 Picnicking/Camping/Other

Picnicking and camping, according to survey responses, is not as frequent of an activity as walking and biking. Families bring their children to lakes when they are young, but tend to do more active pursuits (biking, skating) as the children age. Numbers for picnicking/etc. are, therefore, estimated to be quite low. Since these types of visitors are more likely to come in contact with the water than “high-speed” visitors, it was estimated that picnickers may be more responsive to improvements in water quality. **Alternatives 1** and **3** improve environmental and recreational settings, which should entice more casual visitors. The increased area of lakefront in **Alternative 4** may lead to an increase in picnicking at the lake/dam sites, but due to the rural location of the proposed dams, this effect may be small.

4.9.4.19 Aesthetic Value/Willingness to Pay

This category is an estimate of value for “non-use” value. In other words, many people do not use the Papillion Creek system for recreational purposes, but watershed improvements might be important to them for various reasons (i.e. “want the creek to be like it used to be,” “want to provide the area with an attractive natural resource though we’re not active fishermen or walkers,” etc.). In addition, watershed improvements may positively impact values for houses and businesses located close to the creeks or lakes in the Papillion Creek watershed. Using survey data from the *Papio Creek Community Benefit Survey*, two different approaches were used to approximate criteria values 1) straightforward estimation of an annual “willingness to pay” value and 2) approximations of possible increases in housing values due to watershed improvements.

Survey responses varied widely, ranging from “zero” (not willing to pay anything) to estimates of several thousand dollars. Based on the survey data and assuming the number of households in the Papillion Creek area of 231,000 (Omaha World Herald, 2000), a baseline criterion value was estimated to be $24,000,000. **Alternative 4** would add a slight premium to housing values due to reduced risk of flooding, and additional dam site lake views, so the value of alternative 4 is estimated to be $26,400,000. **Alternative 3** is expected to enhance housing values very little (note that this category is for non-use value, so recreational issues are not considered here, unless they have an impact on house value); therefore, **Alternative 3** was assigned a value of$26,400,000.

4.9.4.20 Regulatory Compliance

The regulatory compliance criterion represents how well each alternative satisfies current and developing regulations for the watershed. The Clean Water Act sets out water quality criteria for specified uses for individual water bodies. Currently, portions of the Big Papillion Creek do not meet those requirements. In addition, the Clean Water Act mandates that Total Maximum Daily Loads (TMDLs) of various pollutants be developed for such impaired water bodies. That is, maximum daily loadings to the stream of various pollutants such as bacteria, sediments, organic matter, and nutrients will be developed in the future.

The regulatory compliance criterion for each alternative is assigned a value on a scale of 0.0 to 3.0 where 3.0 represents complete compliance with regulations. Potential management alternatives that do not have specific management practices directed at reducing loadings of the pollutants were assigned criterion values of 1.0. Those management alternatives that have management practices designed to reduce these loading were assigned a criterion value of 2.0.

In actual practice, regulatory compliance may not be a criterion that can be traded off; i.e. it may be used as a "threshold criterion" that could be used to eliminate alternatives that would be unacceptable from a regulatory perspective. For this study, "regulatory compliance" was included as a trade-off criterion to indicate how well each alternative would likely satisfy future TMDLs.

4.10 Multi-Criteria Decision-Making Tools Used in this Study

The three MCDM tools used for this study were selected for usability and potential applicability to watershed decision making. These tools are:

1. Weighted Average Programming (WAP).
2. Composite Programming (CtP).
3. Multiattribute Utility Theory (MAUT).

The purpose of this study is to evaluate the usefulness of these MCDM tools, so the proposed management alternatives identified for this study were selected to cover the range of potential alternatives. The proposed alternatives were not meant to represent or resemble an actual proposal or proposals. The general process, applicable to the three MCDM, is:

1. Identify the decision criteria. These are the factors (e.g., water quality, flood protection, recreational opportunities) used to evaluate how well each potential management alternative satisfies watershed goals.
2. Identify preference weightings for decision criteria. Each stakeholder identifies his preferences (weightings) regarding the decision criteria. For

example, one stakeholder may select a high preference (importance) for flood control and a low preference for recreational opportunities while another stakeholder would weight recreation higher than flood control.

3. Identify available management alternatives. These consist of the range of potential management alternatives that could be implemented for the watershed.
4. Determine the condition (value) of each decision criterion for each given management alternative. For example, a management alternative that focuses on flood control by stream channelization would likely show a good condition for flood control but would probably show a poor condition for aquatic habitat.
5. Normalize the values of the decision criteria. Since the values of the different decision-criteria will likely be in different units (e.g., water quality might be measured in mg/L of dissolved oxygen, and flood damage might be measured in dollars), the actual values of the criteria must be converted into a unitless 0.0 to 1.0 range so that they can be compared. An example of this normalization process is provided below:

	Dissolve Oxygen Concentration	**Normalized Value**
Alternative X (best)	10 mg/L	1.0
Alternative Y	2 mg/L	0.2
Alternative Z (worst)	0 mg/L	0.0

	Flood Damage	**Normalized Value**
Alternative X (best)	$0	1.00
Alternative Y	$10,000,000	0.69
Alternative Z (worst)	$30,000,000	0.00

6. Compare the management alternatives. Use the MCDM method to compare the management alternatives given the decision criteria and each stakeholder's preferences.

This process will not "select" the "best alternative", because "best" depends on the preferences of the stakeholder group, nor will it end the debate on the merits of the various goals, decision criteria, and alternatives. Rather, it provides a vehicle for stakeholders to specify their goals and preferences, and compares these in a straightforward, fair manner so that the results can be evaluated and discussed by the stakeholder group. The process often can help the stakeholder group narrow the range of potential alternatives and find "consensus" alternatives. Each stakeholder will have a different set of preference weights, and will produce different trade-off values for the alternatives. It is likely that some stakeholders will have different preferred alternatives. However, it is also likely that after the stakeholders conduct their trade-off analysis, some alternatives will emerge showing overall acceptability while other alternatives will show little support among the stakeholder group as a whole. The process is described in more detail below.

4.10.1 *Weighted Average Programming*

Weighted Average Programming is a simple weighted average based on stakeholder preferences of the decision criteria for each management alternative. The mathematical formula for Weighted Average Programming is:

$$Z_A = w_1 c_1 + w_2 c_2 + w_3 c_3 + \ldots w_n c_n \tag{6-1}$$

where:

Z_A = trade-off (compromise) value for alternative A
w_i = preference weighting for decision criterion i
c_i = normalized value of decision criterion I for alternative A.

The calculation is performed for each alternative, and the “best” alternative is identified with the highest trade-off score (Z). In practice, this means that a stakeholder specifies how he or she weights each decision criteria, the weights are entered into a formula set up on a computer, and the computer program automatically calculates the stakeholder’s trade-off score.

4.10.1.1 WAP – Identify and Quantify Decision Criteria

The identified decision criteria for this study are listed in *Table 4-6*. There are decision criteria relating to each proposed watershed goal. *Table 4-6* also shows the estimated value that each decision criterion would have for each of the management alternatives. In an actual application of these tools, a more accurate determination of the decision criteria values would be required. Also shown in *Table 4-6* are the “best” and “worst” values of the decision criteria for the range of proposed alternatives. Finally, *Table 4-7* shows the normalized values of the decision criteria (i.e., the placement of the actual values onto the scale of 0 to 1).

4.10.1.2 WAP – Establish Stakeholder Preference Weighting Systems

In general, once the decision criteria are identified, stakeholders establish preference weights for the decision criteria. To illustrate the process, three hypothetical stakeholders spanning the “range” of potential stakeholders are used:

1. *Stakeholder 1:* An environmental advocate who values environmental quality and wildlife over other issues and goals;
2. *Stakeholder 2:* A land development advocate who values economic development and minimization of implementation costs over other issues and goals;
3. *Stakeholder 3*: A “moderate” who views all issues and goals as important.

The hypothetical stakeholders were selected to from the potential range of stakeholder positions. They were not meant to represent an actual stakeholder group. In this study, preference weights were chosen in a stakeholder forum, toward the end of the process. Ideally, preference weights should be chosen before the management alternatives are known so the weighting process is not influenced by stakeholders preferring one alternative or another.

The weighting systems for each of the three hypothetical stakeholders are shown in Table 4-8. *Stakeholder 1* gives more weight to the environmental issues than “economic” issues, while *Stakeholder 2* gives more weight to economic issues than environmental issues. Note that the sum of the weights must be 1.0.

4.10.1.3 WAP – Calculate the Trade-Off Values for the Management Alternatives

Table 4-8 shows the normalized values of the decision criteria under each proposed management alternative and the preference weights for the decision criteria for each management alternative. *Table 4-8* also shows the “trade-off” values for each decision criterion using the WAP formula, and it shows the overall trade-off value for each alternative. The alternative with the highest overall trade-off value is the preferred alternative for that stakeholder. *Table 4-8* shows that *Stakeholder 1* favors **Alternative 1**; that *Stakeholder 2* favors **Alternative 2** slightly over **Alternative 4**; and *Stakeholder 3* favors **Alternative 1** slightly over **Alternative 3**. From this evaluation, **Alternatives 1** and **3** may be potentially attractive alternatives to the group of stakeholders.

Table 4-6. Decision criteria values for each management alternative.

Decision Criteria	Measurement Type	Units	Alternative 1 Environment	Alternative 2 Development	Alternative 3 Recreation	Alternative 4 Flood Control	Best	Worst
lake habitat	lake area in watershed	acres	1,000	1,000	1,500	3,000	6,000	1000
water velocity	vel. @ watershed outlet	ft/sec	3.2	8.9	3.0	8.4	2.0	10
substrate/cover	habitat assessment	index (0-1)	0.75	0.0	0.75	0.0	1.0	0.0
riparian quantity	area in watershed	acres	13,185	2,560	13,185	2,560	13,185	0.0
riparian connectivity	connected length/total	fraction	0.7	0.1	0.7	0.1	1.0	0.0
coliform bacteria	discharge index	fraction	0.24	1.0	0.43	0.79	0.0	1.0
nitrogen (total)	discharge index	fraction	0.40	1.0	0.61	0.97	0.0	1.0
phosphorous (total)	discharge index	fraction	0.18	0.98	0.35	0.74	0.0	1.0
sediment load	discharge index	fraction	0.20	0.92	0.37	0.70	0.0	1.0
dissolved oxygen	August average	mg/L	6.0	1.0	6.0	1.0	8.0	0.0
flood protection	exp. annual damage	$	300,000	900,000	300,000	100,000	0.0	900,000
implementation cost	total cost	$	86,122,000	22,300,000	65,730,000	103,300,000	22,000,000	103,300,000
real estate cost	half of detention costs	$	22,500,000	0.0	22,500,000	0.0	0.0	22,500,00
creek-side economic activity	index	index (0-1)	0.1	0.0	0.05	0.0	1.0	0.0
business disruption	index	index (0-1)	0.05	0.0	0.04	0.05	0.0	1.0
fishing/boating	total annual	user-days	300,000	200,000	350,000	250,000	800,000	100,000
picnicking/other	total annual	user-days	150,000	100,000	150,000	112,500	400,000	50,000
hiking/biking	total annual	user-days	1,875,000	1,500,000	2,250,000	1,687,500	3,000,000	750,000
green space	area in watershed	acres	13,185	2,560	13,185	2,560	13,185	0.0
aesthetics	willingness to pay	$	32,000,000	24,000,000	26,400,000	26,400,000	40,000,000	16,000,000
regulatory compliance	index	scale (1-3)	2	1	2	1	3	0

Table 4-7. Normalized decision criteria values.

Decision Criteria	Alternative 1 Environmental	Alternative 2 Development	Alternative 3 Recreation	Alternative 4 Flood Control
lake habitat	0.000	0.000	0.100	0.400
water velocity	0.850	0.138	0.875	0.200
substrate/cover	0.750	0.000	0.750	0.000
riparian quantity	1.000	0.194	1.000	0.194
riparian connectivity	0.700	0.100	0.700	0.100
coliform bacteria	0.755	0.000	0.572	0.210
nitrogen (total)	0.604	0.000	0.391	0.030
phosphorous (total)	0.818	0.020	0.648	0.255
sediment load	0.797	0.080	0.634	0.301
dissolved oxygen	0.750	0.125	0.750	0.125
flood protection	0.667	0.000	0.667	0.889
implementation cost	0.211	0.996	0.462	0.000
real estate cost	0.000	1.000	0.000	1.000
creek-side economic activity	0.100	0.000	0.050	0.000
business disruption	0.950	1.000	0.960	0.950
fishing/boating	0.286	0.143	0.357	0.214
picnicking/other	0.286	0.143	0.286	0.179
hiking/biking	0.500	0.333	0.667	0.417
green space	1.000	0.194	1.000	0.194
aesthetics	0.667	0.333	0.433	0.433
regulatory compliance	0.667	0.333	0.667	0.333

Table 4-8. WAP: Stakeholder trade-offs for management alternatives.

Stakeholder 1: Environmental Advocate

		Normalized Criteria Values				Trade-off Values			
Decision Criteria	**Weights**	**Alt 1 Environment**	**Alt 2 Development**	**Alt 3 Recreation**	**Alt 4 Flood Control**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
lake habitat	0.05	0.000	0.000	0.100	0.400	0.00	0.00	0.01	0.02
water velocity	0.1	1.000	0.000	1.000	0.000	0.10	0.00	0.10	0.00
substrate/cover	0.1	0.750	0.000	0.750	0.000	0.08	0.00	0.08	0.00
riparian quantity	0.1	1.000	0.194	1.000	0.194	0.10	0.02	0.10	0.02
riparian connectivity	0.1	0.700	0.100	0.700	0.100	0.07	0.01	0.07	0.01
coliform bacteria	0.1	0.707	0.000	0.685	0.300	0.07	0.00	0.07	0.03
nitrogen (total)	0.1	0.497	0.000	0.491	0.000	0.05	0.00	0.05	0.00
phosphorous (total)	0.05	0.930	0.010	0.922	0.307	0.05	0.00	0.05	0.02
sediment load	0.1	0.898	0.010	0.831	0.307	0.09	0.00	0.08	0.03
dissolved oxygen	0.1	0.750	0.125	0.750	0.125	0.08	0.01	0.08	0.01
flood protection	0.01	0.667	0.000	0.667	0.889	0.01	0.00	0.01	0.01
implementation cost	0.02	0.327	0.996	0.462	0.000	0.01	0.02	0.01	0.00
real estate cost	0.01	0.000	1.000	0.000	1.000	0.00	0.01	0.00	0.01
creek-side economic activity	0.005	0.100	0.000	0.050	0.000	0.00	0.00	0.00	0.00
business disruption	0.005	0.950	1.000	0.960	0.950	0.00	0.01	0.00	0.00
fishing/boating	0.01	0.286	0.143	0.357	0.214	0.00	0.00	0.00	0.00
picnicking/other	0.01	0.286	0.143	0.286	0.179	0.00	0.00	0.00	0.00
hiking/biking	0.01	0.500	0.333	0.667	0.417	0.01	0.00	0.01	0.00
green space	0.005	1.000	0.000	1.000	0.000	0.01	0.00	0.01	0.00
aesthetics	0.005	0.667	0.333	0.433	0.433	0.00	0.00	0.00	0.00
regulatory compliance	0.01	0.667	0.333	0.667	0.333	0.01	0.00	0.01	0.00
Total	1.000								
			Overall Trade-off Values			**0.72**	**0.09**	**0.72**	**0.18**

Stakeholder 2: Land Development Advocate

		Normalized Criteria Values				Trade-off Values			
Decision Criteria	**Weights**	**Alt 1 Environment**	**Alt 2 Development**	**Alt 3 Recreation**	**Alt 4 Flood Control**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
lake habitat	0.05	0.000	0.000	0.100	0.400	0.00	0.00	0.01	0.02
water velocity	0	1.000	0.000	1.000	0.000	0.00	0.00	0.00	0.00
substrate/cover	0	0.750	0.000	0.750	0.000	0.00	0.00	0.00	0.00
riparian quantity	0.05	1.000	0.194	1.000	0.194	0.05	0.01	0.05	0.01
riparian connectivity	0	0.700	0.100	0.700	0.100	0.00	0.00	0.00	0.00
coliform bacteria	0	0.707	0.000	0.685	0.300	0.00	0.00	0.00	0.00
nitrogen (total)	0	0.497	0.000	0.491	0.000	0.00	0.00	0.00	0.00
phosphorous (total)	0	0.930	0.010	0.922	0.307	0.00	0.00	0.00	0.00
sediment load	0	0.898	0.010	0.831	0.307	0.00	0.00	0.00	0.00
dissolved oxygen	0	0.750	0.125	0.750	0.125	0.00	0.00	0.00	0.00
flood protection	0.2	0.667	0.000	0.667	0.889	0.13	0.00	0.13	0.18
implementation cost	0.25	0.327	0.996	0.462	0.000	0.08	0.25	0.12	0.00
real estate cost	0.25	0.000	1.000	0.000	1.000	0.00	0.25	0.00	0.25
creek-side economic activity	0.05	0.100	0.000	0.050	0.000	0.01	0.00	0.00	0.00
business disruption	0.05	0.950	1.000	0.960	0.950	0.05	0.05	0.05	0.05
fishing/boating	0.01	0.286	0.143	0.357	0.214	0.00	0.00	0.00	0.00
picnicking/other	0.01	0.286	0.143	0.286	0.179	0.00	0.00	0.00	0.00
hiking/biking	0.01	0.500	0.333	0.667	0.417	0.01	0.00	0.01	0.00
green space	0.01	1.000	0.000	1.000	0.000	0.01	0.00	0.01	0.00
aesthetics	0.01	0.667	0.333	0.433	0.433	0.01	0.00	0.00	0.00
regulatory compliance	0.05	0.667	0.333	0.667	0.333	0.03	0.02	0.03	0.02
Total	1.000								
			Overall Trade-off Values			0.38	0.58	0.42	0.53

Stakeholder 3: Moderate

		Normalized Criteria Values				Trade-off Values			
Decision Criteria	**Weights**	**Alt 1 Environment**	**Alt 2 Development**	**Alt 3 Recreation**	**Alt 4 Flood Control**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
lake habitat	0.05	0.000	0.000	0.100	0.400	0.00	0.00	0.01	0.02
water velocity	0.05	1.000	0.000	1.000	0.000	0.05	0.00	0.05	0.00
substrate/cover	0.05	0.750	0.000	0.750	0.000	0.04	0.00	0.04	0.00
riparian quantity	0.05	1.000	0.194	1.000	0.194	0.05	0.01	0.05	0.01
riparian connectivity	0.05	0.700	0.100	0.700	0.100	0.04	0.01	0.04	0.01
coliform bacteria	0.05	0.707	0.000	0.685	0.300	0.04	0.00	0.03	0.02
Nitrogen (total)	0.05	0.497	0.000	0.491	0.000	0.02	0.00	0.02	0.00
phosphorous (total)	0.05	0.930	0.010	0.922	0.307	0.05	0.00	0.05	0.02
sediment load	0.05	0.898	0.010	0.831	0.307	0.04	0.00	0.04	0.02
dissolved oxygen	0.05	0.750	0.125	0.750	0.125	0.04	0.01	0.04	0.01
flood protection	0.05	0.667	0.000	0.667	0.889	0.03	0.00	0.03	0.04
implementation cost	0.05	0.327	0.996	0.462	0.000	0.02	0.05	0.02	0.00
real estate cost	0.05	0.000	1.000	0.000	1.000	0.00	0.05	0.00	0.05
creek-side economic activity	0.05	0.100	0.000	0.050	0.000	0.01	0.00	0.00	0.00
business disruption	0.05	0.950	1.000	0.960	0.950	0.05	0.05	0.05	0.05
fishing/boating	0.05	0.286	0.143	0.357	0.214	0.01	0.01	0.02	0.01
picnicking/other	0.05	0.286	0.143	0.286	0.179	0.01	0.01	0.01	0.01
hiking/biking	0.05	0.500	0.333	0.667	0.417	0.03	0.02	0.03	0.02
green space	0.025	1.000	0.000	1.000	0.000	0.03	0.00	0.03	0.00
aesthetics	0.025	0.667	0.333	0.433	0.433	0.02	0.01	0.01	0.01
regulatory compliance	0.05	0.667	0.333	0.667	0.333	0.03	0.02	0.03	0.02
Total	1.000								
			Overall Trade-off Values			0.59	0.23	0.60	0.30

4.10.2 *Composite Programming*

Composite Programming (CtP) is a modification of WAP. In CtP, the decision criteria are placed into groups of related criteria that are composited into fewer, more general groups. For example, the criteria boating, fishing, swimming, hiking and biking may be composited into the general criterion of recreation. Groups are composited until the final trade-off criteria are left. *Tables 4-9* through *4-20* indicate how the criteria were composited into fewer, more general categories, and how the same criteria compositing scheme applies to each hypothetical stakeholder and each management alternative. The following formula is used to calculate the trade-off value for each alternative:

$$Z_{Ai} = \left[(w_1c_1)^p + (w_2c_2)^p + \ldots (w_nc_n)^p\right]^{1/p} \tag{6-2}$$

where:

Z_{Ai} = trade-off value of the i^{th} group of criteria for alternative A
w_m = preference weight for m^{th} criterion of the i^{th} group of criteria
c_m = value of the n^{th} decision criterion in the i^{th} group of criteria
p = balancing factor that accounts for especially negative criteria values

The calculation is performed for each criteria group progressively until the final trade-off is made for the alternative. Each alternative is evaluated in the same manner, and the “best” alternative is identified with the highest final trade-off score (Z).

4.10.2.1 CtP – Identify and Quantify Decision Criteria

The values of the decision criteria under each proposed management alternative are established and are again normalized. The decision criteria and the normalized values are shown in *Tables 4-9* through *4-20*, using the same stakeholders used for WAP. The decision criteria and corresponding normalized values are equivalent to those in the WAP example.

4.10.2.2 CtP – Establish Stakeholder Preference Weighting Systems

The preference weights for the decision criteria are shown on *Tables 4-9* through *4-20*. Preference weights must be established for each trade-off level in CtP. For example, the variables w1, w2, w3, and w4, shown in *Tables 4-9* through *4-20,* are the preference weights for the first, second, third, and fourth trade-off levels respectively. The sum of the preference weights in each trade-off group must equal 1.0.

In addition to the way the decision criteria are composited, the use of p-values distinguishes CtP from WAP. The p values are used to prevent "fatally bad" decision criteria values from being "averaged out" in the analysis. For example, an alternative might have several decision criteria with excellent values and one decision criterion with a completely unacceptable value. In WAP, the completely unacceptable criterion value might be obscured by the excellent values of the other criteria. This would result in accepting an alternative that one really would find "unacceptable" because of the one unacceptable criterion value. In CtP, larger p values give more importance to criteria with "very good" values. Accordingly, these criteria are not so likely to be "averaged" out by other criteria values. Typically, the CtP calculation is performed for p values of 1, 2, and 3 to evaluate how "very good" and "very bad" criteria values affect the outcome. In other words, performing the CtP calculation with different p values indicates the relative sensitivity of the CtP calculation to "very good" or "very bad" criteria values.

Table 4-9. CtP: *Stakeholder 1* (Environmental Advocate) trade-offs for Alternative 1.

Alternative 1

p = 2

Instructions: Change only highlighted cells (p value and weights in Alt 1)

Decision Criteria	c1	w1		Z1	w2		Z2	w3		Z3	w4		Z4
Lake Habitat	0.000				0.3								
Water Velocity	1.000	0.6											
Substrate/Cover	0.750	0.4	River Habitat	0.671	0.3	Habitat	0.333	0.5					
Riparian Quantity	1.000	0.6											
Riparian Connectivity	0.700	0.4	Riparian Habitat	0.662	0.4								
Coliform Bacteria	0.707	0.2							Environment	0.271	0.8		
Nitrogen (Total)	0.497	0.1											
Phosphorus (Total)	0.930	0.1	Water Quality	0.427				0.5					
Dissolved Oxygen	0.898	0.4											
Sediment Load	0.750	0.2											
Flood Protection	0.667	0.3										Final Trade-Off	0.22
Implementation Cost	0.327	0.4											
Real Estate Econ Impact	0.000	0.1	Economics	0.257				0.7					
Creek-Side Economy	0.100	0.1											
Business Disruption	0.950	0.1											
Fishing/Boating	0.286	0.2							Socio-Economics	0.180	0.2		
Picnicking/Other	0.286	0.2											
Hiking/Biking	0.500	0.2											
Green Space	1.000	0.1	Social	0.221				0.3					
Aesthetics	0.667	0.1											
Regulatory Compliance	0.667	0.2											

Table 4-10. CtP: *Stakeholder 1* (Environmental Advocate) trade-offs for Alternative 2.

Alternative 2

p = 2

Instructions: Change only highlighted cells (p value and weights in Alt 1)

Decision Criteria	c1	w1		Z1	w2		Z2	w3		Z3	w4		Z4
Lake Habitat	0.000				0.3								
Water Velocity	0.000	0.6											
Substrate/Cover	0.000	0.4	River Habitat	0.000	0.3	Habitat	0.049	0.5					
Riparian Quantity	0.194	0.6											
Riparian Connectivity	0.100	0.4	Riparian Habitat	0.123	0.4								
Coliform Bacteria	0.000	0.2							Environment	0.028	0.8		
Nitrogen (Total)	0.000	0.1											
Phosphorus (Total)	0.010	0.1	Water Quality	0.025				0.5					
Dissolved Oxygen	0.010	0.4											
Sediment Load	0.125	0.2											
Flood Protection	0.000	0.3										Final Trade-Off	0.06
Implementation Cost	0.996	0.4											
Real Estate Econ Impact	1.000	0.1	Economics	0.423				0.7					
Creek-Side Economy	0.000	0.1											
Business Disruption	1.000	0.1											
Fishing/Boating	0.143	0.2							Socio-Economics	0.296	0.2		
Picnicking/Other	0.143	0.2											
Hiking/Biking	0.333	0.2											
Green Space	0.000	0.1	Social	0.108				0.3					
Aesthetics	0.333	0.1											
Regulatory Compliance	0.333	0.2											

Table 4-11. CtP: *Stakeholder 1* (Environmental Advocate) trade-offs for Alternative 3.

Alternative 3

p = 2

Instructions: Change only highlighted cells (p value and weights in Alt 1)

Decision Criteria	c1	w1		Z1	W2		Z2	w3		Z3	w4		Z4
Lake Habitat	0.100				0.3								
Water Velocity	1.000	0.6											
Substrate/Cover	0.750	0.4	River Habitat	0.671	0.3	Habitat	0.334	0.5					
Riparian Quantity	1.000	0.6											
Riparian Connectivity	0.700	0.4	Riparian Habitat	0.662	0.4								
Coliform Bacteria	0.685	0.2							Environment	0.262	0.8		
Nitrogen (Total)	0.491	0.1											
Phosphorus (Total)	0.922	0.1	Water Quality	0.403				0.5					
Dissolved Oxygen	0.831	0.4											
Sediment Load	0.750	0.2											
Flood Protection	0.667	0.3										Final Trade-Off	0.21
Implementation Cost	0.462	0.4											
Real Estate Econ Impact	0.000	0.1	Economics	0.289				0.7					
Creek-Side Economy	0.050	0.1											
Business Disruption	0.960	0.1											
Fishing/Boating	0.357	0.2							Socio-Economics	0.202	0.2		
Picnicking/Other	0.286	0.2											
Hiking/Biking	0.667	0.2											
Green Space	1.000	0.1	Social	0.236				0.3					
Aesthetics	0.433	0.1											
Regulatory Compliance	0.667	0.2											

Table 4-12. CtP: *Stakeholder 1* (Environmental Advocate) trade-offs for Alternative 4.

Alternative 4

p = 2

Instructions: Change only highlighted cells (p value and weights in Alt 1)

Decision Criteria	c1	w1		Z1	w2		Z2	w3		Z3	w4		Z4
Lake Habitat	0.400				0.3								
Water Velocity	0.000	0.6											
Substrate/Cover	0.000	0.4	River Habitat	0.000	0.3	Habitat	0.130	0.5					
Riparian Quantity	0.194	0.6											
Riparian Connectivity	0.100	0.4	Riparian Habitat	0.123	0.4								
Coliform Bacteria	0.300	0.2							Environment	0.096	0.8		
Nitrogen (Total)	0.000	0.1											
Phosphorus (Total)	0.307	0.1	Water Quality	0.142				0.5					
Dissolved Oxygen	0.307	0.4											
Sediment Load	0.125	0.2											
Flood Protection	0.889	0.3										Final Trade-Off	0.26
Implementation Cost	0.000	0.4											
Real Estate Econ Impact	1.000	0.1	Economics	0.300				0.7					
Creek-Side Economy	0.000	0.1											
Business Disruption	0.950	0.1											
Fishing/Boating	0.214	0.2							Socio-Economics	0.210	0.2		
Picnicking/Other	0.179	0.2											
Hiking/Biking	0.417	0.2											
Green Space	0.000	0.1	Social	0.128				0.3					
Aesthetics	0.433	0.1											
Regulatory Compliance	0.333	0.2											

Table 4-13. CtP: *Stakeholder* 2 (Development Advocate) trade-offs for Alternative 1.

P = 2

Instructions: change only highlighted cells (p value and weights in alt 1)

Alternative 1

Decision Criteria	C1	W1		Z1	W2		Z2	W3		Z3	W4		Z4
Lake Habitat	0.000				0.3								
Water Velocity	1.000	0.6											
Substrate/Cover	0.750	0.4	River Habitat	0.671	0.3	Habitat	0.333	0.5					
Riparian Quantity	1.000	0.6											
Riparian Connectivity	0.700	0.4	Riparian Habitat	0.662	0.4								
Coliform Bacteria	0.707	0.2							Environment	0.271	0.1		
Nitrogen (Total)	0.497	0.1											
Phosphorus (Total)	0.930	0.1	Water Quality	0.427				0.5					
Dissolved Oxygen	0.898	0.4											
Sediment Load	0.750	0.2											
Flood Protection	0.667	0.2										Final Trade-Off	0.14
Implementation Cost	0.327	0.3											
Real Estate Econ Impact	0.000	0.3	Economics	0.191				0.8					
Creek-Side Economy	0.100	0.1											
Business Disruption	0.950	0.1											
Fishing/Boating	0.286	0.2							Socio-Economics	0.180	0.9		
Picnicking/Other	0.286	0.2											
Hiking/Biking	0.500	0.2											
Green Space	1.000	0.1	Social	0.221				0.2					
Aesthetics	0.667	0.1											
Regulatory Compliance	0.667	0.2											

Table 4-14. CtP: *Stakeholder* 2 (Development Advocate) trade-offs for Alternative 2.

P = 2

Instructions: change only highlighted cells (p value and weights in alt 1)

Alternative 2

Decision Criteria	C1	W1		Z1	W2		Z2	W3		Z3	W4		Z4
Lake Habitat	0.000				0.3								
Water Velocity	0.000	0.6											
Substrate/Cover	0.000	0.4	River Habitat	0.000	0.3	Habitat	0.049	0.5					
Riparian Quantity	0.194	0.6											
Riparian Connectivity	0.100	0.4	Riparian Habitat	0.123	0.4								
Coliform Bacteria	0.000	0.2							Environment	0.028	0.1		
Nitrogen (Total)	0.000	0.1											
Phosphorus (Total)	0.010	0.1	Water Quality	0.025				0.5					
Dissolved Oxygen	0.010	0.4											
Sediment Load	0.125	0.2											
Flood Protection	0.000	0.2										Final Trade-Off	0.31
Implementation Cost	0.996	0.3											
Real Estate Econ Impact	1.000	0.3	Economics	0.435				0.8					
Creek-Side Economy	0.000	0.1											
Business Disruption	1.000	0.1											
Fishing/Boating	0.143	0.2							Socio-Economics	0.348	0.9		
Picnicking/Other	0.143	0.2											
Hiking/Biking	0.333	0.2											
Green Space	0.000	0.1	Social	0.108				0.2					
Aesthetics	0.333	0.1											
Regulatory Compliance	0.333	0.2											

Table 4-15. CtP: *Stakeholder* 2 (Development Advocate) trade-offs for Alternative 3.

P = 2

Instructions: change only highlighted cells (p value and weights in alt 1)

Alternative 3

Decision Criteria	C1	W1		Z1	W2		Z2	W3		Z3	W4		Z4
Lake Habitat	0.100				0.3								
Water Velocity	1.000	0.6											
Substrate/Cover	0.750	0.4	River Habitat	0.671	0.3	Habitat	0.334	0.5					
Riparian Quantity	1.000	0.6											
Riparian Connectivity	0.700	0.4	Riparian Habitat	0.662	0.4								
Coliform Bacteria	0.685	0.2							Environment	0.262	0.1		
Nitrogen (Total)	0.491	0.1											
Phosphorus (Total)	0.922	0.1	Water Quality	0.403				0.5					
Dissolved Oxygen	0.831	0.4											
Sediment Load	0.750	0.2											
Flood Protection	0.667	0.2										Final Trade-Off	0.16
Implementation Cost	0.462	0.3											
Real Estate Econ Impact	0.000	0.3	Economics	0.215				0.7					
Creek-Side Economy	0.050	0.1											
Business Disruption	0.960	0.1											
Fishing/Boating	0.357	0.2							Socio-Economics	0.172	0.9		
Picnicking/Other	0.286	0.2											
Hiking/Biking	0.667	0.2											
Green Space	1.000	0.1	Social	0.236				0.3					
Aesthetics	0.433	0.1											
Regulatory Compliance	0.667	0.2											

Table 4-16. CtP: *Stakeholder* 2 (Development Advocate) trade-offs for Alternative 4.

P = 2

Instructions: change only highlighted cells (p value and weights in alt 1)

Alternative 4

Decision Criteria	C1	W1		Z1	W2		Z2	W3		Z3	W4		Z4
Lake Habitat	0.400				0.3								
Water Velocity	1.000	0.6											
Substrate/Cover	0.750	0.4	River Habitat	0.000	0.3	Habitat	0.130	0.5					
Riparian Quantity	1.000	0.6											
Riparian Connectivity	0.700	0.4	Riparian Habitat	0.123	0.4								
Coliform Bacteria	0.707	0.2							Environment	0.096	0.1		
Nitrogen (Total)	0.497	0.1											
Phosphorus (Total)	0.930	0.1	Water Quality	0.142				0.5					
Dissolved Oxygen	0.898	0.4											
Sediment Load	0.750	0.2											
Flood Protection	0.667	0.2										Final Trade-Off	0.26
Implementation Cost	0.327	0.3											
Real Estate Econ Impact	0.000	0.3	Economics	0.361				0.5					
Creek-Side Economy	0.100	0.1											
Business Disruption	0.950	0.1											
Fishing/Boating	0.286	0.2							Socio-Economics	0.289	0.9		
Picnicking/Other	0.286	0.2											
Hiking/Biking	0.500	0.2											
Green Space	1.000	0.1	Social	0.128				0.5					
Aesthetics	0.667	0.1											
Regulatory Compliance	0.667	0.2											

Table 4-17. CtP: *Stakeholder 3* (Moderate) trade-offs for Alternative 1.

Alternative 1

p = 2

Instructions: Change only highlighted cells (p value and weights in Alt 1)

Decision Criteria	c1	w1		Z1	w2		Z2	w3		Z3	w4		Z4
Lake Habitat	0.000				0.3								
Water Velocity	1.000	0.6											
Substrate/Cover	0.750	0.4	River Habitat	0.671	0.3	Habitat	0.333	0.5					
Riparian Quantity	1.000	0.6											
Riparian Connectivity	0.700	0.4	Riparian Habitat	0.662	0.4								
Coliform Bacteria	0.707	0.2							Environment	0.271	0.5		
Nitrogen (Total)	0.497	0.1											
Phosphorus (Total)	0.930	0.1	Water Quality	0.427				0.5					
Dissolved Oxygen	0.898	0.4											
Sediment Load	0.750	0.2											
Flood Protection	0.667	0.3										Final Trade-Off	0.15
Implementation Cost	0.327	0.4											
Real Estate Econ Impact	0.000	0.1	Economics	0.257				0.5					
Creek-Side Economy	0.100	0.1											
Business Disruption	0.950	0.1											
Fishing/Boating	0.286	0.2							Socio-Economics	0.129	0.5		
Picnicking/Other	0.286	0.2											
Hiking/Biking	0.500	0.2											
Green Space	1.000	0.1	Social	0.221				0.5					
Aesthetics	0.667	0.1											
Regulatory Compliance	0.667	0.2											

Table 4-18. CtP: *Stakeholder 3* (Moderate) trade-offs for Alternative 2.

Alternative 2

p = 2

Instructions: Change only highlighted cells (p value and weights in Alt 1)

Decision Criteria	c1	w1		Z1	w2		Z2	w3		Z3	w4		Z4
Lake Habitat	0.000				0.3								
Water Velocity	0.000	0.6											
Substrate/Cover	0.000	0.4	River Habitat	0.000	0.3	Habitat	0.049	0.5					
Riparian Quantity	0.194	0.6											
Riparian Connectivity	0.100	0.4	Riparian Habitat	0.123	0.4								
Coliform Bacteria	0.000	0.2							Environment	0.028	0.5		
Nitrogen (Total)	0.000	0.1											
Phosphorus (Total)	0.010	0.1	Water Quality	0.025				0.5					
Dissolved Oxygen	0.010	0.4											
Sediment Load	0.125	0.2											
Flood Protection	0.000	0.3										Final Trade-Off	0.11
Implementation Cost	0.996	0.4											
Real Estate Econ Impact	1.000	0.1	Economics	0.423				0.5					
Creek-Side Economy	0.000	0.1											
Business Disruption	1.000	0.1											
Fishing/Boating	0.143	0.2							Socio-Economics	0.211	0.5		
Picnicking/Other	0.143	0.2											
Hiking/Biking	0.333	0.2											
Green Space	0.000	0.1	Social	0.108				0.5					
Aesthetics	0.333	0.1											
Regulatory Compliance	0.333	0.2											

Table 4-19. CtP: *Stakeholder 3* (Moderate) trade-offs for Alternative 3.

Alternative 3

p = 2

Instructions: Change only highlighted cells (p value and weights in Alt 1)

Decision Criteria	c1	w1		Z1	w2		Z2	w3		Z3	w4		Z4
Lake Habitat	0.100				0.3								
Water Velocity	1.000	0.6											
Substrate/Cover	0.750	0.4	River Habitat	0.671	0.3	Habitat	0.334	0.5					
Riparian Quantity	1.000	0.6											
Riparian Connectivity	0.700	0.4	Riparian Habitat	0.662	0.4								
Coliform Bacteria	0.685	0.2							Environment	0.262	0.5		
Nitrogen (Total)	0.491	0.1											
Phosphorus (Total)	0.922	0.1	Water Quality	0.403				0.5					
Dissolved Oxygen	0.831	0.4											
Sediment Load	0.750	0.2											
Flood Protection	0.667	0.3										Final Trade-Off	0.15
Implementation Cost	0.462	0.4											
Real Estate Econ Impact	0.000	0.1	Economics	0.289				0.5					
Creek-Side Economy	0.050	0.1											
Business Disruption	0.960	0.1											
Fishing/Boating	0.357	0.2							Socio-Economics	0.144	0.5		
Picnicking/Other	0.286	0.2											
Hiking/Biking	0.667	0.2											
Green Space	1.000	0.1	Social	0.236				0.5					
Aesthetics	0.433	0.1											
Regulatory Compliance	0.667	0.2											

Table 4-20. CtP: *Stakeholder 3* (Moderate) trade-offs for Alternative 4.

Alternative 4

p = 2

Instructions: Change only highlighted cells (p value and weights in Alt 1)

Decision Criteria	c1	w1		Z1	w2		Z2	w3		Z3	w4		Z4
Lake Habitat	0.400				0.3								
Water Velocity	0.000	0.6											
Substrate/Cover	0.000	0.4	River Habitat	0.000	0.3	Habitat	0.130	0.5					
Riparian Quantity	0.194	0.6											
Riparian Connectivity	0.100	0.4	Riparian Habitat	0.123	0.4								
Coliform Bacteria	0.300	0.2							Environment	0.096	0.5		
Nitrogen (Total)	0.000	0.1											
Phosphorus (Total)	0.307	0.1	Water Quality	0.142				0.5					
Dissolved Oxygen	0.307	0.4											
Sediment Load	0.125	0.2											
Flood Protection	0.889	0.3										Final Trade-Off	0.09
Implementation Cost	0.000	0.4											
Real Estate Econ Impact	1.000	0.1	Economics	0.300				0.5					
Creek-Side Economy	0.000	0.1											
Business Disruption	0.950	0.1											
Fishing/Boating	0.214	0.2							Socio-Economics	0.150	0.5		
Picnicking/Other	0.179	0.2											
Hiking/Biking	0.417	0.2											
Green Space	0.000	0.1	Social	0.128				0.5					
Aesthetics	0.433	0.1											
Regulatory Compliance	0.333	0.2											

4.10.3 *Multiattribute Utility Theory*

Multiattribute Utility Theory is similar to WAP except that instead of using the "normalized values" of the decision criteria in the trade-off, the "utilities" of the criteria are used. The "utility" of a criterion is essentially how one feels about the value of a criterion. For example, three alternatives might have costs of \$0.0, \$1,000,000, and \$50,000,000. The utility of each of these cost criteria is determined on a 0.0 to 1.0 scale. Since a cost of \$0.00 is "very good," the utility would approach 1.0 (the best possible). The utility of the \$1,000,000 cost might be considered to have a "medium" utility and be rated 0.5, and the utility of the \$50,000,000 cost might be considered "very poor" and given a utility of 0.01 (approaching zero). Utility values do not necessarily follow the actual costs on a linear, one to one basis.

Once the utilities are determined for the decision criteria for the alternatives, the trade-off proceeds using:

$$U_A = w_1 \cdot u(c_1) + w_2 \cdot u(c_2) + \ldots w_n \cdot u(c_n) \tag{6-3}$$

where:

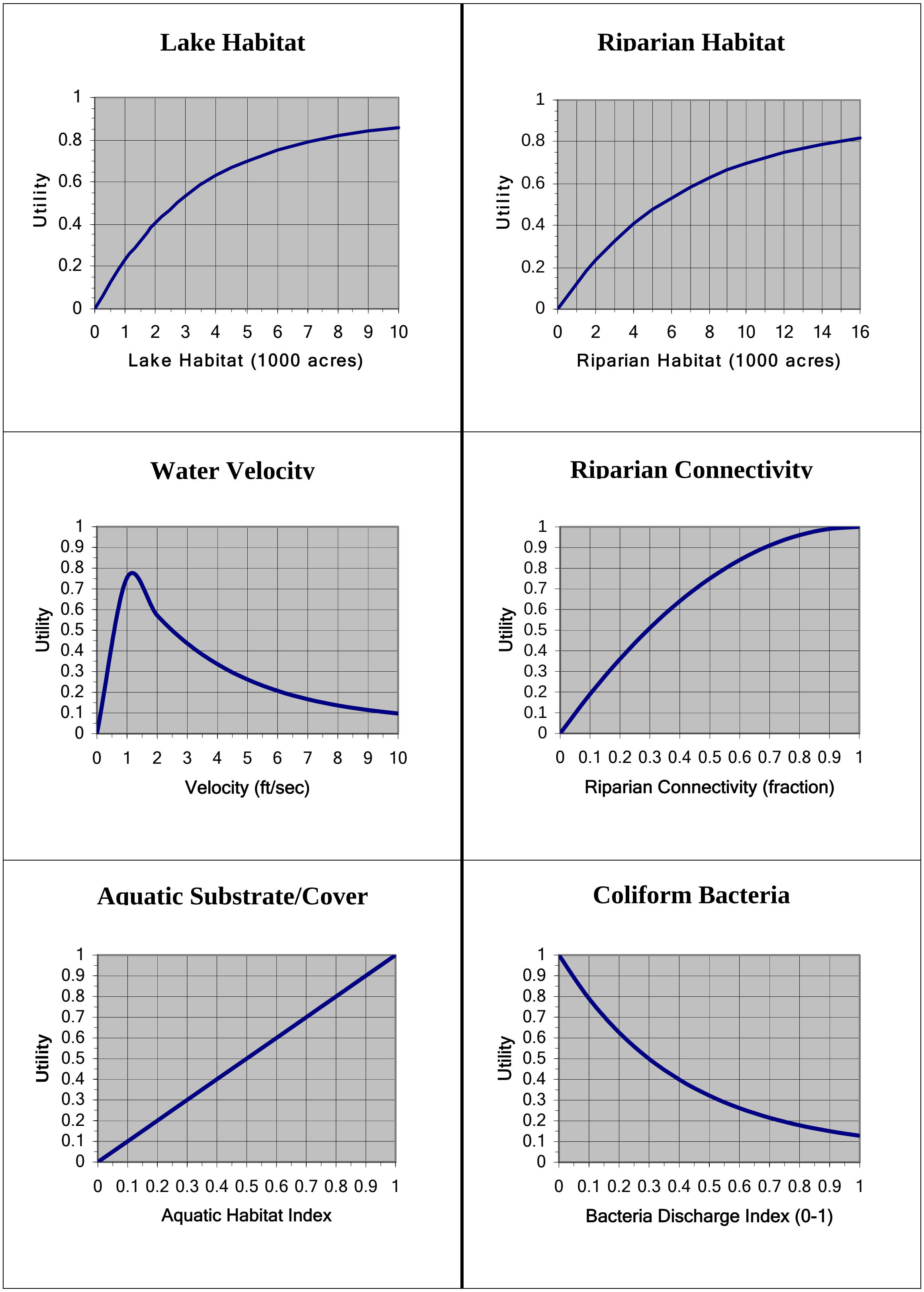
U_A = overall utility of alternative A
w_i = preference weight for decision criteria i
$u(c_i)$ = utility of decision criteria i for alternative A

4.10.3.1 MAUT – Identify and Quantify Decision Criteria

The decision criteria are identified, and their values under each management alternative are established in the same manner as before. However, the values of the decision criteria are not normalized as was done with WAP and CtP. Rather, the utility of the values of the decision criteria are estimated. The utility of a criterion value can be stated as “how satisfied” the stakeholder is with that value. For this example, the utilities of the decision criteria values are estimated from *Figure 4-5* (see Clemen, 1996, for discussion on utility function determination). A utility of 1.0 is given to the best possible value of a criterion. Estimated utility values used for this study are listed in *Table 4-21*. The preference weights for the decision criteria are shown on *Table 4-22*, and are the same decision criteria established for WAP. It should be noted that, in actual practice, this process would be done by each stakeholder, and the utilities for each criterion and management alternative would vary accordingly.

Table 4-21. Utility values of decision criteria.

Decision Criteria	Alternative 1 Environmental	Alternative 2 Development	Alternative 3 Recreation	Alternative 4 Flood Control
lake habitat	0.3	0.3	0.5	0.8
water velocity	0.8	0.1	0.8	0.1
substrate/cover	0.9	0.2	0.9	0.2
riparian quantity	0.6	0.3	0.6	0.3
riparian connectivity	1.0	0.1	1.0	0.1
coliform bacteria	0.6	0.0	0.4	0.0
nitrogen (total)	0.7	0.1	0.7	0.1
phosphorous (total)	0.9	0.0	0.9	0.6
sediment load	0.8	0.1	0.8	0.1
dissolved oxygen	0.9	0.0	0.9	0.6
flood protection	0.2	0.5	0.3	0.1
implementation cost	0.5	0.8	0.5	0.2
real estate cost	0.8	0.9	0.8	0.7
creek-side economic activity	0.8	0.9	0.8	0.9
business disruption	0.9	0.2	0.9	0.2
fishing/boating	0.8	0.2	0.8	0.9
picnicking/other	0.7	0.6	0.8	0.9
hiking/biking	0.7	0.6	0.8	0.9
green space	0.9	0.6	0.9	0.9
Aesthetics	0.6	0.5	0.5	0.5
regulatory compliance	0.7	0.2	0.7	0.2



Lake Habitat

Riparian Habitat

Water Velocity

Riparian Connectivity

Aquatic Substrate/Cover

Coliform Bacteria

Figure 4-5. MAUT: plots to determine decision criteria utility values.

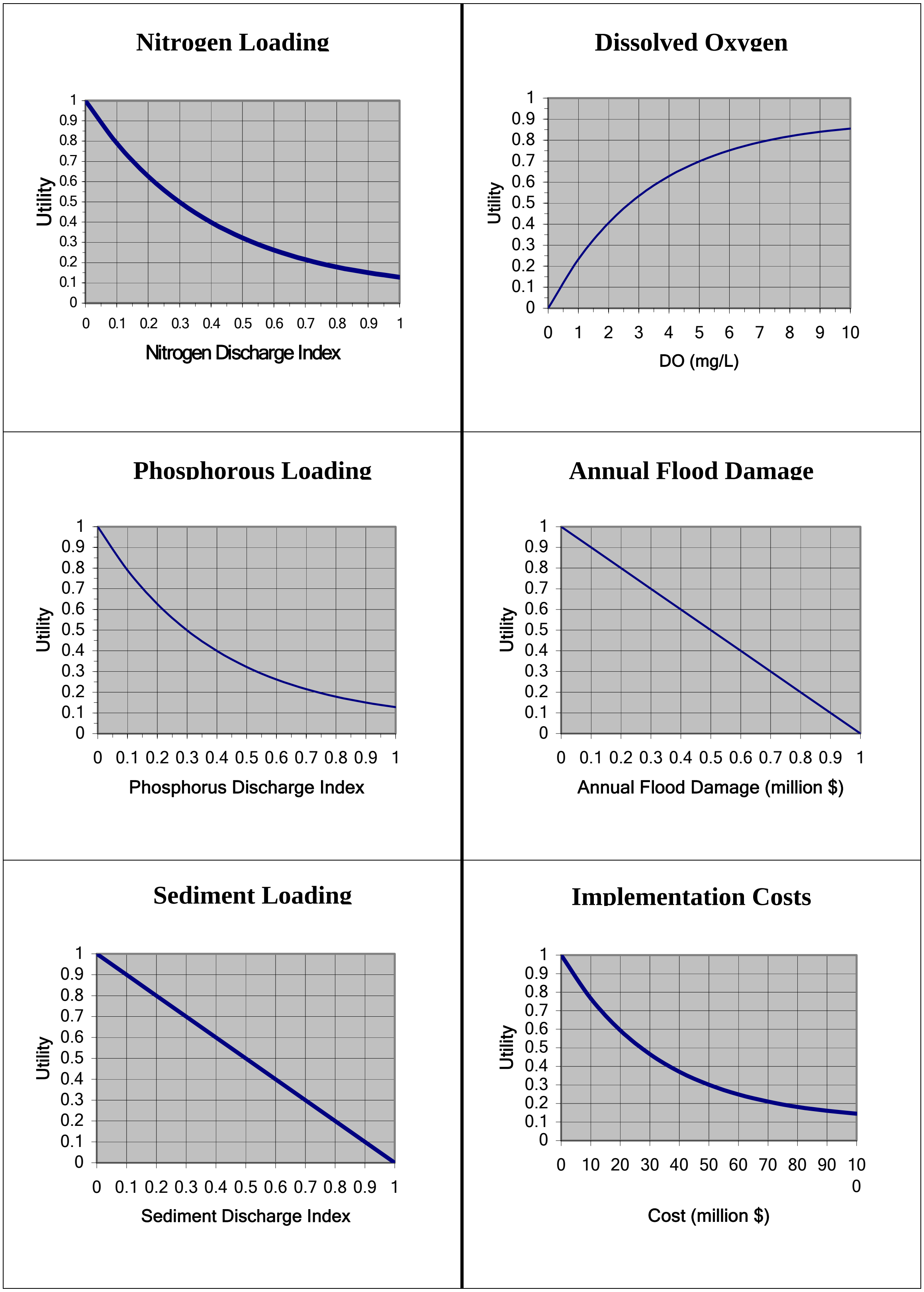


Figure 4-5 (cont.). MAUT: plots to determine decision criteria utility values.

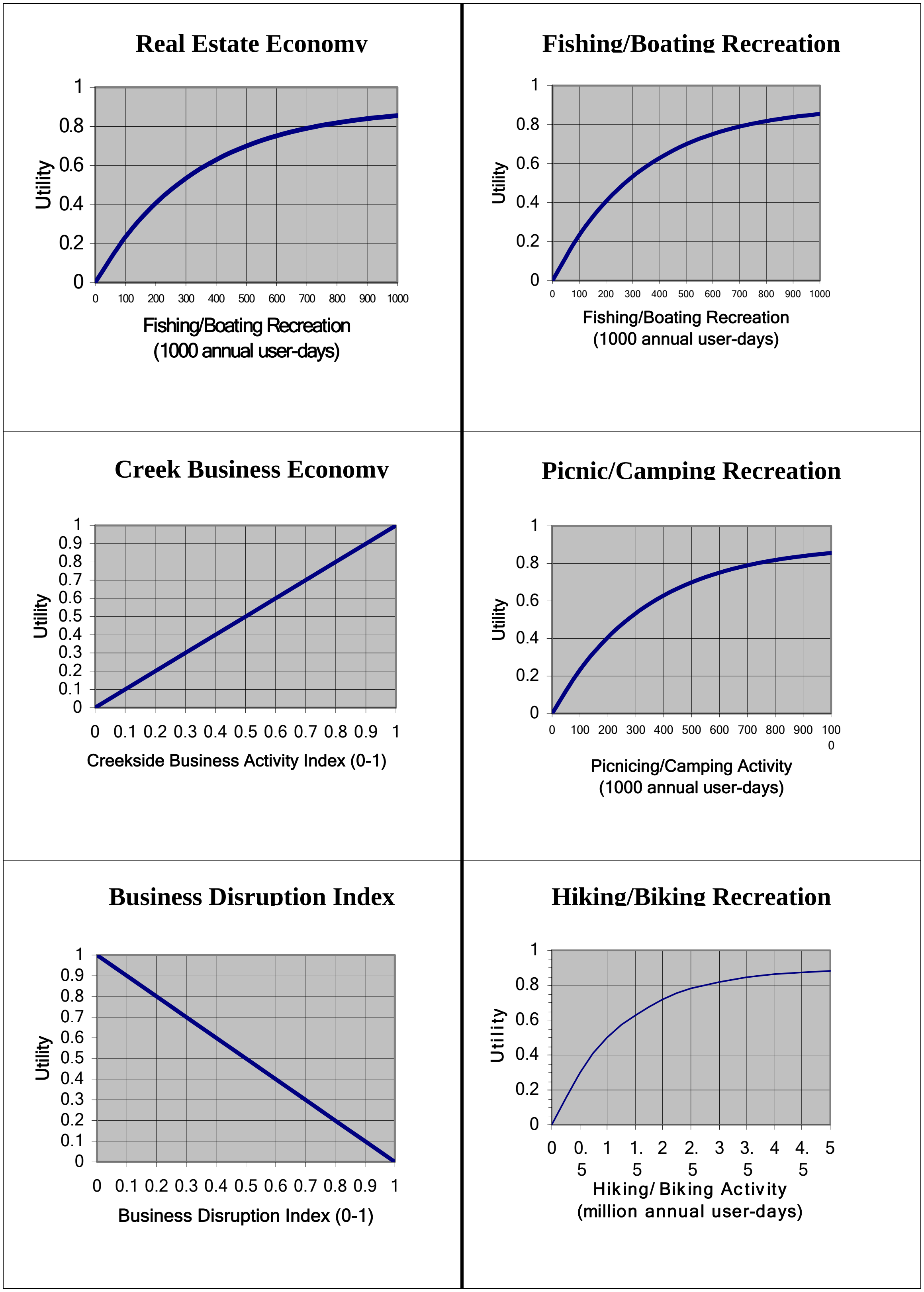
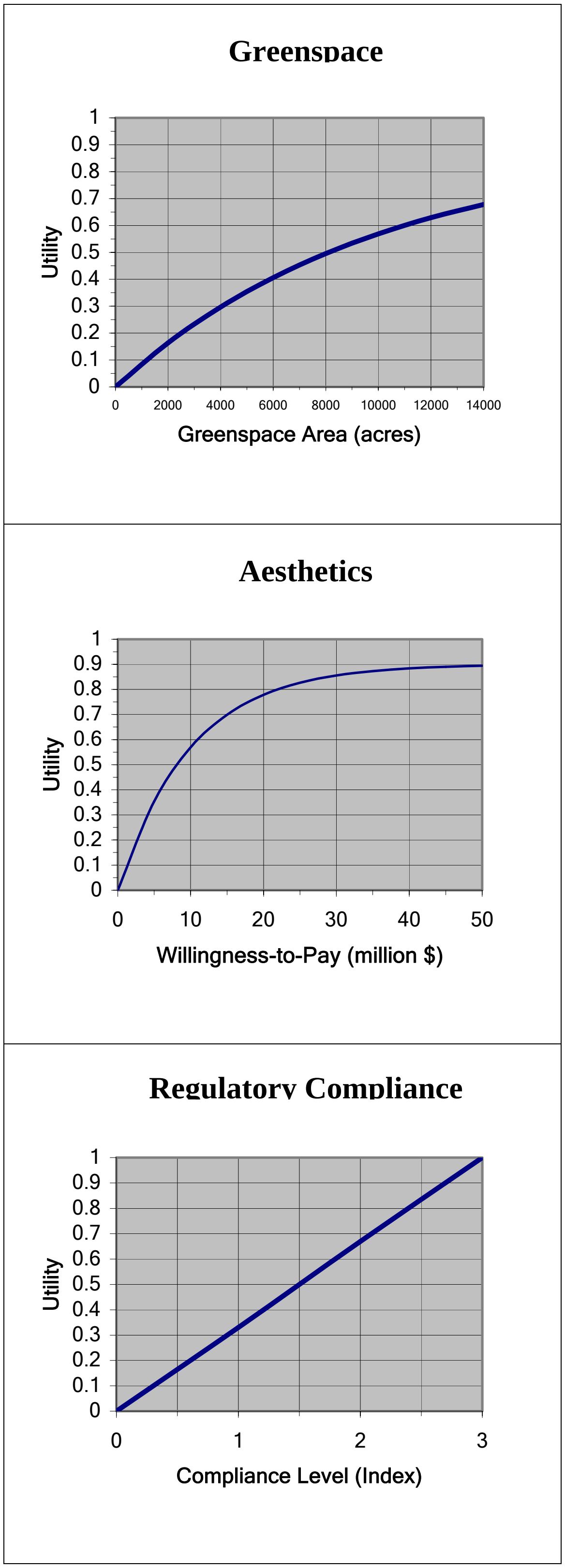


Figure 4-5 (cont.). MAUT: plots to determine decision criteria utility values.



Greenspace

Aesthetics

Regulatory Compliance

Figure 4 5 (cont.). MAUT: plots to determine decision criteria utility values.

Table 4-22. MAUT: Trade-offs for management alternatives.

Stakeholder 1: Environmental Advocate

		Decision Criteria Utility Values				Trade-off Values			
Decision Criteria	**Weights**	**Alt 1 Environment**	**Alt 2 Development**	**Alt 3 Recreation**	**Alt 4 Flood Control**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
lake habitat	0.05	0.3	0.3	0.5	0.8	0.02	0.02	0.03	0.04
water velocity	0.1	0.8	0.1	0.8	0.1	0.08	0.01	0.08	0.01
substrate/cover	0.1	0.9	0.2	0.9	0.2	0.09	0.02	0.09	0.02
riparian quantity	0.1	0.6	0.3	0.6	0.3	0.06	0.03	0.06	0.03
riparian connectivity	0.1	1.0	0.1	1.0	0.1	0.10	0.01	0.10	0.01
coliform bacteria	0.1	0.6	0.0	0.4	0.0	0.06	0.00	0.04	0.00
nitrogen (total)	0.1	0.7	0.1	0.7	0.1	0.07	0.01	0.07	0.01
phosphorous (total)	0.05	0.9	0.0	0.9	0.6	0.05	0.00	0.05	0.03
sediment load	0.1	0.8	0.1	0.8	0.1	0.08	0.01	0.08	0.01
dissolved oxygen	0.1	0.9	0.0	0.9	0.6	0.09	0.00	0.09	0.06
flood protection	0.01	0.2	0.5	0.3	0.1	0.002	0.01	0.003	0.001
implementation cost	0.02	0.5	0.8	0.5	0.2	0.01	0.02	0.01	0.004
real estate cost	0.01	0.8	0.9	0.8	0.7	0.01	0.01	0.01	0.01
creek-side economic activity	0.005	0.8	0.9	0.8	0.9	0.004	0.005	0.004	0.004
business disruption	0.005	0.9	0.2	0.9	0.2	0.005	0.001	0.005	0.001
fishing/boating	0.01	0.8	0.2	0.8	0.9	0.01	0.002	0.01	0.01
picnicking/other	0.01	0.7	0.6	0.8	0.9	0.01	0.01	0.01	0.01
hiking/biking	0.01	0.7	0.6	0.8	0.9	0.01	0.01	0.01	0.01
green space	0.005	0.9	0.6	0.9	0.9	0.005	0.003	0.005	0.005
aesthetics	0.005	0.6	0.5	0.5	0.5	0.003	0.002	0.003	0.003
regulatory compliance	0.01	0.7	0.2	0.7	0.2	0.01	0.002	0.01	0.002
Total	1.000								
					Overall Trade-off Values	**0.75**	**0.16**	**0.75**	**0.27**

Stakeholder 2: Land Development Advocate

		Decision Criteria Utility Values				Trade-off Values			
Decision Criteria	**Weights**	**Alt 1 Environment**	**Alt 2 Development**	**Alt 3 Recreation**	**Alt 4 Flood Control**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
lake habitat	0.05	0.3	0.3	0.5	0.8	0.02	0.02	0.03	0.04
water velocity	0	0.8	0.1	0.8	0.1	0.00	0.00	0.00	0.00
substrate/cover	0	0.9	0.2	0.9	0.2	0.00	0.00	0.00	0.00
riparian quantity	0.05	0.6	0.3	0.6	0.3	0.03	0.02	0.03	0.02
riparian connectivity	0	1.0	0.1	1.0	0.1	0.00	0.00	0.00	0.00
coliform bacteria	0	0.6	0.0	0.4	0.0	0.00	0.00	0.00	0.00
nitrogen (total)	0	0.7	0.1	0.7	0.1	0.00	0.00	0.00	0.00
phosphorous (total)	0	0.9	0.0	0.9	0.6	0.00	0.00	0.00	0.00
sediment load	0	0.8	0.1	0.8	0.1	0.00	0.00	0.00	0.00
dissolved oxygen	0	0.9	0.0	0.9	0.6	0.00	0.00	0.00	0.00
flood protection	0.2	0.2	0.5	0.3	0.1	0.04	0.10	0.06	0.02
implementation cost	0.25	0.5	0.8	0.5	0.2	0.13	0.20	0.13	0.05
real estate cost	0.25	0.8	0.9	0.8	0.7	0.20	0.23	0.20	0.18
creek-side economic activity	0.05	0.8	0.9	0.8	0.9	0.04	0.05	0.04	0.04
business disruption	0.05	0.9	0.2	0.9	0.2	0.05	0.01	0.05	0.01
fishing/boating	0.01	0.8	0.2	0.8	0.9	0.01	0.00	0.01	0.01
picnicking/other	0.01	0.7	0.6	0.8	0.9	0.01	0.01	0.01	0.01
hiking/biking	0.01	0.7	0.6	0.8	0.9	0.01	0.01	0.01	0.01
green space	0.01	0.9	0.6	0.9	0.9	0.01	0.01	0.01	0.01
aesthetics	0.01	0.6	0.5	0.5	0.5	0.01	0.00	0.01	0.01
regulatory compliance	0.05	0.7	0.2	0.7	0.2	0.04	0.01	0.04	0.01
Total	1.000								
					Overall Trade-off Values	**0.57**	**0.64**	**0.60**	**0.40**

Stakeholder 3: Moderate

		Decision Criteria Utility Values				Trade-off Values			
Decision Criteria	**Weights**	**Alt 1 Environment**	**Alt 2 Development**	**Alt 3 Recreation**	**Alt 4 Flood Control**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
lake habitat	0.05	0.3	0.3	0.5	0.8	0.02	0.02	0.03	0.04
water velocity	0.05	0.8	0.1	0.8	0.1	0.04	0.01	0.04	0.01
substrate/cover	0.05	0.9	0.2	0.9	0.2	0.05	0.01	0.05	0.01
riparian quantity	0.05	0.6	0.3	0.6	0.3	0.03	0.02	0.03	0.02
riparian connectivity	0.05	1.0	0.1	1.0	0.1	0.05	0.01	0.05	0.01
coliform bacteria	0.05	0.6	0.0	0.4	0.0	0.03	0.00	0.02	0.00
nitrogen (total)	0.05	0.7	0.1	0.7	0.1	0.04	0.01	0.04	0.01
phosphorous (total)	0.05	0.9	0.0	0.9	0.6	0.05	0.00	0.05	0.03
sediment load	0.05	0.8	0.1	0.8	0.1	0.04	0.01	0.04	0.01
dissolved oxygen	0.05	0.9	0.0	0.9	0.6	0.05	0.00	0.05	0.03
flood protection	0.05	0.2	0.5	0.3	0.1	0.01	0.03	0.02	0.01
implementation cost	0.05	0.5	0.8	0.5	0.2	0.03	0.04	0.03	0.01
real estate cost	0.05	0.8	0.9	0.8	0.7	0.04	0.05	0.04	0.04
creek-side economic activity	0.05	0.8	0.9	0.8	0.9	0.04	0.05	0.04	0.04
business disruption	0.05	0.9	0.2	0.9	0.2	0.05	0.01	0.05	0.01
fishing/boating	0.05	0.8	0.2	0.8	0.9	0.04	0.01	0.04	0.05
picnicking/other	0.05	0.7	0.6	0.8	0.9	0.04	0.03	0.04	0.05
hiking/biking	0.05	0.7	0.6	0.8	0.9	0.04	0.03	0.04	0.05
green space	0.025	0.9	0.6	0.9	0.9	0.02	0.02	0.02	0.02
aesthetics	0.025	0.6	0.5	0.5	0.5	0.01	0.01	0.01	0.01
regulatory compliance	0.05	0.7	0.2	0.7	0.2	0.04	0.01	0.04	0.01
Total	1.000								
					Overall Trade-off Values	**0.72**	**0.33**	**0.73**	**0.43**

4.10.3.2 MAUT – Calculate Trade-Off Values for Management Alternatives

The MAUT formula is applied for each proposed management alternative for each stakeholder. *Table 4-22* shows the “trade-off” values for each decision criterion using the MAUT formula (the weights multiplied times the criteria utilities), and it shows the overall trade-off value for each alternative. For the illustrative example, *Table 4-22* shows that *Stakeholder 1* favors **Alternatives 1** and **3** equally; *Stakeholder 2* favors **Alternative 4**; and *Stakeholder 3* equally favors **Alternatives 1** and **3**. From this evaluation, **Alternatives 1** and **3** could be potentially attractive alternatives to the overall group of hypothetical stakeholders.

4.11 Stakeholder Forum

4.11.1 *Request for Stakeholder Participation*

On June 18, 2001, a letter was sent to approximately 60 watershed residents, representing a cross-section of stakeholders, requesting their participation in a forum scheduled for July 6, 2001. A preliminary report titled *Management Alternative Report* (MAR) was enclosed with the letter. The report summarized watershed conditions, justification for decision criteria, and the management alternatives. In addition, the report contained the information on MCDM tools discussed in this chapter. The purpose of sending the report was to provide stakeholders with enough information to actively participate in the forum. A copy of the MAR is provided in *Appendix E.*

The letter requested confirmation by phone to Dr. Irvin. The results of that request are as follows:

1. 17 stakeholders responded that they would attend; of these, 11 attended.
2. Five responded that they might attend; of these, two attended.
3. Three attended without confirmation.

A total of 16 stakeholders attended the forum.

4.11.2 *Stakeholder Participation in the Forum*

Of the attendees, ten were from city and state agencies, one was from the Nebraska Wildlife Federation, one was from the Joslyn Castle Institute for Sustainability, one was a biologist, and one was from University of Nebraska-Omaha, Environmental Health and Safety. There was little to no representation from the development sector, rural residents, business owners, or commercial property owners.

During the first part of the forum, a review of Papillion Creek watershed issues, a review of the justification for decision criteria and management alternatives, and a review of MCDM concepts and methodology were presented. The PowerPoint™ slides for the presentation are provided in *Appendix F*. During the second part of the forum, the stakeholders used the three MCDM tools to evaluate the four potential watershed management alternatives. Each stakeholder assigned weights and utilities to the decision criteria shown in *Table 4-7* and *Table 4-21*, and then applied the three MCDM tools to score each alternative.

4.11.3 *Stakeholder Evaluation of MCDM*

Prior to leaving the forum, each stakeholder completed a questionnaire regarding the decision-making process and MCDM tools. The questionnaire consisted of 31 questions, which were categorized and analyzed to evaluate stakeholder assessments of the watershed decision-making process and the usefulness of MCDM tools for watershed management. An analysis of stakeholder responses is provided in *Section 5.2*. The questionnaire and compilation of corresponding stakeholder responses are provided in *Appendix G*.

Chapter 5
Results

5.1 Stakeholder Attendance and Participation

As discussed previously, 16 stakeholders out of 60 invitees, who had previously indicated willingness to participate, attended the final stakeholder forum. The low stakeholder attendance significantly limited the stakeholder sample size, which impacted the final results but also provided valuable data for analysis. From the literature (e.g., Berman, 1997; Lawrence and Deagen, 2001; Curry, 1996), and based on discussions with Papillion Creek stakeholders, it appears that several factors may have contributed to the relatively low level of stakeholder participation in this study:

1. Stakeholder perception of the value of the resource to be managed, and whether or not it is in a management crisis;
2. Stakeholder perception of how significantly watershed management decisions will affect the stakeholder (financially, quality of life, etc.);
3. Stakeholder perception that their participation will significantly affect the final management decision.

It is likely that the academic nature of this investigation affected stakeholder participation, given that this study was not an "actual" decision-making process and, therefore, could neither significantly affect the stakeholders directly, nor change management policies that might affect them in the watershed. The group with the highest level of participation was agency representatives who indicated that TMDL and storm water regulations affecting the Papillion Creek would have a significant impact on them and their agencies and, therefore, may have assigned a high value to participation in the study. The development sector was not represented at the forum, indicating the sector may have perceived the study to have low value, would not impact them, and would not significantly affect final watershed management decisions.

It should be noted that after the stakeholder forum, numerous contacts were made with the development sector in an unsuccessful effort to schedule a second stakeholder meeting. This may have been due, in part, to trying to schedule a meeting during the summer, which is generally considered to be a busy time of year for developers. In addition, as discussed previously, it is probable that the academic nature of this investigation unduly influenced their willingness to participate in the study.

This information is important in the assessment of the use of MCDM tools in watershed management decision making and in stakeholder-based decision making for watersheds. If the necessary factors for successful stakeholder-based decision making are not present, it is likely that a representative, fully participating stakeholder group may not persist through the decision-making process, and implementation of other decision-making processes may be necessary. Nevertheless, regardless of the type of decision-making used for watershed management, MCDM can be effective tools for facilitating decision-making for watershed management.

5.2 Survey Results

Stakeholder evaluations provided important information about the overall process. The complete evaluation form can be found in *Appendix G*. Survey results were tabulated and compared to identify trends and responses to certain groupings of questions. *Figures 5-1* through *5-6* show the various analyses.

5.2.1 *Stakeholder Involvement*

Questions 1 to 4, 20, and 26, concern citizen involvement in the watershed decision-making process (see *Figure 5.1*). The responses indicated that stakeholders believe they should be involved in the decision-making process, although they may not have sufficient knowledge to participate effectively. They further indicated that although they would not likely remain engaged in the process, the use of MCDM tools may still help facilitate involvement.

5.2.2 *Stakeholder Understanding*

Questions 4 and 14 reflect the level of understanding of the average stakeholder (see *Figure 5.2*). The survey showed that the respondents felt that stakeholders have insufficient understanding of watersheds to participate in decision-making process, but that MCDM tools would improve stakeholder understanding.

5.2.3 *Preferred Decision-Making Type*

Questions 5a-c, 17, 22-25 are about decision-making styles for watershed management (see *Figure 5.3*). Consensus building among stakeholder groups was clearly the most preferred management style. *Ad hoc* decision making was the least favored. Other data taken from these questions were inconclusive.

5.2.4 *Usefulness of MCDM*

Questions 6, 7, 9-11, 17-19, 21-23 evaluate the perceived usefulness of MCDM tools in watershed management (see *Figure 5.4*). The responses indicated that MCDM tools and their results may properly evaluate decision criteria. Most respondents indicated that MCDM tools could assist decision makers.

5.2.5 *MCDM and Goals*

Questions 12, 13, and 14 evaluate the use MCDM tools to facilitate identification, discussion and understanding of watershed goals and issues (see *Figure 5.5*). The response was positive, with the majority of stakeholders feeling that MCDM helped identify goals, facilitates discussion, and improved understanding of watershed issues.

5.2.6 *MCDM and the Learning Process*

Questions 15, 16, and 18 have to do with how MCDM affects the learning process (see *Figure 5.6*). The stakeholders indicated that working through the MCDM process would help identify issues and alternatives, and improve the learning process.

5.2.7 *Important Factors*

A list of most important to least important factors for management of the Papillion Creek watershed was developed by each stakeholder. The lists appear to be biased, most likely due to the lack of group diversity. In spite of the perceived bias, this group of stakeholders gave the highest number of “1st Concern” responses to “Water Quality” and “Flood Prevention.”

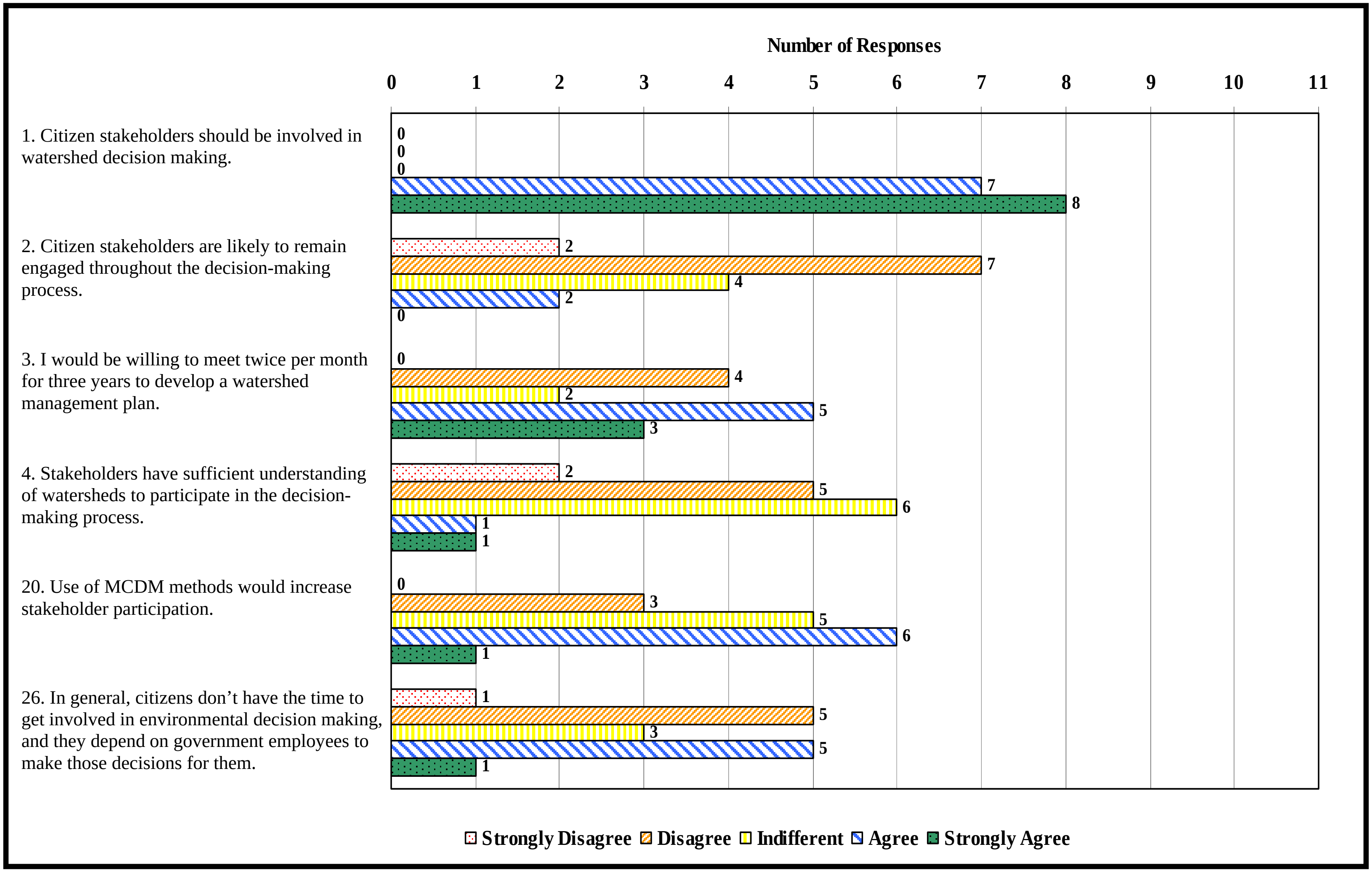


Figure 5-1. Stakeholder Forum Questionnaire: “Stakeholder Involvement.”

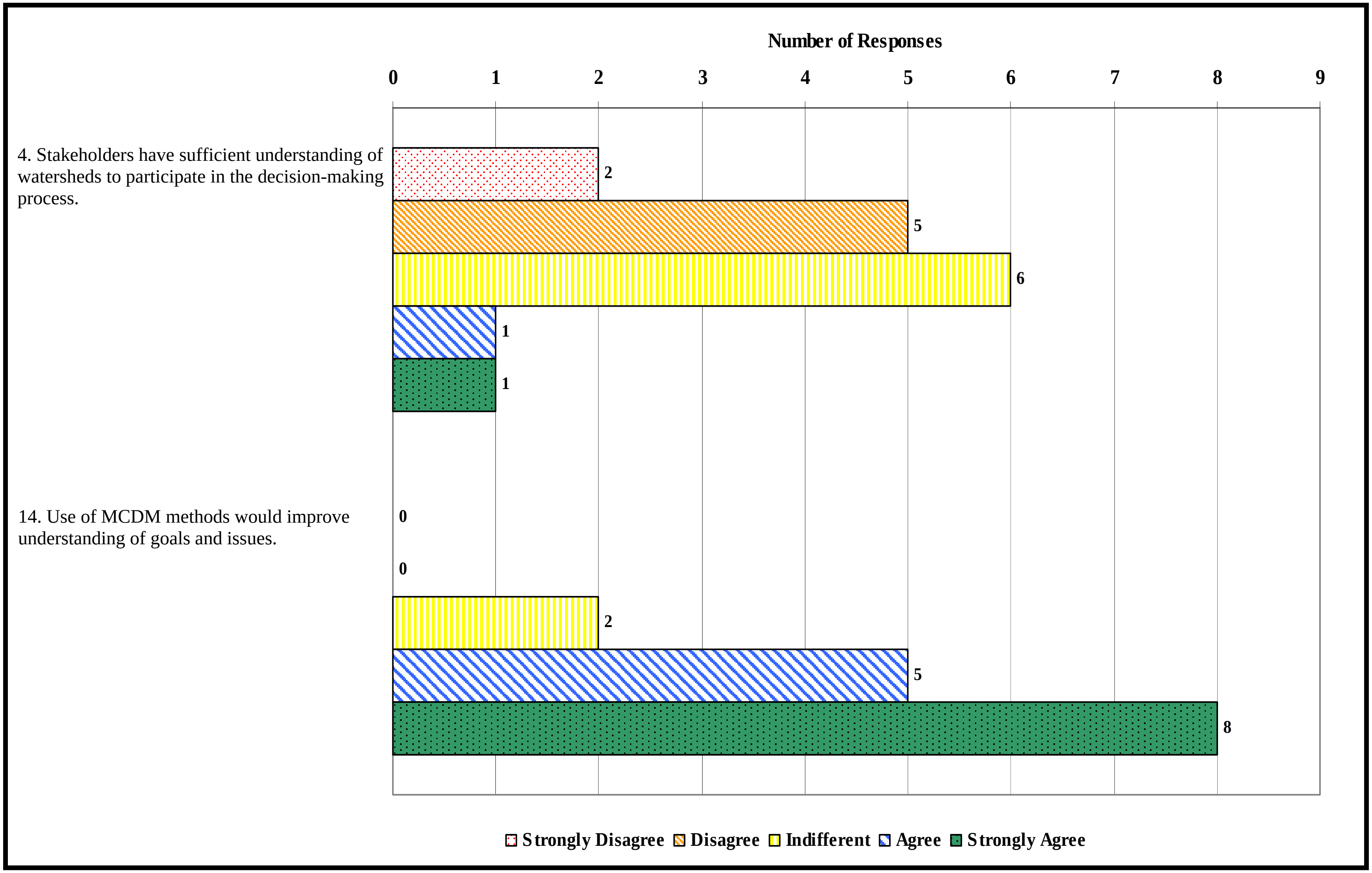


Figure 5-2. Stakeholder Forum Questionnaire: "Stakeholder Understanding."

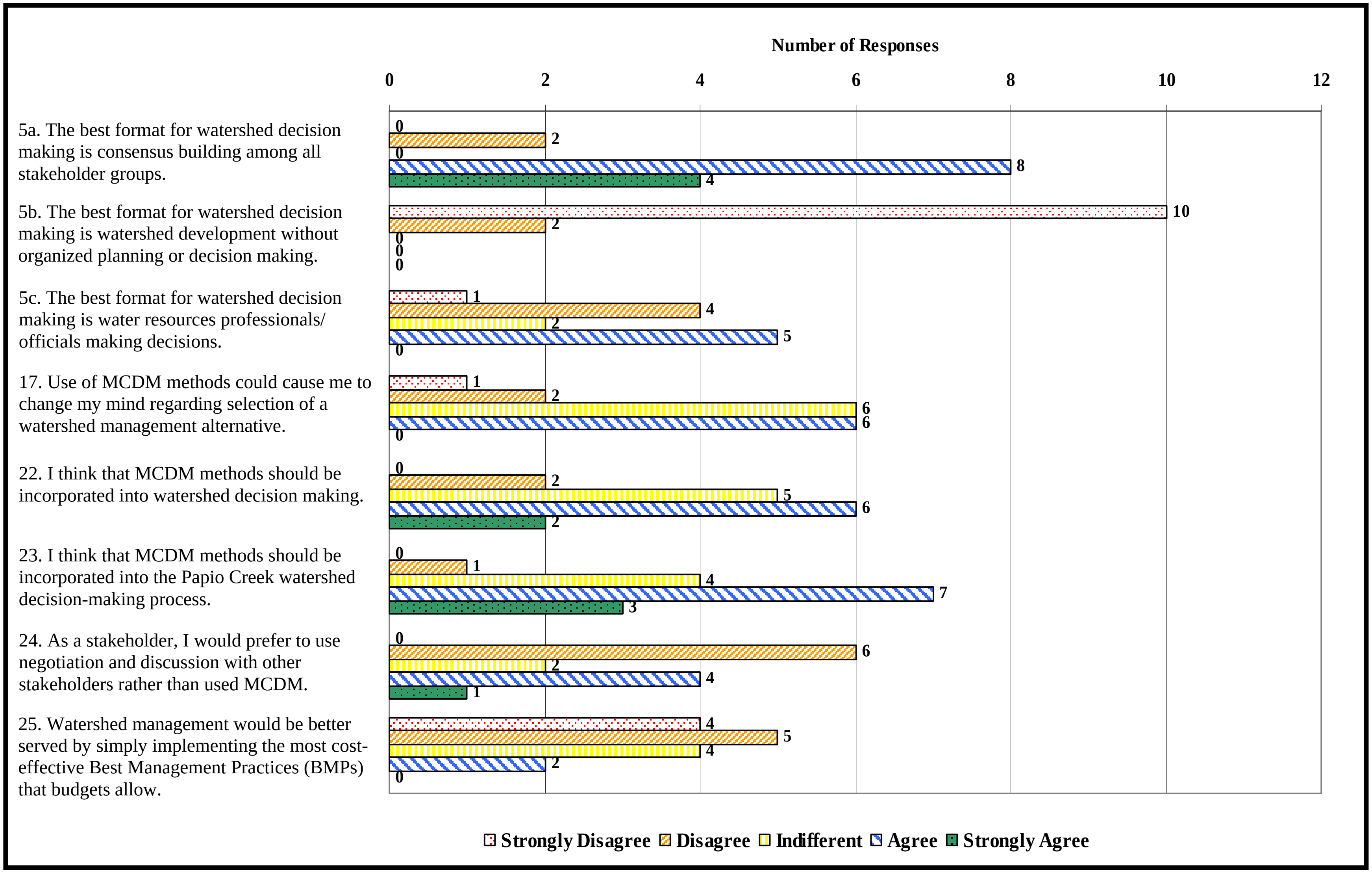


Figure 5-3. Stakeholder Forum Questionnaire: “Preferred Decision-Making Method.”

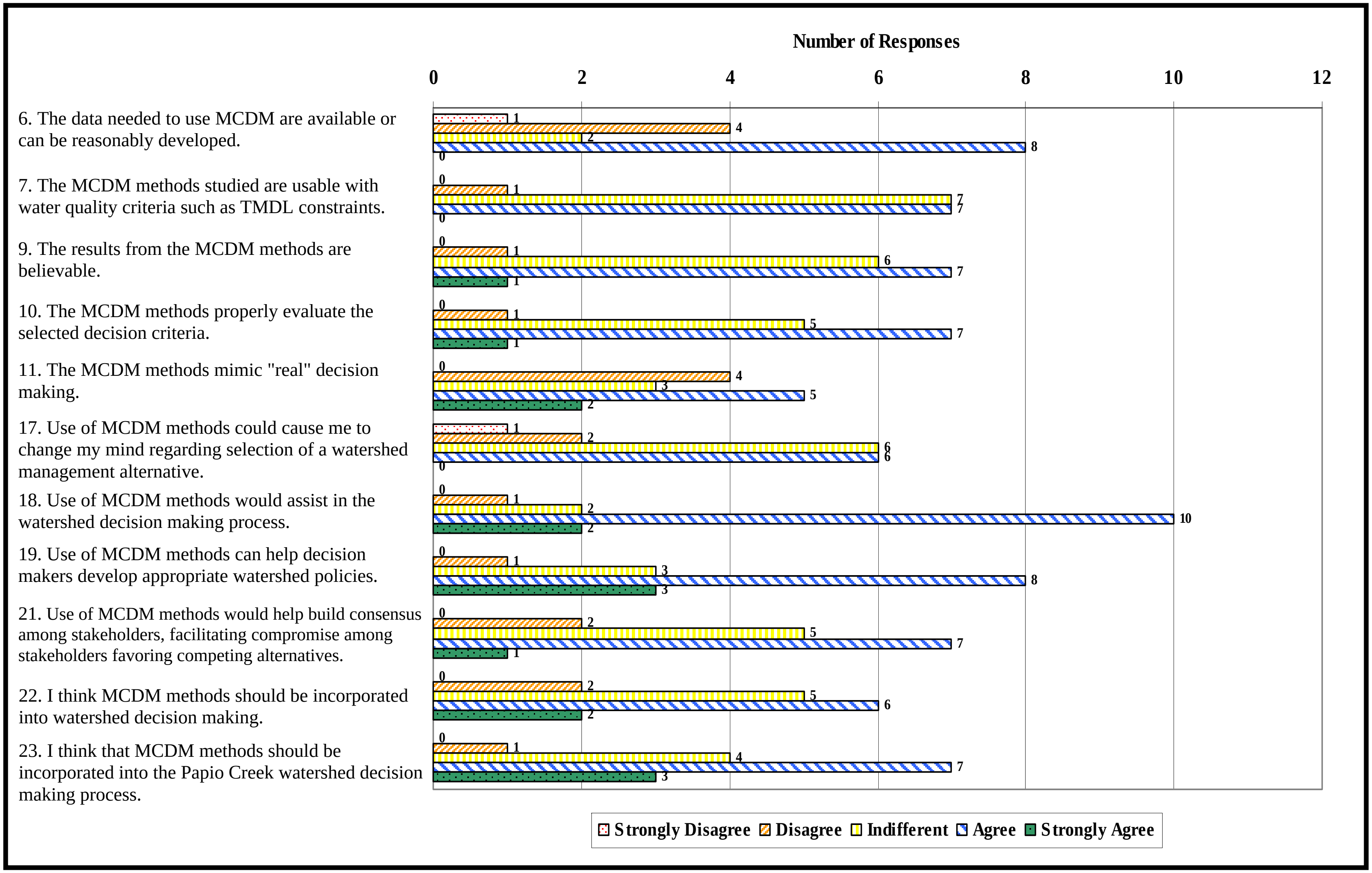


Figure 5-4. Stakeholder Forum Questionnaire: "Usefulness of MCDM Tools."

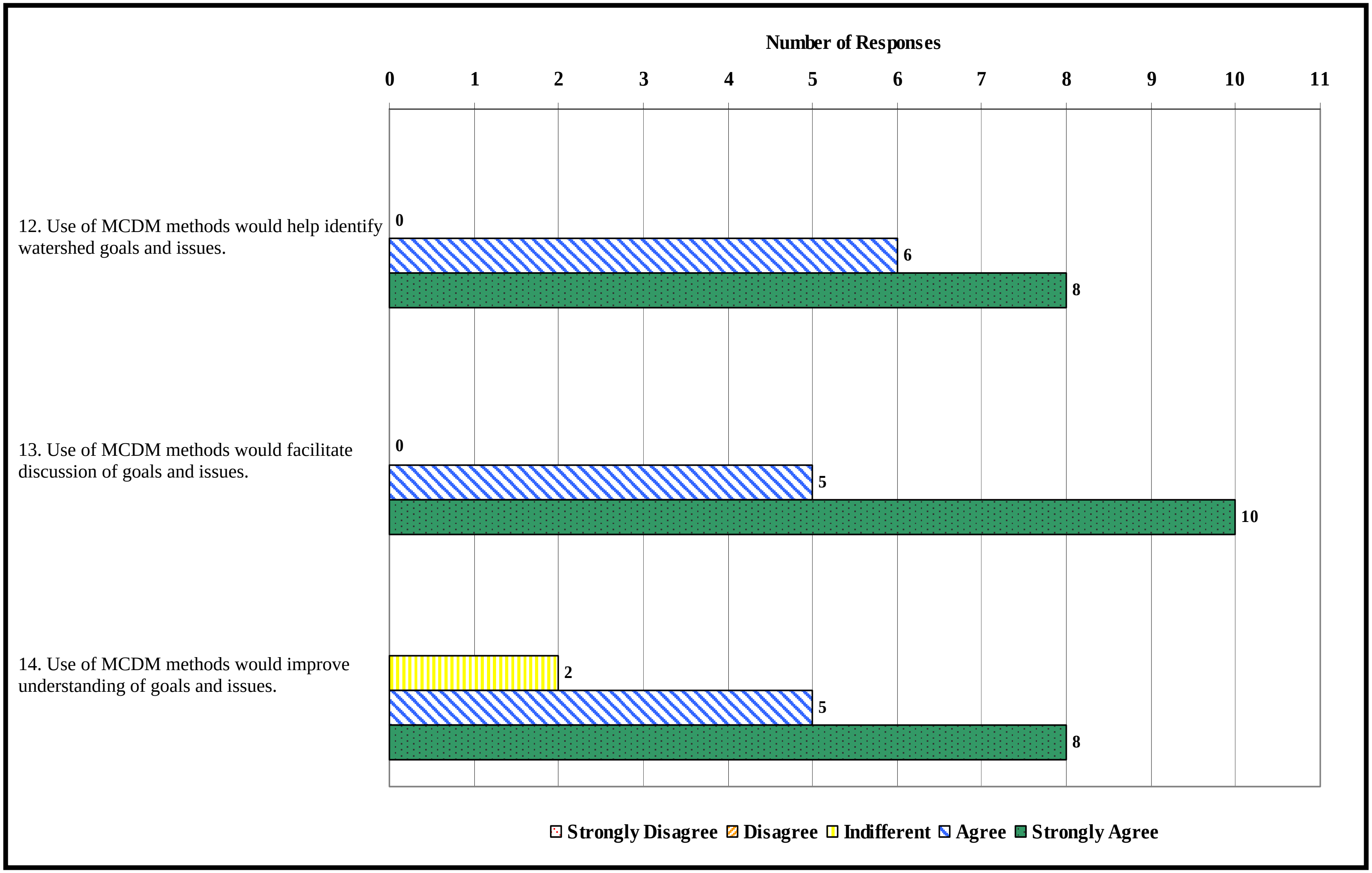


Figure 5-5. Stakeholder Forum Questionnaire: "Use of MCDM Methods Related to Watershed Goals/Issues."

Chapter 6
Conclusions

The overall project objective was to evaluate the use of Multi-Criteria Decision-Making (MCDM) tools to facilitate community-based management of an urbanizing watershed, selecting among competing management alternatives while considering ecological, human health, social, and economic factors defined by a discrete set of parameters. Secondary objectives of the project were to identify critical environmental, social, and economic issues related to the development of management policy for an urbanizing watershed, and to evaluate how different management policies impact those critical issues.

During this study, MCDM tools were effectively used to facilitate identification of critical watershed issues and goals, develop and evaluate management alternatives, educate stakeholders, and provide a platform for a balanced discussion of watershed issues and goals. Though some stakeholders participating in the forum discussed in *Chapter 5* expressed concerns about the complexity of MCDM for use by “lay” people and others expressed concern about the “black-box” nature of the MCDM tools, it was concluded, based on overall results of the study, that MCDM are effective tools for community-based watershed management in an urbanizing watershed.

It follows, therefore, that MCDM tools could potentially be used effectively for watershed management in other watersheds, regardless of location, existing management policies, and management strategies. Furthermore, the use of MCDM tools for watershed management could potentially encourage stakeholder input, facilitate stakeholder education, and facilitate transparency through the decision-making process. As discussed in *Section 6.3*, however, further research would be necessary to investigate the use of MCDM tools for watershed management under different conditions.

Based on the study results, three conclusions can be made regarding stakeholder participation in watershed management.

1. For community-based watershed management and watershed management in general, stakeholder input and participation is essential to develop projects/management alternatives that:
    a. Address a wide range of stakeholder issues;
    b. Have broad stakeholder support;
    c. Consider critical watershed issues and goals.
2. Sustained stakeholder involvement is difficult to obtain and maintain, but is more likely if:
    a. Highly valued resources are at risk;
    b. Controversial projects and/or overall watershed management alternatives are being considered.
3. Effective, ongoing, representative stakeholder participation requires:
    a. Adequate resources (e.g. monetary, dedicated personnel, etc.) to:
        i. Recruit stakeholders;
        ii. Maintain consistent, ongoing efforts to engage them;
    b. Transparency between stakeholder groups and regulatory agencies;
    c. The establishment of clearly defined short-term and long-term watershed management goals early in the process.

6.1 Recommendations

As a result of this study, the following recommendations should be considered:

1. The research should be repeated to investigate the use of MCDM tools for management of watersheds with different decision-making strategies (e.g. government agencies as primary decision-

makers, with little public input, etc.) and/or watershed conditions (rural or urban, mountains or coastal plain, etc.).

2. The research should be repeated using real data, actual proposed management alternatives, and real stakeholders from a real-world pilot or watershed management study, such as the Papillion Creek watershed study performed in the mid-2000s.
3. Further research should be conducted on community-based decision making specifically for watershed management.

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Appendix A

Stakeholder Recruitment Flyer
"Papio Creek Watershed Restoration Study"

Please Join the Team!
Become a community representative by filling out the information below:

Name:________________________

Address:

____

____

Telephone:______________________

Email (optional):

____

Business, School, Organization Affiliation (if any):

____

Do you live or work close to any part of the Papio watershed (Big Papillion, Little Papillion, lakes, etc.) ? If so, describe:

Mail to:
Papio Creek Watershed Project
Dr. Renee Irvin
Department of Public Administration
University of Nebraska- Omaha
Omaha, NE 68182-0276

The Project:
Project leaders John Stansbury (a professor of engineering at UNL) and Renee Irvin (a professor of public administration at UNO) received funding from Region VII of the Environmental Protection Agency to evaluate community involvement in environmental decision-making for the Papillion Creek watershed.

The project will:

- 1) identify and evaluate management alternatives for the watershed
- 2) evaluate economic and environmental impacts of the management alternatives
- 3) evaluate methods to improve decision-making for watersheds like the Papio Creek system.

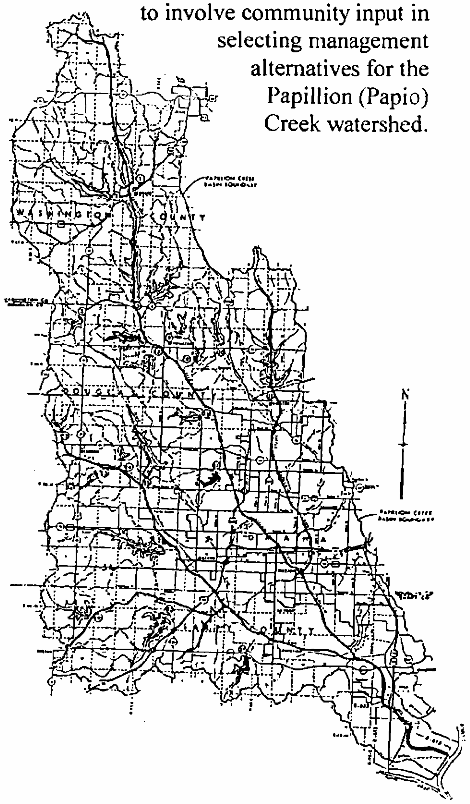
Please feel free to contact our Project Coordinator Chris Swanson for more details about becoming involved as a community representative:

Chris Swanson,
Project Community Coordinator
Papio Creek Watershed Study
Department of Public Administration
University of Nebraska at Omaha
Omaha, NE 68182-0276
Ph. (402) 554-2864
Email: Chris_swanson@unomaha.edu

Papio Creek
Watershed
Restoration Study

Interested in becoming a **decision-maker** for an **important environmental project**?

We invite your participation in a project to involve community input in selecting management alternatives for the Papillion (Papio) Creek watershed.



Papio Creek

Watershed Restoration Study

We need the active involvement of **as many community representatives as possible.** We especially need the involvement of interested citizens. This might include:

- residents living close to Papio Creek
- farm owners/operators near Papio Creek
- business owners/operators near Papio Creek
- representatives of neighborhood groups
- representatives of environmental groups
- students with an interest in environmental planning
- people who engage in recreational activities connected with the Papio Creek system

What will the community representatives do?
During Winter and Spring 2000, community reps will be asked to:

- help identify management alternatives for the watershed (examples might include building dams, building systems to prevent sewer overflows, implementing programs to reduce agricultural runoff, etc.)
- help identify "hot-button" issues associated with the environmental management plans for the watershed
- field-test survey instruments to measure the value of recreational opportunities along the Papio Creek watershed

In the following year (2000-2001), community reps will be asked to answer a survey on environmental benefits of the Creek, or a survey on how the proposed changes in management of the watershed affects businesses and farming. Also, you will be invited to attend some community meetings to evaluate the management plan for the watershed. The time commitment required is minimal..

The model that the **community representatives** develop for environmental decision-making in our project will be applied nationwide for restoration of similar urban watersheds.

Need more information?

The Creek:
Papio Creek, originating in farmland northwest of Omaha, runs through portions of Omaha, Papillion, La Vista and Bellevue before it discharges into the Missouri River. Because of degraded water quality in the Creek, it has been designated by the State of Nebraska as a Priority Watershed for restoration, and use of the stream has been restricted by the Nebraska Department of Environmental Quality.

University of Nebraska-Lincoln
Department of Civil Engineering

University of Nebraska at Omaha
Department of Public Administration

Appendix B

Preliminary List of Papio Creek Watershed Management Alternatives and Stakeholder Review and Feedback

Goals and Proposed Management Alternatives:
Papio Creek Watershed Restoration Study

Introduction

The following preliminary watershed goals, technologies, and alternatives represent the first step in our study of watershed management decision-making. The overall study process will be:

1. identify important issues (i.e. goals) for management of the watershed
2. identify technologies to achieve the watershed goals
3. identify potential management alternatives (i.e., combinations of technologies designed to achieve the management goals).
4. determine impacts caused by the management alternatives (e.g., water quality changes, wildlife habitat changes, costs, benefits)
5. evaluate a variety of decision-making methods to select the most desirable alternative
6. select the best decision-making method and use it to evaluate the Papillion Creek alternatives.

   Note: this is a study of watershed decision-making methods. It is not an attempt to implement any particular management alternative. however, the tools, organization, and information developed in this study should be useful in future decision-making process for this and other watersheds.

Potential Watershed Goals:

Following is a list of potential watershed goals for the Papillion Creek watershed. This list is only meant to be a starting point for discussion. it is not meant to be a final list of watershed goals.

1. Provide good water quality
    - Adequate dissolved oxygen for native aquatic species
    - Low levels of nutrients to avoid eutrophication
    - Low levels of pesticides and other chemicals to avoid health hazard upon water contact and upon fish consumption
    - Low levels of bacteria to avoid health hazard upon water contact

2. Provide good wildlife habitat
    - Riparian (stream-side and bank)
        - Stream-side areas of vegetation including grasses and trees to provide habitat for birds and small animals
    - Aquatic
        - Stream structure (e.g., meanders, bottom substrate) and cover (e.g., vegetation) to provide habitat for native fish and aquatic species
3. Provide recreational opportunities

- Hiking, biking (etc.) trails along streams
- Water sports (e.g., boating in lakes)
- Fishing
- Watershed-related park space

4. Provide opportunity/climate for economic development
    - Agriculture
    - Real estate development
    - Other businesses

5. Provide flood control

6. Provide high quality of life
    - Aesthetically pleasing creek
    - Green space

Potential Technologies

The following technologies could be used, alone or in combination, to help achieve the above potential goals for the Papillion Creek watershed.

1. Water quality

    Combined sewer [sanitary and storm sewers] outflow (CSO) separation
    CSO storage
    CSO disinfection
    Best Management Practices (BMPs) for agricultural land
        Fence livestock from creek and water bodies
        Upland Runoff catchments (e.g., ponds, constructed wetlands) for fields and feedlots
    Best Management Practices for urban and suburban land
        Street/parking lot cleaning
        Fertilizer/pesticide education/management
        Pet manure control
        improvements: terracing, grassed waterways
        Buffer strips (grass and trees) along waterways and creeks
        Fertilizer/pesticide education/management
        Use of pervious surfaces and retention ponds for stormwater

2. Habitat
    Riparian
        Linear parks along creeks
        Forested or grass buffer strips along creeks and waterways

        Natural banks (allow/encourage stream banks to develop natural structure and vegetation rather than having a “bare” levee or cropped land next to stream
    Aquatic
        Restore meanders where stream has been straightened
        Increase plant cover for aquatic species (both instream and bank)
        Restore bottom substrate to natural conditions by reducing sediment load
        Restore hydrology by controlling runoff from agricultural and urban areas

3. Recreation
    Create reservoirs at appropriate locations
    Improve water quality
        Reduce sediment load
        Reduce nutrient load
        Reduce bacteria load (agricultural, suburban, CSO)
    Provide fishing facilities in parks
    Provide canoeing/boating facilities
    Create parks near creeks

4. Economic development
    Foster agricultural production use of watershed
    Foster real estate development in watershed
    Provide recreational opportunities and related businesses
    Provide nice community for workforce to live (aesthetics, parks, water recreation)

5. Flood Control
    Provide bank stabilization to improve flood flow
    Develop higher levees to increase flood protection in low areas
    Build previously planned flood control dams
    Build storage basins (i.e., low areas that will be intentionally flooded during flood events. These basins could be used for other purposes such as parks at other times)
    Build storm water retention facilities for developed areas
    Build storm water retention facilities for new developments
    Install buffer strips to reduce runoff and increase infiltration
    Keep development (urban and agricultural) out of natural flood plains – move development from flood plains
    Build farm ponds and constructed wetland areas to collect runoff

6. High quality of life
    Maintain and enhance property values by providing parks, trails, water access
    Maintain flood control

Provide aesthetically pleasing creek areas
Provide green space
Maintain economic development

Potential Watershed Alternatives

The following are the watershed management alternatives (combinations of technologies that have been selected to evaluate the use of multi-criteria decision-making methods to assist decision-making in the management of the Papillion Creek watershed.

Alternative 1: Environmental Focus

This alternative is designed to restore “natural” ecological and hydrological conditions in and near the creek. The technologies are designed to improve water quality, provide wildlife habitat, and reduce peak flows in the creek.

1. Install buffer strips (grass and trees) on all perennial and intermittent streams.
    a. 100 feet per side for perennial streams
        i. 132 linear miles of stream at 100 feet wide per side (6273 acres)
        ii. costs:
            1. land acquisition and/or easement: 6273 acres @ $3000/acre = $18,819,000
            2. buffer installation: 6273 acres @ $300/acre = $1,881,900
    b. 75 feet per side for intermittent streams
        i. 169 linear miles of stream at 75 feet wide per side (3072 acres)
        ii. costs:
            1. land acquisition and/or easement: 3072 acres @ $3000/acre = $9,216,000
            2. buffer installation: 3072 acres @ $300/acre = $921,600
2. Install planned parks along creek.
    a. Tranquillity Nature Preserve
        i. 120th and Fort to 156th and Bennington Road
        ii. cost: no additional cost; project is currently planned by city
    b. Cunningham Nature Preserve
        i. 96th and Bennington Road to 96th and Dutch Hall Road
        ii. cost: no additional cost; project is currently planned by city
    c. Nature preserve near Kennard at confluence of the NW Branch and Big Papio
        i. cost:
            1. land: 320 acres @$4000/acre = 1,280,000
            2. development: assume $3000/acre = $960,000
3. Install grade control structures to restore hydraulic gradient where natural meanders have been removed (i.e., where streams have been channelized and straightened).
    a. assume 20 grade control structures will be installed throughout the watershed

      i. costs: $30,000 per structure = $600,000
      ii. locations to be determined

4. Install bank stabilization structures to mange lateral stream migration and reduce sediment load to stream from bank erosion.
   a. Assume 20 bank stabilization structures will be installed throughout the watershed
      i. costs: $30,000 per structure = $600,000
      ii. locations to be determined
5. Move levees back to 500 feet per side where development allows.
   a. assume 7 linear miles of stream treated: 4 miles on the Big Papio between Harrison Street and Highway 370, and 3 miles from 72nd Street to 36th Street on the West Branch
   b. costs:
      i. land acquisition and/or easement: 848 acres @ $5000/acre = $4,240,000
      ii. construction: 7 miles @ $1,000,000 per mile = $7,000,000
6. Implement Best Management Practices (BMPs) for agricultural land. Currently, approximately 40% of the agricultural land is in need of further conservation management treatment. BMPs for the watershed land include fencing livestock out of waterways, terracing steep cultivated land, planting waterways to grass, implementing conservation tillage, installing farm ponds to trap runoff and sediment and to increase infiltration, and installing livestock waste control facilities for feedlot operations.
   a. fence livestock from all perennial and intermittent streams
      i. assume 50 miles of fencing along streams
      ii. cost: 50 miles @ $10,000/mile = $500,000
   b. install contour terracing (3,000,000 feet)
      i. cost: 3,000,000 feet @ $1.00/foot = $3,000,000
   c. install grassed waterways (700 acres)
      i. cost: 700 acres @ $2000/acre = $1,400,000
   d. implement conservation tillage practices
      i. cost: 50,000 acres @ $30/acre = $1,500,000
   e. install farm ponds
      i. assume 20 ponds
      ii. cost: $80,000 per pond = $1,600,000
   f. install livestock waste control facilities
      i. assume four facilities
      ii. cost: 4 facilities @ $10,000/facility = $40,000
7. implement BMPs for urban and suburban land.
   a. implement street and parking lot cleaning
      i. cost: no additional cost; already planned or implemented by the city
   b. implement chemical application education
      i. public service announcements, elementary school programs
      ii. cost: $10,000/year
   c. install stormwater retention systems for established developments

    i. current development in watershed = 90 mi^2
    ii. install stormwater retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of approximately 153,000 ft^3 (e.g., approximately 125 ft x 10 ft deep) will be required
    iii. cost: assume $50,000 each; 45 mi^2 x 4 x $50,000 = $9,000,000
  d. install stormwater retention systems for new developments
    i. assume additional urban development of 45 mi^2 in the watershed.
    ii. install retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of 153,000 ft^3 (e.g., 125 ft x 125 ft x 10 ft deep) will be required.
    iii. Cost: assume $50,000 each; 45 mi^2 * 4 * $50,000 = $9,000,000
8. implement CSO separation on Cole Creek
  a. plan
  b. costs

Alternative 2: Development Focus

This alternative represents the prevalent current function of the watershed. The creek system is used primarily as a conduit to remove runoff and flood waters. The use of the land for agriculture and urban development is emphasized.

1. foster real estate development (no new controls).
    a. assume additional urban development of 45 mi^2 primarily in Douglas county west and northwest of Omaha
2. foster agricultural land use (no new controls)
    a. assume current agricultural land use on land not converted to urban developments
3. make channel improvements to improve flood control
    a. channelize, stabilize, and add levees to Big Papio from Center Street to Fort Street ($7,900,000)
    b. channelize, stabilize, and add levees to West Branch from 90th to Lake Zorinsky outlet ($4,800,000)
    c. raise established levees to restore 100 year flood protection
        i. established levees are: L Street to confluence with Missouri River for the Big Papio and 90th Street to confluence with the Big Papio for the West Branch
        ii. assume 24 miles @ $400,000/mile = $9,600,000

Alternative 3: Recreational Focus

This alternative is designed to maximize recreational opportunities in the watershed.

1. build dam 3 (on the Big Papio, near 180th Street and Washington, Douglas County line)
    a. cost: $20,000,000
2. build dam 12 (on the West Branch, near 216th Street and West Maple Road)
    a. cost: $3,000,000
3. build dam 13 (on the West Branch, near 192nd and Blondo)
    a. cost: $3,000,000
4. install linear park system: all linear parks planned by Douglas County plus similar parks in Sarpy and Washington (linear parks and trails for all perennial streams)
    a. Tranquility Nature Preserve
        i. 120th and Fort to 156th and Bennington Road
    b. Cunningham Nature Preserve
        i. 96th and Bennington Road to 96th and Dutch Hall Road
    c. nature preserve near Kennard
        i. land cost: 320 acres @$4000/acre = $1,280,000
        ii. construction cost: assume $1500/acre = $480,000
    d. hiker/biker paths along creeks (assume 50 miles of additional trails)
        i. hiker/biker paths to headwaters of : Little Papio, Thomas Creek, Big Papio, West Branch, and North Branch of West Branch
        ii. cost: $150,000/mile * 50 miles = $7,500,000
5. implement Best Management Practices (BMPs) for agricultural land. Currently, approximately 40% of the agricultural land is in need of further conservation management treatment. BMPs for the watershed land include fencing livestock out of waterways, terracing steep cultivated land, planting waterways to grass, implementing conservation tillage, installing farm ponds to trap runoff and sediment and to increase infiltration, and installing livestock waste control facilities for feedlot operations.
    a. fence out livestock from all perennial and intermittent streams
        i. assume 50 miles of fencing along streams
        ii. cost: 50 miles @ $10,000/mile = $500,000
    b. install contour terracing (3,000,000 feet)
        i. cost: 3,000,000 feet @ $1.00/foot = $3,000,000
    c. install grassed waterways (700 acres)
        i. cost: 700 acres @ $2000/acre = $1,400,000
    d. implement conservation tillage practices
        i. cost: 50,000 acres @ $30/acre = $1,500,000
    e. install farm ponds
        i. assume 20 ponds
        ii. cost: $80,000 per pond = $1,600,000
    f. install livestock waste control facilities (4)
        i. cost: 4 facilities @ $10,000/facility = $40,000

6. Implement BMPs for urban and suburban land.
    a. implement street and parking lot cleaning
        i. cost: no new cost; city is currently implementing this practice
    b. implement chemical application education
        i. public service announcements, elementary school programs
        ii. cost: $10,000/year
    c. install stormwater retention systems for established developments
        i. current development in watershed = 90 mi2
        ii. install retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of approximately 153,000 ft3 (e.g., 125 ft x 125 ft x 10 ft deep) will be required.
        iii. cost: assume $100,000 each; 90 mi2 * 4 * $100,000 = $36,000,000
    d. install stormwater retention systems for new developments
        i. assume additional urban development of 45 mi2 in the watershed.
        ii. install retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of 153,000 ft3 (e.g., 125 ft x 125 ft x 10 ft deep) will be required.
        iii. Cost: assume $50,000 each; 45 mi^2 * 4 * $50,000 = $9,000,000

Alternative 4: Flood Protection Focus

This alternative is designed to provide a high level of flood control for the watershed. It uses conventional flood control methods such as dams, levees, and channel improvements.

1. build dam 1 (near Kennard).
    a. cost = $20,000,000
2. build dam 2 (near Kennard).
    a. cost = $20,000,000
3. build dam 3 (near 180th and Washington, Douglas county line).
    a. cost = $20,000,000
4. build dam 4 (near 168th Street and Washington, Douglas county line)
    a. cost $15,000,000
5. build dam 12 (near 216th and West Maple Road).
    a. cost = $3,000,000
6. build dam 13 (near 192nd and Blondo).
    a. cost = $3,000,000
7. make channel improvements to improve flood control
    a. channelize, stabilize, and add levees to Big Papio from Center Street to Fort Street ($7,900,000)
    b. channelize, stabilize, and add levees to West Branch from 90th Street to Lake Zorinsky outlet ($4,800,000)
    c. raise established levees to restore 100-year flood protection
        i. established levees are: L Street to confluence with Missouri River for the Big Papio and 90th Street to confluence with the Big Papio for the West Branch
        ii. Assume 24 miles @ $400,000/mile = $9,600,000

Alternative 5: Flood Protection Focus (Non-Conventional)

This alternative is designed to provide increase flood control using non-conventional methods. These methods capture stormwater on-site, increase infiltration, and thus reduce runoff to the streams.

1. Install buffer strips (grass and trees) on all perennial and intermittent streams.
    a. 100 feet per side for perennial streams
        i. 132 linear miles of stream at 100 feet wide per side (6273 acres)
        ii. costs:
            1. land acquisition and/or easement: 6273 acres @ $3000/acre = $18,819,000
            2. buffer installation: 6273 acres @ $300/acre = $1,881,900
    b. 75 feet per side for intermittent streams
        i. 169 linear miles of stream at 75 feet wide per side (3072 acres)
        ii. costs:
            1. land acquisition and/or easement: 3072 acres @ $3000/acre = $9,216,000
            2. buffer installation: 3072 acres @ $300/acre = $921,600
2. install planned parks along creek
    a. Tranquility Nature Preserve
        i. 120th and Fort to 156th and Bennington Road
    b. Cunningham Nature Preserve
        i. 96th and Bennington Road to 96th and Dutch Hall Road
    c. Nature preserve near Kennard
        i. land cost: 320 acres @$4000/acre = $1,280,000
        ii. construction cost: assume $1500/acre = $480,000
3. install grade control structures to restore hydraulic gradient where natural meanders have been removed (i.e., where streams have been channelized and straightened)
    a. 20 grade control structures will be installed throughout the watershed
        i. costs: $30,000 per structure = $600,000
        ii. locations to be determined
4. Install bank stabilization structures to mange lateral stream migration and reduce sediment load to stream from bank erosion.
    a. 20 bank stabilization structures will be installed throughout the watershed
        i. costs: $30,000 per structure = $600,000
        ii. locations to be determined
5. Move levees back to 500 feet per side where development allows
    a. assume 7 linear miles of stream treated: 4 miles on the Big Papio between Harrison Street and Highway 370, and 3 miles from 72nd Street to 36th Street on the West Branch
    b. costs:
        i. land acquisition and/or easement: 848 acres @ $5000/acre = $4,240,000
        ii. construction: 7 miles @ $1,000,000 per mile = $7,000,000

6. Implement Best Management Practices (BMPs) for agricultural land. Currently, approximately 40% of the agricultural land is in need of further conservation management treatment. BMPs for the watershed land include fencing livestock out of waterways, terracing steep cultivated land, planting waterways to grass, implementing conservation tillage, installing farm ponds to trap runoff and sediment and to increase infiltration, and installing livestock waste control facilities for feedlot operations.
    a. install contour terracing (3,000,000 feet)
        i. cost: 3,000,000 feet @ $1.00/foot = $3,000,000
    b. grassed waterways (700 acres)
        i. cost: 700 acres @ $2000/acre = $1,400,000
    c. implement conservation tillage practices
        i. cost: 50,000 acres @ $30/acre = $1,500,000
    d. Install farm ponds
        i. assume 20 ponds
        ii. cost: $80,000 per pond = $1,600,000
        iii. locations to be determined
7. Implement BMPs for urban and suburban land
    a. Install stormwater retention systems for established developments
        i. current development in watershed = 90 mi2
        ii. install stormwater retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of approximately 153,000 ft3 (e.g., approximately 125 ft x 125 ft x 10 ft deep) will be required
        iii. cost: assume $50,000 each; 90 mi^2 x 4 x $100,000 = $36,000,000
    b. install stormwater retention systems for new developments
        i. assume additional urban development of 45 mi2 in the watershed.
        ii. install retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of 153,000 ft3 (e.g., 125 ft x 125 ft x 10 ft deep) will be required.
        iii. Cost: assume $50,000 each; 45 mi2 * 4 * $50,000 = $9,000,000

Stakeholder Review and Comments Regarding Management Alternatives

Questionnaire Responses—Potential Watershed Management Alternatives

July 20, 2000, transcribed from original, handwritten responses.

1. After reading the potential watershed goals and alternatives, what potential alternatives (if any) have we left out?

   "The need for serious flood control along streams along which most land on both sides have been developed. Declaring a moratorium on further hardsurfacing in theses watersheds until solutions are developed."
   --Dennis Buller

   "An alternative which may just be an addition to another method would be to install drop structures at regular intervals to raise the creek level to where bank stabilization is no longer a problem.
   "On my land the banks keep getting higher due to sedimentation on the land adjacent to the creek and erosion of the creek bottom. The creek floods our land regularly but we do not have erosion problems due to this flooding. I think the benefits of flooding may be greater than the inconveniences, so the prevention of flooding is not important to me. We have a few feet of low brome grass levees along our banks and drop culverts to reduce run off erosion.
   "The methods description were so brief that one doesn't know what would be an alternative plan. With this in mind I would suggest that any changes to current farming practices be induced with incentive payments and any land diverted from current uses be purchased by public purpose condemnation procedures."
   --No name

   "OK"
   --No name

   "I think you adequately cover goals.
   "On alternatives, I'd like to see combinations with alternatives 2,3,4 & 5 such as you did with the first. Since the Papio was channelized in the 60s and 70s with the intention of flood control, it would seem this would be a likely starting point with modifications from there.
   "Alternatives 2 and 4 seem aimed at developers. None of the alternatives seems targeted to agricultural use—perhaps there should an alternative specifically for them which would include preservation of agricultural land within the Omaha/Bellevue/Millard/Papillion metropolitan areas.
   "Additionally, although it doesn't us closer to the stated watershed goals, doing is also an alternative that always exist."
   --Dave Mucia

   "Seems that none were left out."
   --No name

“Construction of dams in western Douglas County in addition to those in the Kennard and Bennington areas.”
--No name

“I can not think of any alternatives that have been left out.
“Does the recreation component work in conjunction with agencies responsible for hiking/biking trails?
“I believe the proposed Southpoint development (132nd & Harrison) is near a branch of the Papio and hiking/biking trails could add aesthetically to this area.”
--No name

“Looks like a comprehensive list”
--Douglas Cook
County Planner
Washington County Planning Department

2. In general, what is your reaction to the alternatives listed?

“Pretty good overall list. If the numbering indicates priority, then I believe a re-arrangement is required.”
--Dennis Buller

“Based on the thoughts given in answer to the first question , constrution of 100 year levees don’t seem practical.
“Some of the land adjacent to the creek is very good farm land and shouldn’t be converted to other uses unless there is a proven benefit.
“Except for the two thoughts in the previous paragraph, I am not immediately offended by any of the proposals but there is not enough detail in any of them to have an informed opinion and so I reserve judgment until I see more details.
“Even with the most detailed plans there are going to be unforeseen consequences. There need to be straightforward methods in place for farms to obtain compensation for any unforeseen costs resulting from the implementation of these methods. For example, increasing numbers of deer or beaver can cause crop losses and erosion.”
--No name

“OK”
--No name

“My reaction is pretty positive to the alternatives listed. There are plenty of alternatives to both developers and environmentalists. It might seem though that the agricultural side is somewhat neglected. What is ‘pet manure control’?”
--Dave Mucia

“Seems to be a good list of alternatives”
--No name

"Riparian Habitiat – the idea recommendation that "natural structure" be allowed to develop is not compatible with the flood control project. Trees and shrubs do not belong on levees or channels needed for conveyance of floodwaters. Trees and shrubs also impede conveyance and may increase flood heights.
"Flood Control - raising levees and/or moving them 500 feet away from channel is not feasible. The main problems are the cost of land in the area and the restrictions of filling and working in the floodway."
--No name

"Throughout the Papio Watershed, a combination of the alternatives may need to be used. I am aware of the importance of flood control and concerned that the community has adequate flood control management. Flood control needs adequated management and then development-commercial and recreational-should be maximized."
--No name

"How about a mix of alternative 1A and 2?
--Douglas Cook
County Planner
Washington County Planning Department

3. What do you anticipate will be the "hot-button" issues associated with the goals/ (That is, for what issues do you anticipate a strong reaction from community groups when these management alternatives are proposed? Note that businesses, farms, homeowners, and government agencies may have competing objectives—and these competing interests will create the hot button issues.)

"Recreational vs. required buffers and waterways on agricultural
"Flood control dams vs. loss of productive land
"Creating idealistic stream environment vs. tax burden as unnecessary"
--Dennis Buller

"Will farmers be fairly compensated for farm land lost and possible costs and inconveniences resulting from the implementation of the proposal?"
--No name

"Hot Buttons = Dams and Farmers in Washington County"
--No name

"Hot button issues:
"-Sarpy and Douglas counties have done little to restrict development, create 'green space', or limit sprawl. Any goal or alternative that focus on restrictions to development would, in my opinion generate a conflict from the developers and those on city/county boards that may infer a threat to future tax base.
"-More dams – for the same reasons as listed above, plus it would likely take

agricultural land. It would, I suppose, profit a few developers that would surround the areas with high-value homes.
”-Widening levees and installing buffer strips – again same reasons.
”-Restrictions of fertilizer use, fencing livestock. Pre-existing use will probably drive the argument here.
“Unfortunately, while the creek/levee use has really grown with the installation of the trails, I doubt if developers or the cities/counties see much in the way of positive economic impact from this.” (Continued, find sheet)
--Dave Mucia

“Providing Opportunity/Climate for Econ. Development”
--No name

“personal property rights -- this issue always comes up when private property needs to be acquired for a public use.
“manipulation of flood heights (higher or lower) raises numerous development issues.”
--No name

“People owning land at proposed dam sites may not want to sell their land. If something positive can be done with Papio watershed and Southpoint, that would be some good press for the Papio watershed.”
--No Name

“The general “hot button” issue will be “the government taking our land.” There must be a “give and take” attitude present.
“If flood protection is necessary, then stress that it can be done and still not greatly impact agriculture and can benefit development.”
--Douglas Cook
County Planner
Washington County Planning Department

Appendix C

Papio Creek Community Benefit Survey and Results

Papio Creek Community Benefit Survey

Greetings! Please contribute a few moments of your time to complete the following survey of community benefits associated with the Papio Creek watershed.

Background

The area of land surrounding and drained by the Papio Creek, known as the Papio watershed, is extensive. The Creek originates in farmland north and west of Omaha in Washington County and extends south and east through Omaha and several municipalities before entering the Missouri River in Sarpy County south of Offutt Air Force Base. Along the watershed, flood control projects have created the lakes Cunningham, Standing Bear, Zorinsky, and Wehrspann. The Papio watershed includes the Big Papillion, Little Papillion, West Branch, South Branch, North Branch and other creeks.

Because of degraded water quality, contaminated sediment and unsafe fish tissue levels in the various branches of Papio Creek, public use of the Creek has been restricted by the Nebraska Department of Environmental Quality. Area-wide agencies are looking at possible ways of restoring the quality of the creeks and lakes in the Papio system watershed.

Professor John Stansbury of UNL Department of Engineering and Professor Renee Irvin of UNO Department of Public Administration recently received grant funding to measure environmental and economic effects of improving the watershed. In order to do so, however, we need ***careful estimates*** of the ***value to community members*** of improved water quality in the Papio Creek watershed.

Please take a minute to fill out the enclosed questionnaire. Please do not fill out more than one questionnaire, and consider your answers carefully so that the survey provides accurate results regarding your preferences.

The survey comes with a return-addressed envelope so all you need to do is mail the survey back when finished. Your answers will be strictly ***confidential and anonymous. No personal information will be released.***

Thank you for your participation!

1. <u>What sort of recreational activities do you pursue that involve the Papio Creek watershed creeks and lakes? (circle any that apply, and indicate how often you do this activity)</u>

   a. **Fishing** in area lakes (how many times per year?)

   b. **Walking/hiking/jogging** on trails (how many times per year)

   c. **Bicycling** on trails (how many times per year?)

   d. **Inline skating** on trails (how many times per year?)

   e. **Picnicking, visiting** (how many times per year?)

   f. **Other (Boating, Camping, Horseback riding, etc.)** Describe, and estimate how many times per year:

2. <u>The activities listed above are often free, yet there are some indirect costs to those activities that we'd like to count. What costs do you incur that are related to the above recreational activities? (Please include *only* the portion of your costs that are specific to the Papio Creek watershed area.)</u>

   a. Driving to lakes/trails, annual mileage:

   b. Other transportation costs annually:

   c. Fishing license, annual cost:

   d. Camping costs annually:

   e. Boating annual costs (maintenance, fees, etc.):

f. Other gear costs (fishing poles, bait, skates, running shoes, bicycle, etc. – remember to include only an annual share of costs and only costs that pertain to your use of the Papio Creek watershed):

3. a. <u>How far from a creek or lake do you live (estimate)?</u>

   b. <u>Do you think the value of your residence is affected by being close to the Creek system (or lakes)?</u> **Circle one (i, ii, iii):** *Renters, see iv. below.*

      i. Not affected.

      ii. Value of the residence is **negatively** affected by being close to the Papio Creek system. (Living near the lake/ creek makes my residence value lower).

      How much lower? Approximately $________ off the value of my residence.

      iii. Value of the residence is **positively** affected by being close to the Papio Creek system. (Living near the lake/creek makes my residence value higher).

      How much higher? Approximately $_______ added to the value of my residence.

      iv. The rent I pay monthly is
      ___ 1. probably not affected by living close to the Creek system.

      ___ 2. probably increased by $______ per month

      or

      probably decreased by $______ per month, due to living close to a creek or lake.

4. <u>Now we'd like to get an estimate of how much you would be willing to pay annually for improvements in water quality of the Papio Creek watershed. Assume that if these **hypothetical** improvements were undertaken, your local or state taxes would have to increase, or funds from another public works project would have to be reallocated.</u>

   a. **Small improvement in water quality:** First assume that there is a small improvement in water quality of the Papio creek and lake system, resulting in more stream-side vegetation, some improved habitat for fish populations, and improved clarity of the water. There still might remain some degradation, including sediments and nutrients from fields and yards, and possibly some contaminated fish remaining.

How much would your own household be willing to pay *annually* for such an improvement?

0…10¢…$1…$2…$5…$10…$20…$40…$80…$160…$320…$640

Other: $______ annually

How much might this increase the total value of your home? $__________

(Or, how might this increase your monthly rent payment? $______)

b. **Bigger improvement in water quality:** Now assume there is a large increase in water quality of the Papio Creek and lake system, creating improvement in water clarity to near-pristine condition and allowing for increases in creek-side vegetation, fishing for a greater variety of species, and canoeing and other water-contact recreation (no water or fish contamination hazards).

How much would your household be willing to pay *annually* for such an increase? (Circle one)

0…10¢…$1…$2…$5…$10…$20…$40…$80…$160…$320…$640…$1280

Other: $______ annually

How much might this increase the total value of your home? $__________

(Or, how might this increase your monthly rent payment? $______)

5. Assume again hypothetically, that significant improvements were made to the Papio Creek watershed creeks and lakes. What recreational activity would you be most likely to pursue, in connection with the improved watershed? (Examples: biking, canoeing, bird watching, fishing, etc.) Describe:

That's it! Thank you for your time! Please use the enclosed envelope to return your survey. Feel free to add your own comments to any of the questions above.

Survey Response Data

1. What sort of recreational activities do you pursue that involve the Papio Creek watershed creeks and lakes? (circle any that apply, and indicate how often you do this activity)

   a. **Fishing** in area lakes (how many times per year?)
      Average times/year, nonblank responses:........................19.9
      Average times/year, all responses (blank = 0):...................5.8
      Note: 400,000 x 5.8 = 2.3 million times/year

   b. **Walking/hiking/jogging** on trails (how many times per year?)
      Average times/year, nonblank responses:........................59.7
      Average times/year, all responses (blank = 0):.................38.5
      Note: 400,000 x 38.5 = 15.4 million times/year

   c. **Bicycling** on trails (how many times per year?)
      Average times/year, nonblank responses:........................94.8
      Average times/year, all responses (blank = 0):.................50.5
      Note: 400,000 x 50.5 = 20.2 million times/year

   d. **Inline skating** on trails (how many times per year?)
      Average times/year, nonblank responses:........................32.7
      Average times/year, all responses (blank = 0):...................5.1
      Note: 400,000 x 5.1 = 2.04 million times/year

   e. **Picnicking/visiting** (how many times per year?)
      Average times/year, nonblank responses:..........................7.3
      Average times/year, all responses (blank = 0):...................3.1
      Note: 400,000 x 3.1 = 1.24 million times/year

   f. Other (**Boating, Camping, Horseback riding**, etc.) Describe and estimate how many times per year.
      Average times/year, nonblank responses:..........................4.5
      Average times/year, all responses (blank = 0):...................0.6
      Note: 400,000 x 0.6 = 0.24 million times/year

Discussion: The values for recreational use (especially bicycling) are probably inflated due to selection bias arising from the small number of survey respondents (those already involved recreationally with the Papio Creek trail system). Recreational use, therefore, was discounted considerably in the data used to construct management alternatives in the Management Alternative Report. If the above figures (average times per year, counting all blanks as zeros) are collected from all of the recreational categories and valued at $1 per “recreational use”, the collective value of these activities is $103.60.

The high rates of usage of the Papio Creek trails is corroborated by Greer and Hanson (2000) who surveyed 125 households within one block of the trail system and report usage rate of 60% to 100%. Ninety percent of the trail system users were walkers, while 54% report using the trail system for bicycling. Data from this section was severely discounted to reflect selection bias and used in the MAR categories of fishing/boating, hiking/biking/skating/running/walking, and picnicking/other.

Since market transactions often reveal the value of an unpriced activity , the following question probes respondents to report expenditure on complementary goods associated with the Papio Creek watershed (Freeman, 1993 and Willis & Corkindale, 1995).

2. <u>The activities listed above are often free, yet there are some indirect costs to those activities that we'd like to count. What costs do you incur that are related to the above recreational activities? (Please include only the portion of your costs that are specific to the Papio Creek watershed area.)</u>

a. Driving to lakes/trails, annual mileage:
Average mileage/yr, nonblank answers:
308 miles x $0.31/mile = ... $95.48
Average mileage/yr, all responses (blank = 0):
192 miles x $0.31/mile = ... $59.52

b. Other transportation costs annually:
Average annual costs, nonblank answers:.................................... $23.30
Average annual costs, all responses: $1.56

Fishing license, annual cost:
Average annual costs, nonblank answers:.................................... $22.50
Average annual costs, all responses: .... $ 5.51

Camping costs:
Average annual costs, nonblank answers:................................. $407.00
Average annual costs, all responses: .... $ 27.10

Boating costs:
Average annual costs, nonblank answers:.................................... 264.00
Average annual costs, all responses: .... $ 27.10

Other gear costs:
Average annual costs, nonblank answers:................................. $391.00
Average annual costs, all responses: $183.00

<u>Discussion</u>: If the annual average costs for all responses are added together, the total cost of complementary goods is $317.79/year. Again, this figure is probably

considerably overestimated due to over sampling of recreational users of the Papio Creek watershed trails, campsites, and lakes.

3a. How far from a creek or lake do you live?

The average response was 2.6 miles. This might be overestimated if people are estimating the distance to their favorite recreational site instead of the actual distance to the closest branch of the creek system.

3b. Do you think the value of your residence is affected by being close to the creek system (or lakes)? Circle one (I, ii, iii); Renters: see iv below.

i. Not affected: **25 responses**

ii. Value of residence negatively affected by being close to the Papio Creek system: Living near the lake/creek makes my residence value lower. How much lower? Approximately $ ______ off the value of my residence:
1 response, with no value provided.

iii. Value of the residence is positively affected by being close to the Papio Creek system. (Living near the lake/creek makes my residence value higher.) How much higher? Approximately $ ______ added to the value of my residence.
8 responses. 3 provided no value, 5 provided values with an average value of $3800 (range of $1000 to $10,000).

iv. The rent I pay monthly is
___1. probably not affected by living close to the Creek system.
1 response.
___ 2. probably increased by $ ______ per month
1 response, increased $20/month
___ 3. probably decreased by $ ______ per month, due to living close to a creek or lake.
No responses

Blank answers on 3b.: 12

Discussion: The values for housing premiums in this question are unreliable due to the small number of respondents. If the non-responses are counted as zeros, the average home value premium associated by being close to the Papio Creek system is about $400, which seems to provide some support for the values reported in question 2. However, housing house value should be divided by a factor of seven or so for an "annual" value of the premium. Greer and Hanson (2000) found similar housing premium patterns for proximity to Papio Creek recreational trails in their study, with 63.8% of their sample reporting that the proximity of the creek positively influenced their decision to purchase their home. Also, 65.7% of their sample reported that the creek proximity would make it easier to sell their home, 15.2% said there would be no effect on housing price, 17.5% did not know, and 1.5% reported that the creek would make it harder to sell their home.

The next question attempted to gauge the public reaction to a change in water quality in the Papio Creek system, since the focus of this study is on management alternatives that have varying effects on riparian habitat and water quality.

4. Now we'd like to get an estimate of how much you would be willing to pay annually for improvements in water quality of the Papio Creek watershed. Assume that if these **hypothetical** improvements were undertaken, your local or state taxes would have to increase, or funds from another public works project would have to be reallocated.

   a. Small improvement in water quality: First assume that there is a small improvement in water quality of the Papio Creek and lake system, resulting in more stream-side vegetation, some improved habitat for fish populations, and improved clarity of the water. There still might remain some degradation, including sediments and nutrients from fields and yards, and possibly some contaminated fish remaining.

   How much would your own household be willing to pay annually for such an improvement?

   0…10¢…$1…$2…$5…$10…$20…$40…$80…$160…$320…$640

   Other: $________ annually

   Average of non-blank responses: .... $68.10 annually
   Average of all responses, blank = 0: .... $49.96 annually

   How much might this increase the total value of your home? $_________
   (Or, how much might this increase your monthly rent payment? $_________)

   House value responses, average: $2375
   House value average of all responses, blank = 0: . $202.13

   b. Bigger improvement in water quality: Now assume there is a large increase in water quality of the Papio Creek and lake system, creating improvement in water clarity to near-pristine condition and allowing for increases in creek-side vegetation, fishing for a greater variety of species, and canoeing and other water-contact recreation (no water or fish contamination hazards).
   How much would your own household be willing to pay annually for such an increase? (Circle one)

   0…10¢…$1…$2…$5…$10…$20…$40…$80…$160…$320…$640…$1280
   Other: $________ annually

Average of non-blank responses: $105
Average of all responses, blank = 0: $95.78

Discussion: Answers to this question provided reliable evidence that a large improvement in water quality has a higher value to the public than a smaller increase in water quality. Data from this question was used to generate figures for the “Aesthetic Value/Willingness to Pay” category of the MAR. Using a baseline “value” for the current Papio Creek watershed of $103.60 per household (the figure from question 1, verified by figures from question 3b) we multiplied this by the number of households (231,000) in the area (Omaha World-Herald, 2000), for a baseline, status-quo value of $24,000,000. Then, using the $49.96 figure for the annual value to a household of a small increase in water quality, such a change would result in watershed-wide benefits of $11,555,748. A larger increase in water quality, valued at $95.78 by households, would result in increasing benefits of $22,153,914. Note that these benefit figures do not estimate increased property tax revenues to local governments from an increase in water quality along the Papio Creek system. These increases in willingness to pay values were discounted to reflect the bias of the survey sample to $2,2 million and $8 million.

Business Financial Impact

After review of proposed construction projects associated with the different management alternatives, it was determined that business disruption would be minimal, if not indistinguishable from current ongoing infrastructure projects such as road repair in the heavily commercial areas of the metropolitan area. Thus, short and long-term disruption to business revenues and costs were estimated to be negligible. and a survey of businesses located near Papio Creek tributaries and lakes would be superfluous. The main impact on businesses was likely to be increased costs borne by the construction and development sectors, caused by proposed requirements to install stormwater detention basins. These development costs were incorporated into the MAR in the “Real Estate Costs” category.

Assessed Housing Value Data

We researched property values directly by accessing Douglas Count Assessor’s office data on land and home values. Although the assessed data was not detailed enough for a full hedonic analysis of housing prices vis-à-vis the Papio Creek system, it did reveal some evidence that channelization of the Creek may depress local land values. For example, four areas of residential housing were researched along the Papio Creek system:

1. Peony Park area, legally known as the Maenner-Hillside Addition, adjacent to Papio Creek from about 72nd to 78th streets. This area has experienced flooding in the past, and the Creek is channelized with vegetation removed (except grass). Residential land values are around

$7100 to $7,400 per lot, with home (excluding land) values ranging from $70,000 - $83,000.

2. West Dodge Division, beginning at 83rd Street (10 blocks north of Dodge) adjacent to Papio Creek. housing directly across the street from the creek has lot values ranging from $7,800 to $12,300 and home values ranging between $48,000 to $102,000, but predominately around $65,000 to $70,000.

3. Keystone Terrace and Hargleroads-Military Additions, 20 to 40 blocks north of Dodge, between 85th and 90th Streets. Although commercial use (including a concrete mixing facility) predominates, ther is also a large sports field adjacent to the Creek in the area. Lot values average around $12,000 and home values range from $55,000 to $68,000.

4. Democracy Park, further north at 90th and Fort Streets. Here, the Creek is not channelized and trees overhang the creek area, providing a very different natural setting to the area (compared to the Peony Park area). Lot values range from $10,700 to $11,500, with home values ranging from $58,000 to $75,000.

Although the review of assessed home values could not be conducted in an extensive enough way to do a full regression analysis of housing values, the Douglas County Assessor's Office data indicated that there is likely a premium on lot values for homes located next to unchannelized portions of Papio Creek, as shown by the lot value differences for areas 1 and 4 above. Both area have experienced flooding in the past, both are adjacent to city parks, and housing values for both areas are comparable.

Appendix D

Field Observation Sampling Sheet and Habitat Assessment Results

Field Observation Sampling Sheet

D-2

Sampling Site ID:______________________________

Sampled By:______________________

Date:___________________________________

Time:___________________________________

Sample Location Description:____

____

Weather Conditions

Temperature (°F):___________________ Cloud Cover(%):___________________________

Wind (circle one): Calm (0-5 mph); Light (5-15 mph); Strong (>15 mph)

Precipitation in previous 48 hours (in.):_____________________

Channel

Water width (ft.):___________________________

Water depth (ft.):___________________________

Water velocity (ft/sec):______________________

Water appearance:_________________________

Structures (e.g. discharge pipes)

____

____

____

____

Channel Cross Section Sketch

Sketch upstream and downstream cross sections on the grid below. Mark right and left banks, show slopes, significant vegetation, channel bottom water depth, and structures.

Upstream Channel

Downstream Channel

Downstream: Habitat and Biological Communities D-3

Sampling Site ID: ______________________________

Date:________________________________

Photo numbers and descriptions:

____

____

____

____

____

Bank vegetation percentages are from bank edge to water edge by 0.5 mile down stream. Overbank percentages are for the area of 1000 ft from each stream bank by 0.5 mile down stream.

Bank Vegetation (%):

Left Bank:	*Right Bank:*
Trees: ____________	Trees:_____________
Shrubs:_______	Shrubs:_______
Grass: ____________	Grass:_____________
Forbs: ____________	Forbs: ____________
Other: ____________	Other: ____________

Over-Bank Land Use/ Vegetation (%):

Left Bank:	*Right Bank:*
Commercial:_________	Commercial:_________
Residential:_________	Residential:_________
Rural:______________	Rural:______________
Pasture:____________	Pasture:____________
Cultivated:__________	Cultivated:__________
Trees: ____________	Trees: ____________
Grass:_____________	Grass:_____________
Forbs: ____________	Forbs: ____________
Other: ____________	Other: ____________

Upstream: Habitat and Biological Communities D-4

Sampling Site ID: ______________________________

Date:__________________________

Photo numbers and descriptions:

____

____

____

____

____

Bank vegetation percentages are from bank edge to water edge by 0.5 mile up stream. Overbank percentages are for the area of 1000 ft from each stream bank by 0.5 mile up stream.

Bank Vegetation (%):

Left Bank:		*Right Bank:*	
Trees:	__________	Trees:	__________
Shrubs:	_____	Shrubs:	_____
Grass:	__________	Grass:	__________
Forbs:	__________	Forbs:	__________
Other:	__________	Other:	__________

Over-Bank Land Use/ Vegetation (%):

Left Bank:		*Right Bank:*	
Commercial:	_______	Commercial:	_______
Residential:	________	Residential:	________
Rural:	___________	Rural:	___________
Pasture:	__________	Pasture:	__________
Cultivated:	________	Cultivated:	________
Trees:	__________	Trees:	__________
Grass:	___________	Grass:	___________
Forbs:	__________	Forbs:	__________
Other:	__________	Other:	__________

Bioassessment

Sampling Site ID: ______________________________

Date:__________________________

	Condition Category			
Habitat Parameter	**Optimal**	**Suboptimal**	**Marginal**	**Poor**
Epifaunal Substrate/ Available Cover	50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation	Hard-pan clay or bedrock; no root mat or submerged vegetation.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
Sediment Deposition	Little or no enlargement of islands or point bars and less than 20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Sampling Site ID:____

Date:________________________________

	Condition Category			
Habitat Parameter	**Optimal**	**Suboptimal**	**Marginal**	**Poor**
Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
Score_________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
Score_________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
Bank Stability (score each bank) Note: determine left or right side by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
Score (LB)_______	Left Bank 10 9	8 7 6	5 4 3	2 1 0
Score (RB)_______	Right Bank 10 9	8 7 6	5 4 3	2 1 0
Vegetative Protection (score each bank) Note: determine left or right side by facing downstream	More than 90% of the streambank surfaces and immediate riparian zones covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
Score (LB)_______	Left Bank 10 9	8 7 6	5 4 3	2 1 0
Score (RB)_______	Right Bank 10 9	8 7 6	5 4 3	2 1 0
Riparian Vegetative Zone Width (score each bank riparian zone)	Riparian zone width >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Riparian zone width 12-18 meters; human activities have impacted zone only minimally.	Riparian zone width 6-12 meters; human activities have impacted zone a great deal.	Riparian zone width <6 meters: little or no riparian vegetation due to human activities.
Score (LB)_______	Left Bank 10 9	8 7 6	5 4 3	2 1 0
Score (RB)_______	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Manning's Roughness Coefficient Calculation

Equation: $n = (n_0 + n_1 + n_2 + n_3)m$

Variable	Parameter	Condition	Value	Estimate
n_0	Channel substrate (character of channel)[a]	Earth	.020	
		Cut rock	.025	
		Fine gravel	.024	
		Coarse gravel	.028	
n_1	Bank stability (degree of irregularity)	Optimal (smooth)	.000	
		Suboptimal (minor)	.005	
		Marginal (moderate)	.010	
		Poor (severe)	.020	
n_2	Epifaunal substrate (relative effect of obstructions)[a]	Poor (negligible)[a]	.000	
		Marginal (minor)[a]	.010-.015	
		Suboptimal (appreciable)[a]	.020-.030	
		Optimal (severe)[a]	.040-.060	
n_3	Channel vegetation height	Low (avg. depth of flow >3 times vegetation height; vegetation is highly flexible)	.005-.010	
		Medium (avg. depth of flow equal to height of vegetation; vegetation is somewhat flexible; hydraulic radius greater than 2)	.010-.025	
		High (bushy willows and less flexible foliage along channel side slopes; hydraulic radius between 2 to 4 ft.)	.025-.050	
		Very high (dense willow and cattail growth, trees intergrown with weeds and brush in full foliage; hydraulic radius up to 10 or 12 ft.)	.050-.100	
m	Channel sinuosity (degree of meander)[a]	Poor (minor)[a]	1.000	
		Marginal to Suboptimal (appreciable)[a]	1.150	
		Optimal (severe)[a]	1.300	

Source: Cowan, W. L.. 1956. "Estimating Hydraulic Roughness Coefficients." *Agricultural Engineering,* 37(7), 473-475.

[a] Items in parentheses are original designations from the source.

Calculation:

$n = (n_0$______ + n_1______ + n_2______ + n_3______)*m______ = ________

Manning's Roughness Coefficient: n = ________

Instructions and Terms for Field Observations

1. ***sampling site ID***: from sample site map.
2. ***sample location description***: describe site location; e.g. south side of bridge at 60th and Dodge.
3. ***water width:*** measure by pacing on bridge.
4. ***water depth:*** measure with weighted line.
5. ***water velocity:*** estimate by timing a float going a specified distance; estimate the distance by comparing to measured stream width.
6. ***channel cross-section sketch:*** sketch cross section on provided page. Mark right and left banks, show slopes, significant vegetation, channel bottom water depth, and structures.
7. ***bank vegetation:*** identify dominant vegetation types and estimate percent cover.
8. ***over-bank land use/vegetation:*** identify dominant land use types, and estimate percentages within 1000 feet of the bank.
9. ***structures:*** note any structures in stream such as pipes and culverts.
10. ***land use and habitat sketch:*** sketch the land use and habitat on the grids provided; show approximate areas of land use, vegetation and other appropriate details.

Field Observation Sampling Sheet

Sampling Site ID: 3

Sampled By: RCC

Date: 6/29

Time:

Sample Location Description: Little Papio - upper reach s.e. branch CR 40 & Kameo Dr.

Weather Conditions

Temperature (°F): 85° F

Cloud Cover(%): 50%

Wind (circle one): [✓ Calm (0-5 mph)]; Light (5-15 mph); Strong (>15 mph)

Precipitation in previous 48 hours (in.):

Channel

Water width (ft.): 1'-2'

Water depth (ft.): 0.5-1

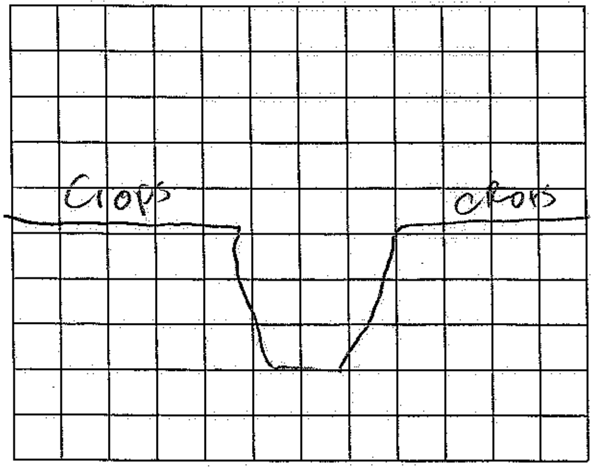
Water velocity (ft/sec): not measurable

Water appearance: clear

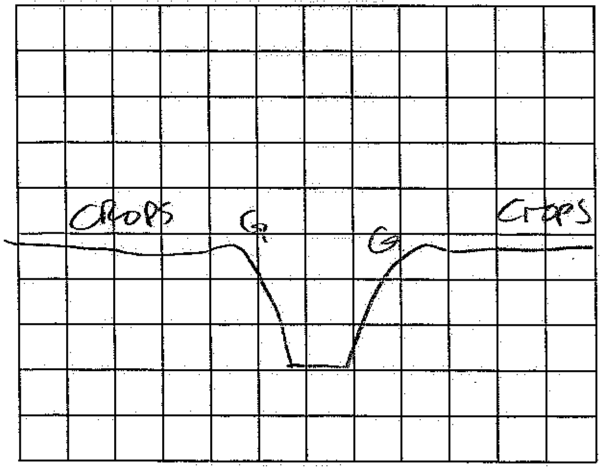
Structures (e.g. discharge pipes)

Channel Cross Section Sketch

Sketch upstream and downstream cross sections on the grid below. Mark right and left banks, show slopes, significant vegetation, channel bottom water depth, and structures.



Upstream Channel



Downstream Channel

Downstream: Habitat and Biological Communities

Sampling Site ID: 3

Date: 6/29

Photo numbers and descriptions:

Photo 25 Disc 1

Bank vegetation percentages are from bank edge to water edge by 0.5 mile down stream. Overbank percentages are for the area of 1000 ft from each stream bank by 0.5 mile down stream.

Bank Vegetation (%):

	Left Bank:	*Right Bank:*
Trees:		
Shrubs:		
Grass:	70	70
Forbs:	30	30
Other:		

Over-Bank Land Use/ Vegetation (%):

	Left Bank:	*Right Bank:*
Commercial:		
Residential:		20
Rural:		
Pasture:		25
Cultivated:	90	20
Trees:		10
Grass:	10	25
Forbs:		
Other:		

Upstream: Habitat and Biological Communities

Sampling Site ID: 3

Date: 6/29

Photo numbers and descriptions:

Photo 26 Disc 1

Bank vegetation percentages are from bank edge to water edge by 0.5 mile up stream. Overbank percentages are for the area of 1000 ft from each stream bank by 0.5 mile up stream.

Bank Vegetation (%):

	Left Bank:	Right Bank:
Trees:	40	40
Shrubs:		
Grass:	25	25
Forbs:	35	35
Other:		

Over-Bank Land Use/ Vegetation (%):

	Left Bank:	Right Bank:
Commercial:		
Residential:		
Rural:		
Pasture:		40
Cultivated:	80	45
Trees:		5
Grass:	10	10
Forbs:	10	
Other:		

Bioassessment

Sampling Site ID: 3

Date: 6/29

	Condition Category			
Habitat Parameter	**Optimal**	**Suboptimal**	**Marginal**	**Poor**
Epifaunal Substrate/ Available Cover	50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
Score________	20 19 18 17 16	15 14 up [✓ 13] 12 down [✓ 11]	10 9 8 7 6	5 4 3 2 1
Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation	Hard-pan clay or bedrock; no root mat or submerged vegetation.
Score________	20 19 18 17 16	15 14 13 12 11	down [✓ 10] 9 8 up [✓ 7] 6	5 4 3 2 1
Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
Sediment Deposition	Little or no enlargement of islands or point bars and less than 20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1
Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
Score________	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1

Sampling Site ID: 3

Date: 6/29

	Condition Category			
Habitat Parameter	**Optimal**	**Suboptimal**	**Marginal**	**Poor**
Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
Score________	20 19 18 17 16	15 14 13 12 11	up 10 9 8 [✓ 7] 6	down [✓ 5] 4 3 2 1
Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	up down [✓ 5] 4 3 [✓ 2] 1
Bank Stability (score each bank) Note: determine left or right side by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
Score (LB)______	Left Bank 10 9	down [✓ 8] 7 6	up [✓ 5] 4 3	2 1 0
Score (RB)______	Right Bank 10 9	[✓ 8] 7 6	[✓ 5] 4 3	2 1 0
Vegetative Protection (score each bank) Note: determine left or right side by facing downstream	More than 90% of the streambank surfaces and immediate riparian zones covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
Score (LB)______	Left Bank 10 9	up [✓ 8] 7 6	down [✓ 5] 4 3	2 1 0
Score (RB)______	Right Bank 10 9	[✓ 8] 7 6	[✓ 5] 4 3	2 1 0
Riparian Vegetative Zone Width (score each bank riparian zone)	Riparian zone width >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Riparian zone width 12-18 meters; human activities have impacted zone only minimally.	Riparian zone width 6-12 meters; human activities have impacted zone a great deal.	Riparian zone width <6 meters: little or no riparian vegetation due to human activities.
Score (LB)______	Left Bank 10 9	8 7 6	5 4 3	up down [✓ 2] [✓ 1] 0
Score (RB)______	Right Bank 10 9	8 7 6	5 4 3	[✓ 2] [✓ 1] 0

Manning's Roughness Coefficient Calculation

Equation: $n = (n_0 + n_1 + n_2 + n_3)m$

Variable	Parameter	Condition	Value	Estimate
n_0	Channel substrate (character of channel)[a]	Earth	.020	0.020
		Cut rock	.025	
		Fine gravel	.024	
		Coarse gravel	.028	
n_1	Bank stability (degree of irregularity)	Optimal (smooth)	.000	
		Suboptimal (minor)	.005	0.005 down
		Marginal (moderate)	.010	0.010 up
		Poor (severe)	.020	
n_2	Epifaunal substrate (relative effect of obstructions)[a]	Poor (negligible)[a]	.000	
		Marginal (minor)[a]	.010-.015	
		Suboptimal (appreciable)[a]	.020-.030	up 0.025 down 0.020
		Optimal (severe)[a]	.040-.060	
n_3	Channel vegetation height	Low (avg. depth of flow >3 times vegetation height; vegetation is highly flexible)	.005-.010	0.005
		Medium (avg. depth of flow equal to height of vegetation; vegetation is somewhat flexible; hydraulic radius greater than 2)	.010-.025	
		High (bushy willows and less flexible foliage along channel side slopes; hydraulic radius between 2 to 4 ft.)	.025-.050	
		Very high (dense willow and cattail growth, trees intergrown with weeds and brush in full foliage; hydraulic radius up to 10 or 12 ft.)	.050-.100	
m	Channel sinuosity (degree of meander)[a]	Poor (minor)[a]	1.000	1.000
		Marginal to Suboptimal (appreciable)[a]	1.150	
		Optimal (severe)[a]	1.300	

Source: Cowan, W. L.. 1956. "Estimating Hydraulic Roughness Coefficients." *Agricultural Engineering*, 37(7), 473-475.

[a] Items in parentheses are original designations from the source.

Calculation:

u 0.010 u 0.025 u = 0.060

n = (n₀ 0.020 + n₁ d 0.005 + n₂ d 0.020 + n₃ 0.005)*m 1.000 = d = 0.050

u = 0.060

Manning's Roughness Coefficient: n = d = 0.050

Field Observation Sampling Sheet

Sampling Site ID: 31

Sampled By: RCC

Date: 6/27

Time:

Sample Location Description: Big Papio - Main
Hwy 30 & CR P30

Weather Conditions

Temperature (°F): 85°F Cloud Cover(%): 50%

Wind (circle one): [✓ Calm (0-5 mph)]; Light (5-15 mph); Strong (>15 mph)

Precipitation in previous 48 hours (in.):

Channel

Water width (ft.): 15'-20'

Water depth (ft.): 2+'

Water velocity (ft/sec): 1.2 fps 36' 30 sec

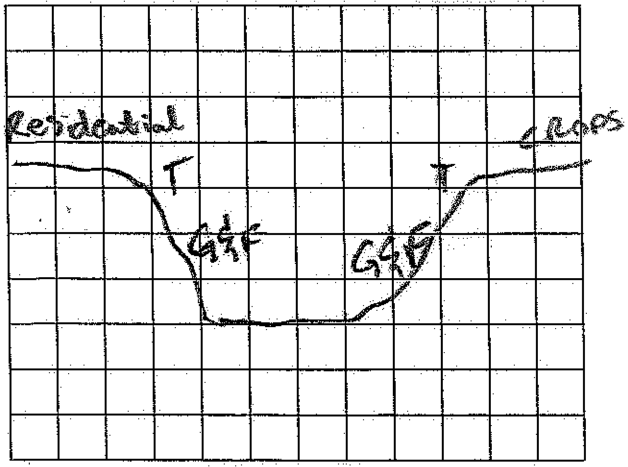
Water appearance: Turbid

Structures (e.g. discharge pipes)

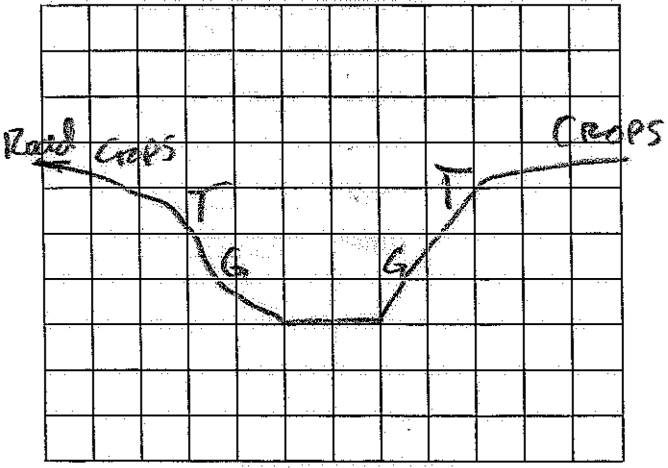
Downstream Left Bank 6'x6' culvert under
CR P30 feeding into Papio
Upstream - RR bridge

Channel Cross Section Sketch

Sketch upstream and downstream cross sections on the grid below. Mark right and left banks, show slopes, significant vegetation, channel bottom water depth, and structures.



Upstream Channel



Downstream Channel

Downstream: Habitat and Biological Communities

Sampling Site ID: 31

Date: 5/27

Photo numbers and descriptions:

Photo 9 Disel pm

Bank vegetation percentages are from bank edge to water edge by 0.5 mile down stream. Overbank percentages are for the area of 1000 ft from each stream bank by 0.5 mile down stream.

Bank Vegetation (%):

	Left Bank:	*Right Bank:*
Trees:	30	30
Shrubs:		
Grass:	35	35
Forbs:	35	35
Other:		

Over-Bank Land Use/ Vegetation (%):

	Left Bank:	*Right Bank:*
Commercial:		
Residential:		
Rural:		
Pasture:		
Cultivated:	90	80
Trees:		10
Grass:	5	5
Forbs:		5
Other:	Road 5%	

Upstream: Habitat and Biological Communities

Sampling Site ID: 31

Date: 6/27

Photo numbers and descriptions:

photo 10 disc 1 pm

Bank vegetation percentages are from bank edge to water edge by 0.5 mile up stream. Overbank percentages are for the area of 1000 ft from each stream bank by 0.5 mile up stream.

Bank Vegetation (%):

Left Bank:

Trees: 40
Shrubs:
Grass: 25
Forbs: 35
Other:

Right Bank:

Trees: 40
Shrubs:
Grass: 25
Forbs: 35
Other:

Over-Bank Land Use/ Vegetation (%):

Left Bank:

Commercial:
Residential:
Rural:
Pasture:
Cultivated: 65
Trees: 15
Grass: 10
Forbs: 5
Other: RR 5

Right Bank:

Commercial:
Residential: 30
Rural:
Pasture:
Cultivated:
Trees: 25
Grass: 30
Forbs: 10
Other: RR 5

Bioassessment

Sampling Site ID: 31

Date: 6/27

	Condition Category			
Habitat Parameter	**Optimal**	**Suboptimal**	**Marginal**	**Poor**
Epifaunal Substrate/ Available Cover	50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1
Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation	Hard-pan clay or bedrock; no root mat or submerged vegetation.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
Sediment Deposition	Little or no enlargement of islands or point bars and less than 20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
Score________	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1

Sampling Site ID: 31
Date: 6/22

	Condition Category			
Habitat Parameter	**Optimal**	**Suboptimal**	**Marginal**	**Poor**
Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	[✓ 5] 4 3 2 1
Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
Score________	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 [✓ 3] 2 1
Bank Stability (score each bank) Note: determine left or right side by facing downstream	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
Score (LB)______	Left Bank 10 9	8 7 6	5 [✓ 4] 3	2 1 0
Score (RB)______	Right Bank 10 9	8 7 6	5 [✓ 4] 3	2 1 0
Vegetative Protection (score each bank) Note: determine left or right side by facing downstream	More than 90% of the streambank surfaces and immediate riparian zones covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
Score (LB)______	Left Bank 10 9	8 7 [✓ 6]	5 4 3	2 1 0
Score (RB)______	Right Bank 10 9	8 7 [✓ 6]	5 4 3	2 1 0
Riparian Vegetative Zone Width (score each bank riparian zone)	Riparian zone width >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Riparian zone width 12-18 meters; human activities have impacted zone only minimally.	Riparian zone width 6-12 meters; human activities have impacted zone a great deal.	Riparian zone width <6 meters: little or no riparian vegetation due to human activities.
Score (LB)______	Left Bank 10 9	8 7 6	5 4 3	[✓ 2] 1 0
Score (RB)______	Right Bank 10 9	8 7 6	5 4 3	2 [✓ 1] 0

Manning's Roughness Coefficient Calculation

Equation: $n = (n_0 + n_1 + n_2 + n_3)m$

Variable	Parameter	Condition	Value	Estimate
n_0	Channel substrate (character of channel)[a]	Earth	.020	0.020
		Cut rock	.025	
		Fine gravel	.024	
		Coarse gravel	.028	
n_1	Bank stability (degree of irregularity)	Optimal (smooth)	.000	
		Suboptimal (minor)	.005	
		Marginal (moderate)	.010	0.010
		Poor (severe)	.020	
n_2	Epifaunal substrate (relative effect of obstructions)[a]	Poor (negligible)[a]	.000	
		Marginal (minor)[a]	.010-.015	0.013
		Suboptimal (appreciable)[a]	.020-.030	
		Optimal (severe)[a]	.040-.060	
n_3	Channel vegetation height	Low (avg. depth of flow >3 times vegetation height; vegetation is highly flexible)	.005-.010	0.005
		Medium (avg. depth of flow equal to height of vegetation; vegetation is somewhat flexible; hydraulic radius greater than 2)	.010-.025	
		High (bushy willows and less flexible foliage along channel side slopes; hydraulic radius between 2 to 4 ft.)	.025-.050	
		Very high (dense willow and cattail growth, trees intergrown with weeds and brush in full foliage; hydraulic radius up to 10 or 12 ft.)	.050-.100	
m	Channel sinuosity (degree of meander)[a]	Poor (minor)[a]	1.000	1.000
		Marginal to Suboptimal (appreciable)[a]	1.150	
		Optimal (severe)[a]	1.300	

Source: Cowan, W. L.. 1956. "Estimating Hydraulic Roughness Coefficients." *Agricultural Engineering*, 37(7), 473-475.

[a] Items in parentheses are original designations from the source.

Calculation:

$n = (n_0 \underline{0.020} + n_1 \underline{0.010} + n_2 \underline{0.013} + n_3 \underline{0.005})*m \underline{1.000} = \underline{0.048}$

Manning's Roughness Coefficient: $n = \underline{0.048}$

Sampling Site Locations and Dates

Site ID	Sample Location Description	Sampled By	Date
	6.1.1.2 Little Papio--upper reach, main branch		
1A	CR 38 btwn CR 39 & CR 41	RCC	6/29/2000
	Little Papio--upper reach, west branch		
1B	CR 39 btwn CR P38 & CR 1	RCC	6/29/2000
	Little Papio--upper reach, northeast branch		
1C	CR P38 btwn CR 41 & CR P41	RCC	6/29/2000
	Little Papio--upper reach, main branch		
1	CR 41 0.5 mile N. of CR 1	RCC	6/29/2000
2	CR 1 btwn CR 41 & CR P41	RCC	6/27/2000
	Little Papio--upper reach, southeast branch		
3	CR 40 & Karneo Dr.	RCC	6/29/2000
4	Dutch Hall Rd. btwn CR P41 & CR 36	RCC	6/27/2000
	Little Papio--main		
5	Pawnee Rd. btwn N. 96th St. (CR 40) & N. 84th St. (CR 36)	RCC	6/27/2000
6	Bennington Rd. btwn N. 96th St. & N. 84th St.	RCC	6/27/2000
7	State St. at approx. Wenninghoff Rd.	RCC	6/21/2000
	Thomas Creek--upper reach, east branch		
8A	CR P38 0.3 mile E. of CR 35	RCC	6/29/2000
	Thomas Creek--upper reach, west branch		
8	CR 40 0.2 mile W. of CR 35	RCC	6/29/2000
	Thomas Creek--main		
9	CR 1 btwn N. 126th St. & Blair High Rd.	RCC	6/29/2000
10	Pawnee Rd. btwn N. 126th St. & Blair High Rd.	RCC	6/29/2000
11	Bennington Rd. btwn N. 126th St. & Blair High Rd.	RCC	6/29/2000
12	Rainwood Rd. btwn N. 120th St. & Blair High Rd.	RCC	6/21/2000
13	State St. & Irvingtion Rd.	RCC	6/21/2000
14	Irvington Rd. 0.1 mile N. of Blair High Rd.	RCC	6/21/2000
	Little Papio--main		
15	Fort St. btwn Irvington Rd. & N. 87th Ave.	RCC	6/19/2000
16	Maple St. btwn N. 88th St. & Keystone Ave.	RCC	6/19/2000
	Cole Creek	RCC	6/21/2000
17	Ames Ave. btwn Benson Park Dr. & N. 66th St.		
18	Western Ave. btwn Cole Creek Dr. & Maenner Dr.	RCC	6/21/2000
	Little Papio--main		
19	Dodge St. btwn Beverly Dr. & S. 77th St.	RCC	6/19/2000
20	Mercy Rd. & Aksarben Dr.	RCC	6/19/2000

Site ID	Sample Location Description	Sampled By	Date
21	L St. btwn S. 67th St. & S. 62nd St.	RCC	6/29/2000
	Big Papio--upper reach, center branch		
22	CR 21 btwn CR 16 & CR 14	RCC	6/26/2000
23	CR 23 btwn CR 18 & CR 14	RCC	6/26/2000
24	CR 18 btwn CR 25 & CR 23	RCC	6/26/2000
25	Hwy 91 btwn CR 25 & CR 23	RCC	6/26/2000
26	CR 25 & CR 24	RCC	6/26/2000
	Big Papio--upper reach, east branch		
26A	CR 24 btwn CR 27 & CR 25	RCC	6/26/2000
	Big Papio--upper reach, west branch		
27	CR 18 btwn CR 21 & CR 19	RCC	6/26/2000
28	CR 24 btwn CR 23 & CR 21	RCC	6/26/2000
	Big Papio--upper reach, center branch		
29	CR 26 btwn CR 25 & CR 27	RCC	6/26/2000
	Big Papio--East Fork--Richter Branch		
30	Hwy 30 btwn CR 29 & Century Ln.	RCC	6/27/2000
	Big Papio--East Fork--upper reach		
30A	CR 26 & CR 29	RCC	6/26/2000
	Big Papio--East Fork--Boston Branch		
30B	CR 30 0.5 mile W. of Blair High Rd. (Hwy 133)	RCC	6/27/2000
	Big Papio--East Fork--Leach Branch		
30C	CR 30 500 ft. E. of CR 29	RCC	6/27/2000
	Big Papio--East Fork--main		
30D	CR 27 0.3 mile N. of Hwy 30	RCC	6/27/2000
	Big Papio--main		
31	Hwy 30 0.3 mile E. of Kennard	RCC	6/27/2000
	Big Papio--N.W. Branch--upper reach, main		
32	CR 26 btwn Loree Ln & CR P17	RCC	6/26/2000
	Big Papio--N.W. Branch--upper reach, west branch		
32A	CR 24 btwn CR P17 & CR P19	RCC	6/26/2000
	Big Papio--N.W. Branch--upper reach, N.E. branch		
32B	CR 26 btwn CR 15 & Loree Ln	RCC	6/26/2000
	Big Papio--N.W. Branch--upper reach, S.E. branch		
32C	CR 21 btwn CR 26 & CR 28	RCC	6/28/2000
	Big Papio--N.W. Branch		
33	CR 28 btwn CR P17 & CR P19	RCC	6/29/2000
34	CR 23 btwn CR 30 & CR 32	RCC	6/29/2000
35	CR P30 (2nd St., Kennard) btwn CR 23 & CR 25	RCC	6/29/2000

Site ID	Sample Location Description	Sampled By	Date
	Big Papio--S.W. Branch		
36	Hwy 30 btwn CR 17 & CR 19	RCC	6/28/2000
37	CR 19 btwn Hwy 30 & CR 36	RCC	6/28/2000
38	CR 21 btwn Hwy 30 & CR 36	RCC	6/28/2000
39	Hwy 30 & CR 23	RCC	6/28/2000
39A	CR 32 & CR 25		
	Big Papio--N.W. Branch		
40	Hwy 30 btwn CR P25 & Linn St., Kennard	RCC	6/28/2000
	Big Papio--main		
41	CR 34 btwn CR P25 & CR P27	RCC	6/20/2000
42	CR 36 btwn CR P25 & CR 29	RCC	6/20/2000
43	CR 38 btwn CR P25 & CR P27	RCC	6/20/2000
44	CR 40 btwn CR P25 & CR P27	RCC	6/20/2000
45	Dutch Hall Rd. btwn CR P25 & CR 29	RCC	6/20/2000
	Butter Flat Creek		
46	CR 34 btwn CR 31 & Trail Ridge Rd.	RCC	6/20/2000
47	CR 36 btwn CR 31 & CR 33	RCC	6/20/2000
48	CR 38 btwn CR 31 & CR 33	RCC	6/20/2000
49	CR 40 btwn CR 29 & CR31	RCC	6/20/2000
50	Dutch Hall Rd. & N. 168th St.	RCC	6/20/2000
	Big Papio--main		
51	Hwy 36 btwn CR 68 & N. 168th St.	RCC	6/20/2000
52	Bennington Rd. btwn N. 168th St. & N. 156th St.	RCC	6/20/2000
53	State St. btwn N.144th St. & N.138th St.	RCC	6/20/2000
54	N. 126th St. 0.2 mile N. of Military Rd.	RCC	6/20/2000
55	Fort St. btwn Tranquility Park & N.120th St.	RCC	6/20/2000
56	Old Maple Rd. btwn N. 120th St. & Sahler St.	RCC	6/20/2000
62	Harrison St. & S. 60th St.	RCC	6/29/2000
63	Cornhusker Rd. & S. 48th St.	RCC	6/23/2000
	West Papio--North Branch		
64	State St. btwn N.186th St. & N.168th St.	Pam	6/7/2000
65	Ida St. btwn N.180th St. & N.168th St.	Pam	6/7/2000
66	Fort St. btwn N.180th St. & N.168th St.	Pam	6/12/2000
67	Maple St. at N.168th St.	Pam	6/8/2000
68	Blondo St. btwn N.168th St. & N.156th St.	Pam	6/8/2000
	West Papio--main		
69	Mount Michael Rd W. of Elkhorn 0.5 mile N. of Maple St. (Hwy 64)	Pam	6/19/2000
70	Maple St. (Hwy 64) W. of Elkhorn btwn Ramblewood Dr. & CR 80	Pam	6/19/2000

Site ID	Sample Location Description	Sampled By	Date
71	Hwy 31 S. of Elkhorn btwn E. Railroad Ave. & Old Lincoln Hwy	Pam	6/19/2000
72	S.192nd St. btwn Old Lincoln Hwy & W. Dodge Rd.	Pam	6/13/2000
73	W. Dodge Rd. btwn S.168th St. & S.156th St.	Pam	6/18/2000
74	Pacific St. btwn S.168th St. & S.156th St.	Pam	6/13/2000
75	W. Center Rd. at approx. S.156th St.	Pam	6/13/2000
	Box Elder Creek		
76	S.192nd St. 0.2 mile S. of West Center Rd.	Pam	6/13/2000
77	S.180th St. 0.5 mile S. of West Center Rd.	Pam	6/13/2000
	West Papio--main		
78	S.144th St. btwn F St. & West Center Rd.	Pam	6/20/2000
79	Q St. btwn S.144th St. & S.132nd St.	Pam	6/20/2000
80	Harrison St. & I-80	Pam	6/20/2000
	West Papio--South, upper reach		
81	S.192nd St. btwn Giles Rd. & Cornhusker Rd.	Pam	6/19/2000
82	S.180th St. btwn Harrison St. & Giles Rd.	Pam	6/19/2000
83	S.168th St. btwn Harrison St. & Giles Rd.	Pam	6/19/2000
84	S.156th St. btwn Harrison St. & Giles Rd.	Pam	6/19/2000
	West Papio--South, lower reach		
	S.180th St. (CR 68) btwn Schram Rd. & Hwy 370	Pam	6/19/2000
85	S.168th St. (CR 64) btwn Schram Rd. & Hwy 370	Pam	6/19/2000
86	Hwy 370 btwn CR 64 & CR 60	Pam	6/19/2000
	West Papio--South, main		
87	Hwy 50 btwn Harrison St. & Giles Rd.	Pam	6/20/2000
88	Giles Rd. at S.132nd St.	Pam	6/20/2000
	West Papio--main		
89	Giles Rd. btwn CR 46 & S. 108th St.	Pam	6/20/2000
	Walnut Creek		
90	Hwy 370 0.2 mile E. of Turkey Rd. (approx. S.102nd St.)	Pam	6/29/2000
	West Papio--main		
91	Hwy 85 btwn Lincoln St. & 1st St.	Pam	6/29/2000
92	Fleetwood Dr. approx. 0.8 miles S. of Cornhusker Rd.	Pam	6/29/2000
93	S.48th St. (CR G21) 0.8 miles N. of Hwy 370	Pam	6/29/2000
	Big Papio--main		
94	Hwy 370 btwn Kate Fox Rd. & S. 25th St.	RCC	6/23/2000
95	Capehart Rd. 0.3 mile W. of Hwy 75	RCC	6/23/2000
96	Fairview Rd. approx. .8 mile E. of Ft. Crook Rd.	RCC	6/23/2000
97	Harlan Lewis Rd. 0.5 mile N. of E. Laplatte Rd.	RCC	6/23/2000
98	O.5 mile E. of Harlan Lewis Rd. bridge, 0.3 mile W. of mouth of Big Papio Creek	RCC	6/23/2000

Weather and Channel Characteristics

	Weather					Channel				
Site ID	**Temp. (°F)**	**Cloud Cover**	**Wind**	**Wind Value[1]**	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
1A	85	25	calm	1		0.5 to 1	0.25 to 0.5	not meas.	clear	none
1B	85	15	calm	1		5 to 10	2+	not meas.	mod. turbid w/ algal blooms	none
1C	85	40	calm	1		0.5 to 1	0.25 to 0.75	not meas.	slight turbid	none
1	85	80	calm	1		5 to 10	1 to 2	0.43	slight to mod. turbid	none
2	80	5	calm	1		2 to 4	2+	snag under bridge, not meas.	slight to mod. turbid	none
3	85	50	calm	1		1 to 2	0.5 to 1	not meas.	clear	none
4	80	10	calm	1		2 to 3	0.5 to 1.5	not meas.	slight to mod. turbid	none
5	80	5	calm	1		20 to 25	2+	0.19	turbid	none
6	80	20	calm	1		Cunningham Lake, see photos				
7	90	0	light	2		5 to 10	0 to 1	not meas.	slight turbid	**Downstream**--concrete wall and wings on both banks. ***Left bank***--30" discharge pipe ***right bank*** 24" discharge pipe **Upstream**--concrete wall and wings on both banks. Cunningham Lake dam is 0.3 mile upstream, with spillway approx. 0.1 mile upstream.
8A	80	5	calm	1		1 to 2	0.25 to 1	not meas.	slight turbid	**Upstream**--small dam 500 ft. from road

	Weather					Channel				
Site ID	**Temp. (^{o}F)**	**Cloud Cover**	**Wind**	**Wind Value^1**	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
8	80	5	calm	1		1 to 2	0.25 to 0.75		clear	**Upstream**--creek emerges from 8" PVC pipe
9	80	10	calm	1		5 to 10	1.5 to 2.5	0.8	mod. turbid	none
10	80	10	calm	1		10 to 15	0.25 to 1	0.48	clear	**Downstream**--***Left bank***, approx 100' downstream, 24" galvanized pipe.
11	80	5	calm	1		10 to 15	0.5 to 1.5	not meas. snags under bridge	slight turbid	none
12	90	5	light	2		10	1 to 2	not meas. wind too strong	slight turbid	**Downstream**--***right bank***--25' above water wooden chute or retaining wall ***left bank*** --5' x 4' concrete chute down embankment, 3' x 15' and 3' x 10' wing walls at top of chute (see fig. on FOSS)
13	90	0	calm	1		7 to 10	0 to 1.5	not meas.	slight turbid	**Downstream**-- ***left bank*** --30' discharge pipe
14	90	0	calm	1		10 to 15	1 to 2	not meas.	slight turbid	**Downstream**--heavy riprap on both banks; **Upstream**-- ***left bank*** --30" discharge pipe
15	65	85	light	2	trace	25 to 30	2 to 3	not meas.	turbid	**Downstream**--***right bank***--30" discharge pipe
16	65	85	light	2	trace	20 t0 25	1 to 2	1.5	slight turbid; pools turbid	**Downstream**--***right bank***--30" discharge pipe; **Upstream**-- ***left bank*** -- two 30" discharge pipes

	Weather					Channel				
Site ID	Temp. (°F)	Cloud Cover	Wind	Wind Value[1]	Precip.	Width (ft.)	Depth (ft.)	Vel. (ft/sec)	Water Appear.	Structures
17dnstrm	90	0	calm	1		3 to 4	0 to 1	not meas.	slight to mod. turbid	Creek piped under road; **Downstream**--concrete spillway with wing walls; **Upstream**--golf cart bridge
17 upstrm						10 to 15	0 to 1	not meas.	slight to mod. turbid	
18	85	0	calm	1	Mon. (6/19) night storm	4 to 5	0 to 1	not meas.	slight to mod. turbid	Creek piped under road; **Downstream**--both banks--30" discharge pipes
19	65	100	light	2	trace	25 to 30	1 to 2	not meas. traffic too heavy	turbid	**Upstream**--***right bank***--large debris field extending into creek
20	70	100	light	2	trace	25 to 30	2 to 3	not meas. traffic too heavy	turbid	**Upstream**--***right bank***--30" discharge pipe; ***left bank*** --36" discharge pipe
21	75	100	calm	1		20 to 25	2+	1.7	mod. turbid to turbid	**Downstream**--***right ban***k--24" discharge pipe; ***left bank*** --30" concrete discharge pipe w/spillway, bike trail; **Upstream**--***right bank***--24" discharge pipe
22	80	3	calm	1	Fri. (6/23) & Sun. (6/25) storms	2 to 3	0.5-1.5	0.32	turbid	30" creek overflow pipe, parallel to creek culvert, 1' above water surface; **Upstream**-- ***left bank*** --8" concrete discharge pipe

	Weather					Channel				
Site ID	**Temp. (^{o}F)**	**Cloud Cover**	**Wind**	**Wind Value**[1]	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
23	80	3	calm	1	Fri. (6/23) & Sun. (6/25) storms	10 to 15; 100' dnstrm from bridge--2 to 3		1.1	turbid	
24	85	3	calm	1	Fri. (6/23) & Sun. (6/25) storms	5 to 10	1 to 2	0.83	turbid	**Downstream**--***right bank***--deep ditch entering close to culvert outlet
25	85	3	calm	1	Fri. (6/23) & Sun. (6/25) storms	5 to 10	2 to 3	1.4	turbid	**Downstream**--***left bank***--deep ditch entering close to culvert outlet
26	80	5	calm	1	Fri. (6/23) & Sun. (6/25) storms	10 to 15	2+	2.4	turbid	**Downstream**--***left bank***--12" galvanized discharge pipe; **Upstream**--***left bank***--30" discharge pipe
26A	80	5	calm	1	Fri. (6/23) & Sun. (6/25) storms	2 to 3	0.25 to 1	0.8	clear to slight. Turbid	
27	80	1	calm	1	Fri. (6/23) & Sun. (6/25) storms	3 to 5	0.25 to 1	1.3	clear to slight. turbid	
28	80	3	calm	1	Fri. (6/23) & Sun. (6/25) storms	3 to 6	1 to 2	0.89	turbid	

	Weather					Channel				
Site ID	**Temp. (°F)**	**Cloud Cover**	**Wind**	**Wind Value[1]**	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
9	80	3	calm	1	Fri. (6/23) & Sun. (6/25) storms	10 to 15	2+	3.2	turbid	**Downstream**--***right bank***--24" discharge pipe; ***left bank***--18" discharge pipe; **Upstream**--***right bank***--18" galvanized discharge pipe; ***left bank***--24" galvanized discharge pipe
30	85	10	calm	1	Sun. (6/25) storms	.5 to 1	.5 to 1.5	not meas.	slight to mod. turbid	
30A	80	5	calm	1	Fri. (6/23) & Sun. (6/25) storms	0.5 to 1	0.25 to 1	not meas.	slight to mod. turbid	
30B	85	10	calm	1	Sun. (6/25) storms	1 to 2	0.25 to 1	not meas.	clear	
30C	85	15	calm	1	Sun. (6/25) storms	1 to 2	.25 to 1	not meas.	clear	
30D	85	40	calm	1	Sun. (6/25) storms	3 to 8	.5 to 1.5	0.73	slight. to mod. turbid	
31	85	50	calm	1	Sun. (6/25) storms	15 to 20	2+	1.2	turbid	**Downstream**--***left bank***--6'x6' culvert under CR P30 feeding into creek; **Upstream**--railroad bridge
32	80	5	calm	1	Fri. (6/23) & Sun. (6/25) storms	3 to 5	1 to 2	not meas.	mod. turbid to turbid	
32A	80	2	calm	1	Fri. (6/23) & Sun. (6/25) storms	1 to 2	.5 to 1.5	not meas.—obstr. in culvert	clear to slight. turbid	**Downstream**--small dam and reservoir about 30' downstream
32B	80	5	calm	1	Fri. (6/23) & Sun. (6/25) storms	1.5 to 2.5	.5 to 1.5	not meas.	clear	

	Weather					**Channel**				
Site ID	**Temp. (°F)**	**Cloud Cover**	**Wind**	**Wind Value[1]**	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
32C	80	2	calm	1	Wed. (6/28) storms	5 to 10	.25 to 1	1.7	clear to slight. turbid	
33	75	1	calm	1	Wed. (6/28) storms	5 to 10	2+	2.1	slight. to mod. turbid	Streambed under road is corrugated, galvanized pipe
34	80	3	calm	1	Wed. (6/28) storms	7 to 12	2 to 3	0.97	mod. turbid to turbid	**Downstream**--***right bank***--24" galvanized discharge pipe; **Upstream**--***right bank***--24" galvanized discharge pipe, ***left bank***--30" galvanized discharge pipe
35	80	5	calm	1	Wed. (6/28) storms	8 to 13	2 to 3	1.1	mod. turbid	**Downstream**--***right bank***--30" galvanized discharge pipe
36	80	3	calm	1	Wed. (6/28) storms	3 to 6	1 to 2	1.4	slight. to mod. turbid	**Upstream**--***left bank***--6'x12' culvert under highway parallel to creek
37	80	3	calm	1	Wed. (6/28) storms	3 to 5	1 to 2	2.3	slight. to mod. turbid	
38	80	5	calm	1	Wed. (6/28) storms	5 to 10	1 to 2+	not meas.	slight. to mod. turbid	**Downstream**--***right bank***--24" galvanized discharge pipe; **Upstream**--***right & left banks***--24" galvanized discharge pipe
39	80	20	calm	1	Wed. (6/28) storms	5 to 10	1 to 2	3.1	slight. to mod. turbid	**Upstream**--concrete bridge damming/crossing stream, 24" galvanized pipe allows water to pass
40	80	10	calm	1	Wed. (6/28) storms	10 to 15	2+	0.65	mod. turbid to turbid	
41	85	60	light	2		20 to 25	2 to 3	not meas.	mod. turbid	**Downstream**--***right bank***--30" discharge pipe

	Weather					**Channel**				
Site ID	**Temp. (°F)**	**Cloud Cover**	**Wind**	**Wind Value[1]**	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
42	85	10	light	2		10 to 15	2 to 4	not meas.	turbid	
43	90	5	light	2		**No access to creek--land use data only**				
44	85	80	light	2		20 to 25	1.5 to 2.5	0.36	turbid	
45	85	80	light	2		25 to 30	1 to 2	0.48	turbid	**Upstream**--***left bank***--30" discharge pipe, 15' above water surface
46dnstrm	85	60	light	2		8 to 10	.5 to 1	not meas.	slight. to mod. turbid	Creek piped under road
46upstrm						1 to 3	1 to 2	not meas.	slight. to mod. turbid	
47	90	50	light	2		5 to 7	1 to 2	not meas.	clear to slight. turbid	Creek piped under road
48	90	5	light	2		5 to 7	1 to 2	not meas.	clear to slight. turbid	**Downstream**--beaver dam
49	85	85	light	2		10 to 15	0 to 1	not meas.	clear to slight. turbid	**Downstream**--***left bank***--30" discharge pipe, 15' above creek
50	85	60	light	2		10 to 15	0.5 to 1	0.5	mod. turbid	**Downstream**--***left bank***--30" discharge pipe
51	90	40	light	2		25 to 30	2 to 3	0.7	turbid	**Downstream**--***right bank***--30" discharge pipe, ***left bank***--24" discharge pipe; **Upstream**--***left bank***--30" discharge pipe
52	90	20	light	2		25 to 30	2 to 3	1.9	turbid	**Downstream**--***right bank***--8" discharge pipe; **Upstream**--left bank--30" discharge pipe

	Weather					Channel				
Site ID	**Temp. (^{o}F)**	**Cloud Cover**	**Wind**	**Wind Value**[1]	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
53	85	5	light	2		25 to 30	2 to 3	1.4	turbid	**Downstream**--***right bank***--24" discharge pipe; **Upstream**--***left bank***--36" discharge pipe
54	85	10	light	2		20 to 25	2 to 3	1.1	turbid	**Downstream**--pipe crossing from top right bank to top left bank
55	85	20	light	2		25 to 30	2 to 3	2.1	turbid	**Downstream**--***right bank***--30" discharge pipe; **Upstream**--***left bank***--48" discharge pipe w/substantial flow
56	80	60	light	2		25 to 30	2 to 3	0.51	highly turbid-muddy	**Downstream**--***left bank***--30" discharge pipe
62	75	100	calm	1		40 to 50	2+	5.7	turbid	**Downstream**--***right bank***--30" gated, galvanized discharge pipe; **Upstream**--***right bank***--48" gated, galvanized discharge pipe, heavy concrete riprap spillway, ***left bank***--30" gated, galvanized discharge pipe
63	85	80	light	2		40 to 50	2+	not meas.--too windy	turbid	**Downstream**--***right bank***--30" gated, galvanized discharge pipe; **Upstream**--***left bank***--two 30" galvanized discharge pipes, side by side
64	85	0	light	2	0	10 dwnstrm; 25 upstream	0.5 dwnstrm; 1 to 2 upstream	1.5		**Upstream**--beaver dam, velocity close to 0 fps

	Weather					**Channel**				
Site ID	**Temp. (°F)**	**Cloud Cover**	**Wind**	**Wind Value**[1]	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
65	85	0	light	2	0	20	3	0	mucky, floaties	**Upstream**--***left bank***--erosion dike; **Both up and down stream**--***both sides***--Steep constructed banks
66	90	0	light	2	1	10	1	1		
67	89	0	light	2	0	8	1	1		**Downstream**--***right bank***--drainage pipe; **Downstream**--concrete slabs distributed scarcely along right and left bank
68	93	0	strong	3	0	10	1.5	1		**Downstream**--***left bank***--sewer pipe high on bank; **Upstream**--***right bank***--drain pipe
69	88	90	strong	3		1.5	0.3	1		
70	88	90	strong	3	0	1.5	0.5	1		
71	83	95	strong	3	0	12	1.5	3		**Downstream**--***right bank***--concrete slabs; **Upstream**--***left bank***--concrete slabs, pipe connected from bank to bank

	Weather					Channel				
Site ID	**Temp. (°F)**	**Cloud Cover**	**Wind**	**Wind Value[1]**	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
72	85	80	light	2	2	12	1.5	1		**Upstream**--***left bank***--beaver dam, ***left bank***--significant tree removal and graded ground, ***left bank***--rocks and concrete riprap **Upstream**--***right bank***--drainage structure
73	78	0	light	2	0	7	2	1		**Downstream**--***left bank***--trail **Upstream**--***left bank***--trail
74	85	95	light	2	2	12	2	1		**Downstream**--***left bank***--heavy rock shoring, ***left bank***--trail; **Upstream**--***right bank***--drainage structures
75	85	98	light	2	2	10	1	4		
76	85	95	light	2	2	5	1	4		
77	85	98	light	2	2	17	3	0		**Upstream**--***left bank***--wildlife area
78	75	25	light	2	0.5	12	1	1		**Upstream**--***right bank***--drainage pipe, ***right bank***--trail
79	75	10	light	2	0.5	20	1	1		**Downstream**--***right bank***--huge water pipe
80	75	5	light	2	0.5	15	1	0.83		
81	83	95	strong	3	0	6	2	0		**Upstream**--***left bank***--discharge pipe

	Weather					Channel				
Site ID	Temp. (°F)	Cloud Cover	Wind	Wind Value[1]	Precip.	Width (ft.)	Depth (ft.)	Vel. (ft/sec)	Water Appear.	Structures
82	80	95	strong	3	0	3	0.8	0.4		**Downstream**--***left bank***--steep bank and erosion; **Upstream**--huge pipe in middle of channel
83	83	95	strong	3	0	5	1	0		**Downstream**--***right bank***--drain pipe; **Upstream**--***left bank***--two drain pipes
84	83	95	strong	3	0	18	2	0.33		**Downstream**--***left bank***--huge drainage pipe, both banks--rocks **Upstream**--both banks--drainage pipes--has a Y
no Site ID	80	95	strong	3	0	2	0.5	0		
85	80	95	strong	3	0	24	3	0		**Downstream**--affected by lake, 10 ft. deep; **Upstream**<downstream depth by 3 feet
86	80	95	strong	3	0	10	0.5	0.4		**Upstream**--***right bank***--drain pipe
87	75	10	light	2	0.5	9	0.8	0.8		**Upstream**--***right bank***--drainage pipe
88	73	5	light	2		22	2	0.33		
89	70	5	light	2		24	1	1		**Downstream**--***right bank***--drainage pipe, --evidence of remains of bridge; **Upstream**--***left bank***--drainage pipe

	Weather					Channel				
Site ID	**Temp. (°F)**	**Cloud Cover**	**Wind**	**Wind Value[1]**	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
90	76	95	calm	1	2	5	0.5	1		**Downstream**--***right bank***--discharge pipe, --pipe crossing creek
91	75	95	calm	1	2	22	1.5	1		**Downstream**--***right bank***--discharge pipe, ***both banks***--large rocks, concrete bags; **Down and Upstream**--***left bank***--trail
92	75	95	calm	1	2	24	1.5	1		**Downstream**--***left bank***--discharge pipe; **Upstream**--***left bank***--discharge pipe, ***right bank***--discharge pipe
93	75	95	calm	1	2	24	1.5	1		**Downstream**--***right bank***--discharge pipe; **Upstream**--***right bank***--3 discharge pipes
94	90	40	light	2	Thu (6/22) storm	40 to 50	2+	not meas.--too windy	turbid	**Downstream**--***right bank***--30" gated, galvanized discharge pipe, ***left bank***--24" galvanized discharge pipe, rock toe along bank; **Upstream**--***left bank***--two 30" galvanized discharge pipes spaced at approx. 100'
95	90	40	light	2	Thu (6/22) storm	40 to 50	2+	not meas.--too windy	turbid w/ scum on top	

	Weather					Channel				
Site ID	**Temp. (°F)**	**Cloud Cover**	**Wind**	**Wind Value[1]**	**Precip.**	**Width (ft.)**	**Depth (ft.)**	**Vel. (ft/sec)**	**Water Appear.**	**Structures**
96	85	80	calm	1	Thu (6/22) storm	50 to 70	not meas.	0.66	turbid	**Downstream**--***right bank***--4' square discharge pipe w/gate **Upstream**--***right bank***--4' square discharge pipe w/gate
97	80	100	calm	1	Thu (6/22) storm	80 to 100	not meas.	not meas.	mod. turbid to turbid	**Downstream**--***left bank***--10' to 12' square discharge w/gate, at water level
98	80	100	calm	1	Thu (6/22) storm	80 to 100	not meas.	not meas.	mod. turbid to turbid	Heavily channelized banks on both sides, flood control dikes on both banks

Downstream: Habitat and Biological Communities (Land Use)

	Downstream Bank Vegetation (%)											
	Left Bank						Right Bank					
Site ID	Trees	Shrub	Grass	Forbs	Other	Dscrp	Trees	Shrub	Grass	Forbs	Other	Dscrp
1A	0	0	60	40	0		0	0	60	40	0	
1B	60	0	15	25	0		60	0	15	25	0	
1C	10	0	20	70	0		10	0	20	70	0	
1	20	0	45	35	0		20	0	45	35	0	
2	0	0	90	10	0		0	0	90	10	0	
3	0	0	70	30	0		0	0	70	30	0	
4	60	10	20	10	0		60	10	20	10	0	
5	0	0	95	5	0		0	0	95	5	0	
6	**Cunningham Lake**											
7	40	0	35	25	0		40	0	35	25	0	
8A	10	20	25	45	0		10	20	25	45	0	
8	2	0	80	18	0		2	0	80	18	0	
9	20	10	25	45	0		20	10	25	45	0	
10	30	10	10	50	0		35	10	5	50	0	
11	30	10	45	15	0		30	10	45	15	0	
12	60	0	15	25	0		60	0	15	25	0	
13	60	0	15	25	0		60	0	15	25	0	
14	30	0	35	35	0		40	0	25	15	0	
15	60	0	25	15	0		60	0	25	15	0	
16	0	0	99	1	0		0	0	98	2	0	
17	80	0	5	15	0		80	0	5	15	0	
18	70	0	15	15	0		50	0	20	30	0	
19	0	0	100	0	0		0	0	100	0	0	
20	20	3	75	0	2	rock	3	1	95	0	1	rock
21	0	0	70	30	0		0	0	70	30	0	
22	0	0	55	45	0		0	0	45	55	0	
23	0	0	40	60	0		0	0	85	15	0	
24	0	0	85	15	0		2	0	83	15	0	
25	0	0	60	40	0		0	0	50	50	0	
26	0	2	49	49	0		0	2	59	39	0	
26A	2	0	80	18	0		2	0	80	18	0	
27	3	0	57	40	0		3	0	97	20	0	
28	5	0	60	35	0		3	0	62	35	0	
29	0	1	64	35	0		0	1	64	35	0	
30	40	0	35	25	0		40	0	35	25	0	
30A	2	0	60	38	0		5	0	60	35	0	

	Downstream Bank Vegetation (%)											
	Left Bank						Right Bank					
Site ID	Trees	Shrub	Grass	Forbs	Other	Dscrp	Trees	Shrub	Grass	Forbs	Other	Dscrp
30B	40	0	30	30	0		40	0	30	30	0	
30C	5	5	60	30	0		3	2	70	30	0	
30D	10	0	65	25	0		15	0	45	40	0	
31	30	0	35	35	0		30	0	35	35	0	
32	0	0	60	40	0		0	0	60	40	0	
32A	30	5	35	30	0		30	5	35	30	0	
32B	0	0	70	30	0		0	0	70	30	0	
32C	15	0	50	35	0		15	0	50	35	0	
33	1	0	65	34	0		0	0	60	40	0	
34	0	5	70	25	0		0	5	65	30	0	
35	10	0	60	30	0		10	0	60	30	0	
36	0	2	38	60	0		0	2	38	60	0	
37	0	0	60	40	0		0	0	50	50	0	
38	0	0	45	55	0		2	0	43	55	0	
39	10	0	60	30	0		10	0	50	40	0	
40	30	0	45	25	0		30	0	45	25	0	
41	50	0	45	5	0		50	0	45	5	0	
42	30	0	60	10	0		30	0	60	10	0	
43	50	0	35	15	0		50	0	35	15	0	
44	60	0	30	10	0		60	0	30	10	0	
45	10	0	55	35	0		10	0	55	35	0	
46	60	0	30	10	0		60	0	30	10	0	
47	50	0	30	20	0		50	0	30	20	0	
48	45	0	35	20	0		50	0	35	15	0	
49	25	0	40	35	0		70	0	20	10	0	
50	60	0	25	15	0		60	0	25	15	0	
51	0	0	65	35	0		0	0	35	65	0	
52	50	0	20	30	0		40	0	35	25	0	
53	50	0	30	20	0		50	0	30	20	0	
54	40	0	45	15	0		40	0	45	15	0	
55	35	0	45	20	0		40	0	40	20	0	
56	40	0	50	10	0		45	0	45	10	0	
62	0	0	70	30	0		0	0	70	30	0	
63	0	0	65	35	0		0	0	65	35	0	
64	2	0	13	85	0		2	0	85	13	0	
65	0	0	90	10	0		0	0	95	5	0	
66	1	0	66	33	0		1	0	66	33	0	

	Downstream Bank Vegetation (%)											
	Left Bank						Right Bank					
Site ID	Trees	Shrub	Grass	Forbs	Other	Dscrp	Trees	Shrub	Grass	Forbs	Other	Dscrp
67	0	0	90	10	0		0	0	99	1	0	
68	1	0	93	5	0		1	0	95	4	0	
69	0	0	95	5	0		0	0	95	5	0	
70	0	0	98	2	0		20	0	70	10	0	
71	30	0	10	60	0		30	0	20	50	0	
72	32	0	47	21	0		5	0	90	5	0	
73	4	0	52	44	0		1	0	50	49	0	
74	22	0	56	22	0		33	0	44	23	0	
75	11	0	45	44	0		11	0	45	44	0	
76	1	0	25	74	0		1	0	39	60	0	
77	1	0	90	10	0		1	0	90	10	0	
78	33	0	34	33	0		33	0	34	33	0	
79	20	0	40	40	0		20	0	40	40	0	
80	15	0	50	35	0		10	0	45	45	0	
81	10	0	85	5	0		20	0	70	10	0	
82	11	0	89	0	0		40	0	40	20	0	
83	33	0	34	33	0		30	0	20	50	0	
84	20	0	70	10	0		10	0	80	10	0	
No Site ID	10	0	10	80	0		10	0	10	80	0	
85	22	0	11	67	0		20	0	20	60	0	
86	20	0	40	40	0		20	0	40	40	0	
87	20	0	40		40		20	0	40		40	
88	20	0	40	40	0		20	0	40	40	0	
89	20	0	40	40	0		10	0	50	40	0	
90	22	0	34	44	0		31	0	19	50	0	
91	0	0	40	50	0		0	0	50	50	0	
92	0	0	50	50	0		0	0	50	50	0	
93	0	0	90	10	0		0	0	90	10	0	
94	0	0	75	25	0		0	0	85	15	0	
95	0	0	80	20	0		0	0	80	20	0	
96	0	0	80	20	0		0	0	75	25	0	
97	0	0	70	30	0		0	0	70	30	0	
98	50	0	35	15	0		50	0	35	15	0	

Downstream: Land Use

	Downstream Over-Bank Land Use / Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	**Commercial**	**Residential**	**Rural**	**Pasture**	**Cultivated**	**Trees**	**Grass**	**Forbs**	**Other**	**Descript.**	**Commercial**	**Residential**	**Rural**	**Pasture**	**Cultivated**	**Trees**	**Grass**	**Forbs**	**Other**	**Descript.**	**Comments**
1A	0	0	100	0	100	0	0	0	0		0	5	0	0	85	5	5	0	0		
1B	0	0	5	0	85	5	5	0	0		0	0	0	0	90	5	5	0	0		
1C	0	0	0	0	85	5	10	0	0		0	0	10	50	0	15	25	0	0		
1	0	0	0	0	90	5	5	0	0		0	0	0	0	75	5	20	0	0		
2	0	0	0	0	0	60	25	15	0		0	0	0	0	0	60	25	15	0		
3	0	0	0	0	90	0	10	0	0		0	20	0	25	20	10	25	0	0		
4	0	0	0	0	65	20	10	5	0		0	0	10	35	20	25	15	0	0		
5	0	0	0	0	0	35	45	20	0		0	0	0	10	0	40	35	15	0		
6	**Cunningham Lake**																				
7	0	0	0	0	70	3	22	5	0		0	0	0	0	70	3	22	5	0		
8A	0	0	10	0	0	30	30	30	0	60% wetland	0	0	0	0	50	25	15	10	0		
8	0	0	0	0	100	0	0	0	0		0	0	5	0	85	5	5	0	0		
9	0	0	0	0	70	15	10	5	0		0	0	20	0	40	10	25	5	0		
10	0	0	0	0	95	0	5	0	0		0	3	10	0	67	10	10	0	0		
11	0	0	0	0	95	5	0	0	0		0	0	5	20	65	5	5	0	0		
12	0	0	0	0	80	0	20	0	0		0	0	10	0	70	5	15	0	0		
13	60	0	0	0	0	15	25	0	0		0	10	0	0	60	0	15	15	0		
14	70	0	0	0	0	10	20	0	0		70	0	0	0	0	20	10	0	0		
15	0	65	0	0	0	20	10	0	5		25	40	0	0	0	20	10	0	5		
16	90	0	0	0	0	6	4	0	0		5	70	0	0	0	15	7	3		yard plants	

	Downstream Over-Bank Land Use / Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	**Comments**
17	0	0	0	0	0	30	70	0	0	Park, ballfields	0	0	0	0	0	20	40	10	30	park bldg and parking lot	
18	0	65	0	0	0	10	20	5	0	0	0	65	0	0	0	10	20	5	0		
19	90	0	0	0	0	5	2	0	3		90	0	0	0	0	5	2	0	3		
20	70	0	0	0	0	20	5	0	5	75	0	0	0	0	0	10	10	0	5	park	
21	25	0	0	0	0	20	55	0	0	Ball park	75	0	0	0	0	5	20	0	0		
22	0	0	0	0	80	10	5	5	0		0	5	0	5	75	5	5	5	0		
23	0	0	0	0	100	0	0	0	0		0	0	0	0	100	0	0	0	0		
24	0	0	0	30	70	0	0	0	0		0	0	10	25	60	5	0	0	0		
25	0	0	10	0	80	10	0	0	0		0	0	0	0	95	0	5	0	0		
26	0	0	0	0	100	0	0	0	0		0	0	15	0	70	0	5	0	10	road	Rural is mostly feed lot area
26A	0	0	0	35	60	0	5	0	0		0	0	10	50	30	5	5	0	0		
27	0	0	0	0	100	0	0	0	0		0	0	0	0	100	0	0	0	0		
28	0	0	0	0	89	1	4	2	5	road	0	0	0	0	89	2	3	2	5	road	
29	0	0	0	0	82	3	15	0	0		0	0	0	0	85	10	5	0	0		
30	0	0	0	0	20	20	30	10	20	road	0	0	5	0	75	5	10	5	0		
30A	0	0	0	0	55	0	25	10	10	railroad	0	0	0	0	90	0	10	0	0		Feed lot on hill about 0.3 mile north east of sample site

	Downstream Over-Bank Land Use/Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	**Comments**
30B	0	0	0	0	45	30	15	10	0		0	0	0	40	20	25	10	5	10	road	
30C	0	0	20	0	45	10	10	5	10	road	0	0	10	0	60	10	10	5	5	road	Rural has a cattle shed within 5 to 10 feet of left bank of creek
30D	0	0	0	0	90	0	10	0	0		0	0	0	0	75	0	10	0	15	road	
31	0	0	0	0	90	0	5	0	5	road	0	0	0	0	80	10	5	5	0		
32	0	0	0	0	86	0	7	0	7	road	0	0	0	0	90	0	5	0	5	road	
32A	0	0	0	0	0	15	30	55	0		0	0	5	0	0	0	80	15	0		
32B	0	0	0	0	95	0	5	0	0		0	0	0	0	100	0	0	0	0		
32C	0	0	0	0	100	0	0	0	0		0	0	0	0	90	0	10	0	0		
33	0	0	0	0	85	0	5	10	0		0	0	0	0	75	0	15	10	0		
34	0	0	10	0	75	5	10	0	0		0	0	0	0	100	0	0	0	0		
35	0	0	0	0	85	5	5	0	5	road	0	0	10	15	60	10	5	0	0		
36	0	0	0	0	90	0	5	0	5	railroad	0	0	0	0	80	5	10	0	5	railroad	
37	0	0	5	5	90	0	0	0	0		0	0	0	0	80	5	10	0	5	railroad	
38	0	0	0	0	85	5	5	0	5	railroad	0	0	0	0	85	5	5	0	5	railroad	
39	0	0	0	0	60	0	30	0	10	road	0	0	0	0	0	60	20	10	10	road	
40	0	0	0	0	82	3	15	0	0		0	0	10	0	50	5	15	5	15	road	
41	0	0	0	60	30	10	0	0	0		0	0	5	0	90	5	0	0	0		
42	0	0	0	0	85	5	10	0	0		0	0	15	35	45	5	0	0	0		
43	0	0	0	0	70	10	20	0	0		0	0	0	0	70	10	20	0	0		

	Downstream Over-Bank Land Use/Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	**Commercial**	**Residential**	**Rural**	**Pasture**	**Cultivated**	**Trees**	**Grass**	**Forbs**	**Other**	**Descript.**	**Commercial**	**Residential**	**Rural**	**Pasture**	**Cultivated**	**Trees**	**Grass**	**Forbs**	**Other**	**Descript.**	**Comments**
44	0	0	0	0	70	10	15	5	0		0	0	0	0	75	10	10	5	0		
45	0	0	10	0	80	7	3	0	0		0	0	0	0	85	10	5	0	0		
46	0	0	15	0	55	30	0	0	0		0	0	0	0	80	20	0	0	0		
47	0	0	0	5	85	10	0	0	0		0	0	10	5	75	10	0	0	0		
48	0	0	10	10	60	0	20	0	0		0	0	5	0	70	0	25	0	0		
49	0	0	0	10	30	20	10	30	0		0	0	10	10	55	15	5	5	0		
50	0	0	0	0	85	10	5	0	0		0	0	10	0	65	10	5	0	0		
51	0	0	0	0	0	10	55	35	0		0	0	0	0	0	0	60	40	0		
52	0	30	0	0	40	20	10	0	0		0	5	15	0	65	10	5	0	0		
53	0	0	0	0	85	10	5	0	0		0	0	0	0	70	10	20	0	0		
54	0	0	0	0	40	0	60	0	0		0	30	0	0	40	10	15	5	0		golf course on left bank
55	40	0	0	0	50	0	5	5	0		0	0	2	0	0	13	80	5	0		cultivated area on left bank is an orchard
56	5	15	0	0	0	25	35	20	0		10	15	0	0	0	25	35	15	0		power line and right of way cross the stream here
62	10	10	0	0	0	30	25	15	10	shrubs	0	30	0	0	50	20	10	0	0		
63	0	0	0	0	65	10	15	10	0		0	0	0	0	85	0	10	5	0		
64	0	0	0	0	95	1	2	2	0		0	0	0	0	90	3	4	3	0		

	Downstream Over-Bank Land Use / Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
65	0	0	0	0	90	3	5	2	0		0	0	0	0	90	3	5	2	0		
66	0	0	1	0	90	5	2	2	0		0	0	1	0	90	5	2	1	1	bldg	
67	0	0	0	40	40	10	7	3	0		0	0	40	0	0	12	40	8	0		
68	0	60	0	0	0	5	33	0	2	trail	0	0	0	0	50	20	25	5	0		
69	0	0	0	0	90	0	8	2	0		0	0	10	0	75	10	5	0	0		
70	0	0	2	0	89	2	6	1	0		0	0	7	0	89	1	1	2	0		
71	60	5	0	0	0	10	10	15	0		40	0	0	0	0	10	20	30	0		
72	0	0	0	0	90	5	4	1	0		0	20	20	0	0	10	45	5	0		
73	0	40	0	0	0	15	30	15	0		0	9	1	0	70	10	7	3	0		trail on left bank
74	0	10	0	0	0	30	20	40	0		0	60	0	0	0	20	10	10	0		
75	20	5	0	0	0	20	40	15	0		0	0	0	0	0	10	40	40	5	trail	
76	90	0	0	0	0	0	0	0	10	Mulhull's nursery	0	0	20	10	0	30	30	10	0		
77	0	0	10	0	0	35	35	20	0		0	0	10	0	0	30	40	20	0		
78	50	0	0	0	0	1	49	10	0		50	0	0	0	0	0	40	10	0		
79	80	0	0	0	0	0	10	10	0		50	0	0	0	0	2	45	3	0		soccer field on right bank included in grass area
80	50	0	0	0	0	0	25	25	0		20	10	0	0	0	10	30	30	0		commercial area on right bank includes

	Downstream Over-Bank Land Use / Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
																					golf course
81	0	0	5	0	80	5	5	5	0		0	0	10	0	40	20	25	5	0		
82	20	0	0	0	40	10	10	20	0		0	0	0	0	40	10	30	20	0		
83	0	75	0	0	0	5	10	10	0		0	30	0	0	0	10	10	50	0		
84	0	50	0	0	0	20	20	10	0		20	0	0	0	0	0	30	0	50	railroad	railroad area contains cleared land
No Site ID	0	0	0	0	90	5	4	1	0		0	0	0	0	90	5	4	1	0		
85	0	0	0	0	20	10	60	10	0		0	0	0	0	30	10	30	30	0		
86	5	10	0	0	0	30	40	15	0		10	0	0	0	60	30	0	0	0		Commercial on left bank includes a park
87	90	0	0	0	0	3	2		5		78	0	0	0	10	5	2		5		
88	0	0	10	0	0	10	40	40	0		0	0	0	30	0	10	30	20	0		
89	0	0	0	0	10	15	35	40	0		0	0	0	0	80	5	5	10	0		
90	0	0	0	0	85	2	6	7	0		0	5	0	0	80	5	5	5	0		
91	95	0	0	0	0	0	5	0	0		95	0	0	0	0	0	5	0	0		
92	0	10	0	0	0	0	45	45	0		0	0	0	0	40	20	20	20	0		
93	0	0	0	0	89	1	4	0	6	trail	0	0	2	0	90	0	3	5			
94	1	0	0	0	0	2	60	37	0		0	0	0	0	25	50	20	5	0		Papio Trail runs down left bank, 10' wide concrete

	Downstream Over-Bank Land Use / Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
95	0	0	0	0	0	10	60	30	0		0	10	0	0	0	20	60	10	0		Papio Trail runs down left bank, 10' wide concrete; golf course on right bank
96	0	0	0	0	40	20	25	5	10	railroad	25	0	0	0	35	10	20	10	0		Papio Trail runs down left bank, 10' wide concrete
97	0	0	0	0	50	15	25	10	0		0	0	0	0	60	10	20	10	0		Papio Trail runs down left bank, 10' wide concrete
98	0	0	0	0	0	50	35	15	0		0	20	0	0	0	50	20	10	0		Papio Trail runs down left bank, 10' wide concrete

Upstream: Habitat and Biological Communities

	Upstream Bank Vegetation (%)											
	Left Bank						Right Bank					
Site ID	Trees	Shrub	Grass	Forbs	Other	Descript.	Trees	Shrub	Grass	Forbs	Other	Descript.
1A	20	20	15	45	0		20	20	15	45	0	
1B	0	0	90	10	0		0	0	90	10	0	
1C	0	0	30	70	0		0	0	30	70	0	
1	20	0	45	35	0		20	0	45	35	0	
2	5	0	90	5	0		5	0	90	5	0	
3	40	0	25	35	0		40	0	25	35	0	
4	40	10	30	20	0		40	10	30	20	0	
5	0	0	95	5	0		1	0	94	5	0	
6	**Cunningham Lake**											
7	10	15	37	38	0		0	20	45	35	0	
8A	10	10	30	50	0		10	10	30	50	0	
8	0	0	90	10	0		0	0	90	10	0	
9	0	0	60	40	0		0	1	70	29	0	
10	30	10	15	45	0		30	10	15	45	0	
11	30	10	35	25	0		30	10	35	25	0	
12	60	0	15	25	0		60	0	15	25	0	
13	60	0	15	25	0		60	0	15	25	0	
14	40	0	40	20	0		40	0	40	20	0	
15	70	0	15	15	0		70	0	15	15	0	
16	0	0	98	2	0		0	0	80	20	0	
17	65	15	15	5	0		50	10	25	5	0	
18	70	0	10	20	0		70	0	10	20	0	
19	0	0	100	0	0		0	0	100	0	0	
20	5	0	93	0	2	riprap	5	0	93	0	2	riprap
21	0	0	60	40	0		0	0	60	40	0	
22	0	0	50	50	0		0	0	50	50	0	
23	1	0	59	40	0		0	0	80	20	0	
24	0	0	65	35	0		0	0	50	50	0	
25	0	0	50	50	0		0	0	50	50	0	
26	0	0	60	40	0		0	0	60	40	0	
26A	0	0	80	20	0		0	0	80	20	0	
27	20	0	50	30	0		20	0	50	30	0	
28	5	0	60	35	0		5	0	60	35	0	
29	5	2	63	30	0		5	0	65	30	0	
30	35	0	40	25	0		30	0	40	30	0	
30A	2	3	60	35	0		0	0	55	45	0	

	Upstream Bank Vegetation (%)											
	Left Bank						Right Bank					
Site ID	Trees	Shrub	Grass	Forbs	Other	Descript.	Trees	Shrub	Grass	Forbs	Other	Descript.
30A 2nd Channel	0	0	80	20	0		0	0	80	20	0	
30B	15	0	50	35	0		15	0	50	35	0	
30C	1	0	80	19	0		0	0	80	20	0	
30D	10	0	65	25	0		15	0	45	40	0	
31	40	0	25	35	0		40	0	25	35	0	
32	0	2	58	40	0		0	0	60	40	0	
32A	40	0	35	25	0		40	0	35	25	0	
32B	0	0	80	20	0		0	0	80	20	0	
32C	30	0	40	30	0		30	0	40	30	0	
33	0	0	80	20	0		0	0	80	20	0	
34	5	0	65	30	0		5	1	60	34	0	
35	0	0	70	30	0		0	0	70	30	0	
36	0	0	80	20	0		0	0	80	20	0	
37	0	0	80	20	0		0	0	80	20	0	
38	0	0	25	75	0		1	0	29	70	0	
39	0	0	80	20	0		0	0	80	20	0	
39A	30	0	45	25	0		30	0	45	25	0	
40	30	0	45	25	0		30	0	45	25	0	
41	50	0	45	5	0		50	0	45	5	0	
42	35	0	55	10	0		35	0	55	10	0	
43	50	0	35	15	0		50	0	35	15	0	
44	60	0	20	20	0		55	0	25	20	0	
45	30	0	50	20	0		40	0	45	15	0	
46	10	0	60	30	0		20	0	55	25	0	
47	20	0	50	30	0		20	0	50	30	0	
48	50	0	35	15	0		50	0	35	15	0	
49	10	0	70	20	0		10	0	75	15	0	
50	70	0	15	15	0		70	0	10	20	0	
51	15	0	55	30	0		30	0	45	25	0	
52	40	0	35	25	0		40	0	35	25	0	
53	50	0	30	20	0		50	0	25	25	0	
54	40	0	45	15	0		40	0	45	15	0	
55	40	0	50	10	0		50	0	40	10	0	
56	10	0	80	10	0		20	0	65	15	0	
62	0	0	65	35	0		0	0	65	35	0	
63	0	0	65	35	0		0	0	65	35	0	
64	30	0	40	30	0		20	0	40	40	0	

	Upstream Bank Vegetation (%)											
	Left Bank						Right Bank					
Site ID	Trees	Shrub	Grass	Forbs	Other	Descript.	Trees	Shrub	Grass	Forbs	Other	Descript.
65	1	0	96	3	0		0	0	96	3	0	
66	1	0	95	4	0		1	0	95	4	0	
67	0	0	50	50	0		2	0	50	48	0	
68	0	0	94	6	0		0	0	94	6	0	
69	1	0	99	0	0		5	0	90	5	0	
70	20	0	75	5	0		10	0	89	1	0	
71	67	0	33	0	0		67	0	33	0	0	
72	4	0	46	50	0		2	0	48	50	0	
73	22	0	56	22	0		22	0	56	22	0	
74	22	0	44	34	0		10	0	85	5	0	
75	1	0	49	50	0		1	0	49	50	0	
76	10	0	60	30	0		10	0	60	30	0	
77	15	0	75	10	0		75	0	75	10	0	
78	0	0	50	50	0		0	0	50	50	0	
79	10	0	45	45	0		11	0	47	42	0	
80	10	0	45	40	0		10	0	45	40	0	
81	20	0	50	30	0		15	0	80	5	0	
82	20	0	30	50	0		20	0	30	50	0	
83	20	0	40	40	0		20	0	40	40	0	
84	21	0	52	32	0		38	0	38	24	0	
No Site ID	0	0	50	50	0		0	0	50	50	0	
85	0	0	50	50	0		0	0	50	50	0	
86	10	0	45	45	0		10	0	45	45	0	
87	20	0	40	40	0		20	0	40	40	0	
88	15	0	45	40	0		15	0	45	40	0	
89	20	0	40	40	0		20	0	40	40	0	
90	40	0	30	30	0		40	0	30	30	0	
91	1	0	50	49	0		1	0	49	50	0	
92	0	0	50	50	0		0	0	50	50	0	
93	0	0	50	50	0		0	0	50	50	0	
94	0	0	70	30	0		0	0	65	35	0	
95	0	0	80	20	0		0	0	80	20	0	
96	0	0	90	10	0		0	0	80	20	0	
97	0	0	70	30	0		0	0	70	30	0	
98	0	0	60	40	0		0	0	60	40	0	

Upstream Land Use

	Upstream Over-Bank Land Use / Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
1A	0	0	0	0	82	3	5	10	0		0	0	0	0	90	0	5	5	0		
1B	0	0	0	0	100	0	0	0	0		0	0	20	10	65	5	5	0	0		
1C	0	0	0	0	90	0	10	0	0		0	0	0	0	85	0	10		5	road	
1	0	0	0	0	85	3	12	0	0		0	0	20	0	40	10	30	0	0	feedlot	
2	0	0	0	0	95	0	5	0	0		5	0	5	0	80	5	5	0	0		
3	0	0	0	0	80	0	10	10	0		0	0	0	40	45	5	10	0	0		
4	0	0	0	0	80	10	10	0	0		0	0	15	50	0	20	15	0	0		
5	0	0	0	0	0	50	35	15	0	archery range	0	0	0	0	10	45	30	15	0		
6	**Cunningham Lake**																				
7	0	0	0	0	0	35	65	0		park	0	0	0	0	0	60	20	20	0	park	
8A	0	0	0	0	70	5	10	15	0	30% wetland	0	0	0	0	70	5	10	15	0	30% wetland	
8	0	0	0	0	100	0	0	0	0		0	0	0	0	100	0	0	0	0		
9	0	0	0	0	85	5	10	0	0		0	0	0	0	85	5	10	0	0		
10	0	0	10	0	70	10	10	0	0		0	0	0	0	80	10	5	0	5	road	
11	0	0	5	0	65	20	10	0	0		0	0	0	0	85	10	5	0	0		
12	0	15	0	0	65	10	10	0	0		0	0	0	0	60	10	30	0	0		
13	20	0	10	10	0	0	15	5	40	feed lot with lagoons	0	0	0	0	75	10	10	5	0		
14	25	0	0	0	0	40	35	0	0		25	0	10	0	0	25	40	0	0		
15	50	0	0	0	30	15	5	0	0		75	0	0	0	0	15	6	4	0		

	Upstream Over-Bank Land Use/Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
16	72	0	0	0	0	20	50	0	3		72	0	0	0	0	20	5	0	3		
17	0	0	0	0	0	20	80	0	0	golf course	0	0	0	0	0	20	80	0	0	golf course	
18	0	65	0	0	0	10	20	5	0		0	65	0	0	10	20	5	0			
19	60	0	0	0	0	28	7	5	0		95	0	0	0	0	1	4	0	0		
20	60	0	0	0	0	10	25	0	5		25	0	0	0	0	10	25	0	40	ball field	
21	0	50	0	0	0	15	35	0	0		70	0	0	0	0	20	10	0	0		
22	0	0	0	98	0	2	0	0	0		0	0	10	80	0	10	0	0	0		
23	0	0	0	0	95	0	3	2	0		0	0	0	0	100	0	0	0	0		
24	0	0	0	30	70	0	0	0	0		0	0	10	60	0	15	15	0	0		
25	0	0	5	0	75	10	10	0	0		0	0	0	0	90	0	10	0	0		
26	0	0	0	0	89	1	0	0	10	road	0	0	0	0	94	1	5	0	0		
26A	0	0	0	55	40	0	5	0	0		0	0	0	35	55	5	5	0	0		
27	0	0	0	0	92	3	5	0	0		0	0	0	0	94	1	5	0	0		
28	0	0	10	0	65	10	5	0	0		0	0	0	0	90	5	5	0	0		
29	0	0	0	0	90	0	10	0	0		0	0	0	0	80	0	10	0	10	road	
30	0	0	10	75	0	0	10	0	5	road	0	0	15	30	0	15	30	10	0		
30A	0	0	10	25	0	10	30	25	0		0	0	0	0	45	20	30	15	10	railroad	
30A 2nd Channel	0	0	0	0	85	3	5	0	7	road	0	0	0	0	90	3	7	0	0		
30B	0	0	0	40	0	45	5	10	0		0	0	0	15	0	60	10	15	0		
30C	0	0	0	0	90	0	10	0	0		0	0	0	0	70	5	15	5	5	road	

	Upstream Over-Bank Land Use/Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
30D	0	0	0	0	100	0	0	0	0		0	0	0	0	75	0	10	0	15	road	
31	0	0	0	0	65	15	10	5	5	railroad	0	30	0	0	0	25	30	10	5	railroad	
32	0	0	5	0	85	3	7	0	0		0	0	15	10	60	10	5	0	0		
32A	0	0	15	0	50	25	10	0	0		0	0	0	0	95	0	0	0	5	road	
32B	0	0	15	30	0	10	25	20	0		0	0	0	0	80	0	10	0	10	road	
32C	0	0	0	0	90	10	0	0	0		0	0	0	0	95	15	0	0	0		
33	0	0	0	0	85	0	5	10	0		0	0	0	0	70	0	20	10	0		
34	0	0	15	0	65	10	10	0	0		0	0	10	25	45	10	10	0	0		Left bank rural includes hog confinement and house
35	0	0	0	0	100	0	0	0	0		0	0	0	0	90	0	5	0	5	road	
36	0	0	0	0	95	0	5	0	0		0	0	0	0	75	5	10	0	10	road	
37	0	0	0	55	40	5	0	0	0		0	0	0	50	25	5	10	5	5	railroad	
38	0	0	0	0	83	2	10	0	5	railroad	0	0	0	0	95	0	0	0	5	road	
39	0	0	0	0	90	0	5	0	5	road											
39A	0	5	0	0	70	5	15	0	5	railroad	0	10	0	0	60	10	15	0	5	railroad	
40	0	5	0	0	70	5	15	0	5	railroad	0	10	0	0	60	10	15	0	5	railroad	
41	0	0	5	0	85	10	0	0	0		0	0	0	0	90	10	0	0	0		
42	0	0	0	0	0	65	35	5	0		0	0	0	0	85	10	5	0	0		
43	0	0	10	40	25	15	10	0	0		0	0	5	0	80	10	5	0	0		
44	0	0	0	0	80	15	5	0	0		0	0	10	0	70	10	10	0	0		

	Upstream Over-Bank Land Use/Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
45	0	0	5	5	80	10	0	0	0		0	0	5	2	88	5	0	0	0		
46	0	0	0	0	85	10	5	0	0		0	0	0	0	65	20	15	0	0		
47	0	0	0	0	90	5	5	0	0		0	0	10	0	80	10	0	0	0		
48	0	0	0	0	40	30	20	10	0		0	0	20	10	50	15	5	0	0		
49	0	0	30	10	50	15	5	0	0		0	0	15	5	70	8	2	0	0		
50	0	0	15	0	75	10	0	0	0		0	0	25	10	40	10	15	0	0		
51	0	0	10	0	75	10	5	0	0		0	0	0	0	70	25	5	0	0		
52	0	40	0	0	0	20	40	0	0		0	0	0	0	30	30	40	0	0		park
53	0	0	5	0	80	10	5	0	0		0	0	0	0	60	15	25	0	0		
54	0	0	0	0	0	2	90	8	0		0	0	0	0	80	5	10	5	0		golf course on left bank
55	0	0	0	0	80	10	6	4	0		5	0	0	0	0	15	75	5	0		ballfields are approx. 60% of right bank area
56	0	10	0	0	0	10	80	0	0		5	0	0	0	0	10	80	0	5	parking lot	golf course
62	20	0	0	0	0	30	40	0	10	cleared area	20	0	0	0	0	30	50	0	0		park
63	0	0	5	0	65	10	13	7	0		0	0	0	0	85	0	10	5	0		
64	0	0	0	0	87	3	5	5	0		0	0	0	0	95	2	3	0	0		

	Upstream Over-Bank Land Use/Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
65	0	0	0	0	85	10	5	0	0		0	0	20	25	30	15	10	0	0		rural area includes buildings and gravel road
66	0	0	0	0	95	1	3	1	0		0	0	0	0	95	1	3	1	0		
67	0	60	0	0	0	5	30	5	0		0	0	5	0	5	75	10	5	0		left bank--bike trail; right bank--tree area includes tree farm
68	0	0	0	0	0	50	50	0	0		0	15	0	0	0	5	75	5	0		left bank--heavy ground removal, almost all dirt remaining
69	0	0	0	0	90	1	7	2	0		0	0	2	0	90	4	3	1	0		
70	0	0	3	0	90	3	3	1	0		0	5	3	0	80	3	6	3	0		
71	60	0	0	0	0	10	10	20	0		5	60	0	0	0	10	20	5	0		
72	0	0	0	0	85	10	4	1	0		0	10	10	10	10	25	30	5	0		
73	0	40	0	0	0	10	35	15	0		0	8	2	0	60	15	13	2	0		left bank--bike trail
74	0	30	0	0	0	20	30	20	0		10	5	0	0	0	25	20	20	0		
75	20	10	0	0	0	10	30	30	0		0	40	0	0	0	10	30	15	5	trail	

	Upstream Over-Bank Land Use/Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	**Commercial**	**Residential**	**Rural**	**Pasture**	**Cultivated**	**Trees**	**Grass**	**Forbs**	**Other**	**Descript.**	**Commercial**	**Residential**	**Rural**	**Pasture**	**Cultivated**	**Trees**	**Grass**	**Forbs**	**Other**	**Descript.**	**Comments**
76	5	0	0	0	0	50	40	5	0		16	0	0	0	0	52	21	11	0		Mulhull's nursery and tree farm make up commercial area on left bank, tree area on right bank
77	0	0	0	0	0	70	25	5	0		0	0	0	0	0	70	25	5	0		
78	40	0	0	0	0	10	40	10	0		45	0	0	0	0	0	50	5	0		
79	30	20	0	0	0	10	20	20	0		75	0	0	0	0	5	20	20	0		ballfield included in commercial area
80	0	0	0	0	0	5	35	60	0		0	0	0	0	0	10	45	45	0		
81	0	0	10	0	40	10	30	10	0		0	0	0	0	60	10	20	10	0		
82	0	0	0	0	85	5	5	5	0		0	0	0	0	85	5	5	5	0		
83	0	0	0	0	30	10	40	20	0		10	30	0	0	0	0	20	40	0		
84	0	50	0	0	0	0	40	10	0		0	0	0	0	0	10	60	0	30	soccer park	
	0	0	0	0	10	20	60	10	0		0	0	65	0	0	15	15	5	0		

	Upstream Over-Bank Land Use/Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
85	0	10	0	0	0	80	10	0	0		0	0	0	0	80	0	10	10	0		tree farm on left bank included in tree area
86	0	0	0	0	0	20	20		60	lake/dam/ forbes	0	0	0	0	30	30	30	10	0		
87	0	0	0	75	0	5	10	0	10	railroad	0	5	0	0	80	5	5	0	5	trail	
88	25	0	0	0	0	15	30	30	0		0	0	5	0	0	5	85	5	0		
89	80	0	0	0	0	5	10	5	0		0	0	0	0	0	0	80	20	0		
90	0	0	0	30	0	10	20	40	0		0	0	0	0	60	15	10	15	0		
91	80	0	0	0	0	1	1	18	0		0	80	0	0	0	5	10	5	0		
92	5	0	0	0	0	0	45	45	0		5	0	0	0	0	0	45	45	0		commerical is powerline
93	0	0	0	0	85	5	5	5	0		0	0	1	0	85	4	5	5	0		
94	5	0	0	0	60	10	15	10	0		0	0	0	0	60	10	15	15	0		Papio Trail runs down left bank, 10' wide concrete
95	0	0	0	0	0	4	80	14	2	shrubs	0	0	0	0	0	30	60	5	5	golf course bldgs	Papio Trail runs down left bank, 10' wide concrete

	Upstream Over-Bank Land Use/Vegetation (%)																				
	Left Bank										Right Bank										
Site ID	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Commercial	Residential	Rural	Pasture	Cultivated	Trees	Grass	Forbs	Other	Descript.	Comments
96	5	0	5	0	40	25	20	5	0		0	0	0	0	80	5	10	5	0		Papio Trail runs down left bank, 10' wide concrete
97	0	0	0	0	75	0	15	10	0		0	0	0	0	75	0	15	10	0		Papio Trail runs down left bank, 10' wide concrete
98	30	0	0	0	0	40	20	10	0		0	0	0	0	60	5	25	10	0		Commercial on left bank is WWTP; Papio Trail runs down left bank, 10' wide concrete

Bioassessment 1

	Habitat Parameter													
	Epifaunal Substrate / Available Cover		Pool Substrate Characterization		Pool Variability		Sediment Deposition		Channel Flow Status		Channel Alteration		Channel Sinuosity	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
1A dwnstrm	marginal	6	marginal	6	marginal	6	poor	5	marginal	7	marginal	6	poor	2
1A upstrm	suboptimal	11	marginal	6	marginal	6	poor	5	marginal	7	marginal	6	poor	2
1B dwnstrm	suboptimal	13	marginal	6	marginal	6	marginal	8	suboptimal	11	marginal	9	poor	4
1B upstrm	marginal	7	marginal	6	marginal	6	marginal	8	suboptimal	11	marginal	6	poor	4
1C dwnstrm	suboptimal	15	suboptimal	11	marginal	6	marginal	8	marginal	8	marginal	6	poor	3
1C upstrm	suboptimal	15	suboptimal	11	marginal	6	marginal	8	marginal	8	marginal	6	poor	3
1	marginal	8	marginal	6	marginal	6	marginal	6	marginal	10	marginal	6	poor	5
2 dwnstrm	optimal	16	suboptimal	14	marginal	10	suboptimal	13	suboptimal	15	suboptimal	13	marginal	6
2 upstrm	suboptimal	11	suboptimal	11	marginal	6	marginal	8	suboptimal	15	marginal	8	poor	4
3 dwnstrm	suboptimal	11	marginal	10	marginal	6	marginal	8	marginal	10	poor	5	poor	2
3 upstrm	suboptimal	13	marginal	7	marginal	6	marginal	8	marginal	10	marginal	7	poor	5
4	suboptimal	13	suboptimal	11	marginal	10	suboptimal	11	suboptimal	11	marginal	8	poor	5
5	suboptimal	15	marginal	10	marginal	6	suboptimal	13	suboptimal	15	marginal	10	marginal	6
6	**Cunningham Lake**													
7	suboptimal	11	marginal	9	marginal	6	marginal	8	marginal	7	suboptimal	12	marginal	7
8A dwnstrm	optimal	17	suboptimal	15	suboptimal	11	marginal	8	suboptimal	11	suboptimal	13	marginal	6
8A upstrm	optimal	17	suboptimal	15	suboptimal	11	marginal	8	suboptimal	11	suboptimal	13	marginal	6
8	marginal	8	marginal	9	marginal	6	marginal	10	suboptimal	11	marginal	8	poor	3
9 dwnstrm	marginal	10	marginal	6	marginal	6	marginal	6	suboptimal	11	marginal	8	poor	3
9 upstrm	marginal	6	marginal	6	marginal	6	marginal	6	suboptimal	11	marginal	6	poor	3
10	marginal	6	marginal	6	marginal	6	poor	5	marginal	8	marginal	6	poor	5
11	marginal	10	marginal	6	marginal	6	marginal	6	marginal	8	marginal	6	poor	4
12	suboptimal	12	suboptimal	11	marginal	8	marginal	8	suboptimal	11	suboptimal	11	poor	5

	Habitat Parameter													
	Epifaunal Substrate / Available Cover		**Pool Substrate Characterization**		**Pool Variability**		**Sediment Deposition**		**Channel Flow Status**		**Channel Alteration**		**Channel Sinuosity**	
Site ID	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**
13	suboptimal	11	marginal	8	marginal	6	marginal	8	suboptimal	11	marginal	10	poor	5
14	suboptimal	11	marginal	8	marginal	8	marginal	7	marginal	8	marginal	6	poor	5
15	suboptimal	14	suboptimal	11	marginal	8	marginal	8	suboptimal	11	marginal	10	marginal	7
16	marginal	7	marginal	7	poor	5	marginal	8	suboptimal	11	marginal	6	marginal	6
17 dwnstrm	suboptimal	12	marginal	6	poor	5	marginal	8	marginal	6	marginal	8	poor	4
17 upstrm	marginal	6	marginal	6	marginal	8	suboptimal	11	suboptimal	13	marginal	6	poor	4
18	marginal	10	marginal	6	poor	3	poor	3	marginal	7	marginal	6	marginal	6
19	marginal	6	marginal	7	marginal	7	marginal	10	marginal	10	marginal	6	poor	4
20	marginal	7	marginal	8	marginal	7	marginal	8	marginal	9	marginal	6	poor	5
21	poor	5	poor	5	poor	5	marginal	6	marginal	8	poor	5	poor	2
22 dwnstrm	suboptimal	13	suboptimal	13	marginal	8	suboptimal	13	suboptimal	15	marginal	6	poor	2
22 upstrm	suboptimal	13	suboptimal	13	marginal	8	suboptimal	13	suboptimal	15	suboptimal	13	marginal	8
23	marginal	10	marginal	8	marginal	8	marginal	9	suboptimal	13	marginal	6	poor	5
24	suboptimal	11	suboptimal	12	marginal	8	marginal	8	suboptimal	12	marginal	9	poor	5
25	marginal	6	marginal	6	poor	5	suboptimal	11	suboptimal	11	marginal	8	marginal	6
26	marginal	6	marginal	6	marginal	6	marginal	8	suboptimal	11	marginal	6	poor	3
26A	poor	5	poor	5	poor	5	marginal	8	marginal	7	marginal	8	poor	5
27 dwnstrm	marginal	9	suboptimal	11	marginal	8	marginal	6	marginal	10	marginal	10	poor	5
27 upstrm	suboptimal	11	suboptimal	11	marginal	8	marginal	6	marginal	10	marginal	10	poor	5
28	marginal	8	marginal	8	marginal	6	marginal	8	suboptimal	11	suboptimal	11	poor	5
29	marginal	6	marginal	6	marginal	6	marginal	8	suboptimal	12	marginal	6	poor	3
30 dwnstrm	optimal	16	suboptimal	13	marginal	10	marginal	8	marginal	10	marginal	10	poor	4
30 upstrm	optimal	16	suboptimal	13	marginal	10	marginal	8	marginal	10	suboptimal	15	marginal	10
30A dwnstrm	optimal	13	marginal	10	marginal	8	marginal	8	marginal	9	marginal	10	poor	5

	Habitat Parameter													
	Epifaunal Substrate / Available Cover		Pool Substrate Characterization		Pool Variability		Sediment Deposition		Channel Flow Status		Channel Alteration		Channel Sinuosity	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
30A upstrm	optimal	13	marginal	10	marginal	8	marginal	8	marginal	9	marginal	10	poor	5
30B dwnstrm	optimal	17	suboptimal	13	marginal	10	suboptimal	11	marginal	10	suboptimal	11	marginal	6
30B upstrm	optimal	17	suboptimal	13	marginal	10	suboptimal	11	marginal	10	optimal	16	suboptimal	11
30C	marginal	8	marginal	6	poor	5	marginal	6	marginal	6	marginal	7	poor	5
30D	marginal	10	marginal	8	marginal	6	marginal	6	marginal	7	marginal	6	poor	3
31	marginal	8	marginal	6	marginal	6	marginal	6	suboptimal	11	poor	5	poor	3
32	suboptimal	13	suboptimal	11	marginal	6	marginal	8	suboptimal	11	marginal	10	poor	5
32A dwnstrm	suboptimal	13	suboptimal	11	suboptimal	11	marginal	6	marginal	7	suboptimal	13	marginal	7
32A upstrm	suboptimal	13	suboptimal	11	suboptimal	11	marginal	6	marginal	7	suboptimal	13	marginal	7
32B	suboptimal	13	suboptimal	13	marginal	10	suboptimal	14	suboptimal	11	marginal	6	poor	3
32C dwnstrm	suboptimal	15	suboptimal	11	marginal	8	marginal	6	suboptimal	11	marginal	6	poor	3
32C upstrm	suboptimal	15	suboptimal	11	marginal	8	marginal	6	suboptimal	11	marginal	10	poor	4
33	marginal	6	marginal	6	marginal	8	marginal	8	suboptimal	11	marginal	6	poor	3
34	marginal	6	marginal	6	marginal	6	marginal	6	marginal	10	marginal	6	poor	3
35	marginal	6	marginal	6	marginal	6	poor	5	suboptimal	11	marginal	6	poor	3
36	marginal	10	marginal	10	marginal	6	marginal	8	suboptimal	11	marginal	6	poor	4
37 dwnstrm	marginal	6	marginal	6	marginal	6	marginal	6	suboptimal	11	marginal	6	poor	5
37 upstrm	marginal	6	marginal	6	marginal	6	marginal	6	suboptimal	11	marginal	6	marginal	7
38	marginal	10	suboptimal	11	marginal	6	marginal	8	suboptimal	12	marginal	6	poor	3
39	marginal	6	marginal	7	marginal	6	marginal	6	suboptimal	11	poor	5	poor	3
39A														
40	marginal	8	marginal	6	marginal	6	marginal	8	marginal	10	marginal	6	poor	4
41	suboptimal	11	suboptimal	11	marginal	6	marginal	8	suboptimal	15	marginal	6	poor	3
42	suboptimal	14	suboptimal	13	suboptimal	12	suboptimal	13	suboptimal	15	marginal	6	poor	5

	Habitat Parameter													
	Epifaunal Substrate / Available Cover		Pool Substrate Characterization		Pool Variability		Sediment Deposition		Channel Flow Status		Channel Alteration		Channel Sinuosity	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
43														
44	poor	5	marginal	6	poor	5	marginal	6	marginal	9	marginal	6	poor	5
45	marginal	6	marginal	6	marginal	6	marginal	7	marginal	8	marginal	6	poor	4
46 dwnstrm	marginal	10	marginal	10	marginal	6	marginal	8	suboptimal	11	marginal	8	marginal	6
46 upstrm	suboptimal	15	marginal	10	marginal	6	marginal	8	suboptimal	11	suboptimal	14	marginal	9
47 dwnstrm	marginal	10	marginal	9	poor	5	marginal	8	marginal	8	marginal	8	marginal	6
47 upstrm	suboptimal	15	suboptimal	11	marginal	10	suboptimal	11	suboptimal	14	marginal	8	marginal	6
48	suboptimal	13	marginal	8	marginal	8	marginal	8	suboptimal	11	marginal	7	marginal	6
49	marginal	10	marginal	7	marginal	6	marginal	6	marginal	6	suboptimal	11	marginal	6
50	suboptimal	11	marginal	6	marginal	6	poor	4	marginal	8	marginal	8	marginal	6
51	poor	5	marginal	7	marginal	6	marginal	7	marginal	9	poor	5	poor	5
52	marginal	10	marginal	8	marginal	6	marginal	7	suboptimal	13	marginal	7	marginal	7
53	marginal	10	marginal	6	marginal	6	marginal	8	suboptimal	13	marginal	6	marginal	6
54	marginal	7	marginal	8	marginal	6	marginal	8	suboptimal	13	marginal	7	marginal	7
55	marginal	10	marginal	8	marginal	7	marginal	6	suboptimal	13	marginal	10	marginal	6
56	marginal	8	marginal	8	marginal	6	marginal	6	suboptimal	13	marginal	8	marginal	6
62	poor	2	poor	5	poor	3	marginal	10	suboptimal	11	poor	3	poor	1
63	poor	2	poor	5	poor	3	marginal	10	suboptimal	11	poor	3	poor	1
64	marginal	10	marginal	10	poor	4	poor	5	marginal	9	marginal	7	marginal	7
65	poor	2	marginal	7	poor	2	suboptimal	13	optimal	17	suboptimal	11	marginal	6
66	marginal	6	marginal	7	poor	5	marginal	6	poor	5	suboptimal	11	suboptimal	13
67	marginal	10	suboptimal	14	suboptimal	11	marginal	10	suboptimal	14	suboptimal	13	marginal	10
68	marginal	10	suboptimal	11	marginal	8	suboptimal	13	marginal	7	poor	4	marginal	9
69	marginal	6	marginal	6	poor	5	marginal	8	marginal	7	suboptimal	12	suboptimal	13

	Habitat Parameter													
	Epifaunal Substrate / Available Cover		Pool Substrate Characterization		Pool Variability		Sediment Deposition		Channel Flow Status		Channel Alteration		Channel Sinuosity	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
70	marginal	7	marginal	6	poor	2	marginal	6	poor	4	suboptimal	11	marginal	8
71	poor	5	suboptimal	11	marginal	9	marginal	9	marginal	9	marginal	9	marginal	8
72	marginal	10	suboptimal	11	marginal	8	marginal	8	marginal	8	marginal	9	marginal	10
73	suboptimal	11	suboptimal	11	marginal	10	marginal	10	marginal	10	marginal	10	marginal	10
74	marginal	7	marginal	6	poor	4	marginal	6	suboptimal	11	marginal	6	poor	5
75	poor	5	poor	5	poor	4	marginal	8	marginal	8	marginal	10	marginal	9
76	marginal	9	poor	3	poor	3	poor	3	poor	3	marginal	6	suboptimal	11
77	optimal	17	suboptimal	14	suboptimal	14	optimal	16	suboptimal	15	suboptimal	15	suboptimal	13
78	poor	5	marginal	6	suboptimal	13	marginal	9	marginal	10	marginal	10	marginal	6
79	marginal	7	marginal	10	marginal	10	marginal	10	marginal	8	marginal	10	marginal	8
80	marginal	10	suboptimal	11	marginal	10	suboptimal	12	suboptimal	12	marginal	7	marginal	8
81	marginal	8	marginal	10	suboptimal	15	suboptimal	11	suboptimal	13	suboptimal	11	suboptimal	11
82	optimal	16	suboptimal	13	marginal	10	marginal	10	marginal	10	suboptimal	12	marginal	8
83	suboptimal	11	suboptimal	11	suboptimal	12	suboptimal	11	suboptimal	13	marginal	10	marginal	10
84	suboptimal	11	marginal	10	poor	1	marginal	6	optimal	16	marginal	8	suboptimal	11
No Site ID	suboptimal	14	suboptimal	11	marginal	9	optimal	18	optimal	16	o	16	suboptimal	13
85	marginal	6	optimal	16	suboptimal	15	optimal	16	suboptimal	15	suboptimal	11	marginal	6
86	marginal	10	marginal	8	marginal	9	marginal	8	marginal	8	marginal	7	marginal	8
87	suboptimal	15	suboptimal	15	suboptimal	11	suboptimal	11	suboptimal	12	suboptimal	12	marginal	10
88	marginal	8	marginal	10	suboptimal	11	marginal	10	suboptimal	11	suboptimal	11	marginal	6
89	marginal	10	suboptimal	11	marginal	8	marginal	10	marginal	8	marginal	10	suboptimal	11
90	marginal	10	suboptimal	11	marginal	7	marginal	8	marginal	8	marginal	9	marginal	8
91	poor	3	poor	5	poor	3	poor	4	marginal	8	poor	3	poor	3
92	poor	3	poor	4	poor	5	poor	4	marginal	7	marginal	6	marginal	6

	Habitat Parameter													
	Epifaunal Substrate / Available Cover		Pool Substrate Characterization		Pool Variability		Sediment Deposition		Channel Flow Status		Channel Alteration		Channel Sinuosity	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
93	poor	3	poor	5	poor	5	poor	5	marginal	6	marginal	6	poor	3
94	poor	2	poor	5	poor	3	suboptimal	13	suboptimal	11	poor	3	poor	1
95	poor	2	poor	5	poor	3	suboptimal	11	suboptimal	11	poor	5	poor	1
96	poor	3	poor	5	poor	3	optimal	16	suboptimal	11	poor	5	poor	1
97	poor	2	poor	5	poor	2	optimal	16	suboptimal	12	poor	5	poor	1
98	poor	2	poor	5	poor	2	optimal	16	suboptimal	12	poor	5	poor	1

Bioassessment 2

	Habitat Parameter											
	Bank Stability				Vegetative Protection				Riparian Vegetative Zone Width			
	Left Bank		Right Bank		Left Bank		Right Bank		Left Bank		Right Bank	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
1A dwnstrm	marginal	5	marginal	5	suboptimal	8	suboptimal	8	poor	0	poor	0
1A upstrm	marginal	3	marginal	3	suboptimal	6	suboptimal	6	poor	2	poor	2
1B dwnstrm	suboptimal	6	suboptimal	6	marginal	5	marginal	5	poor	2	poor	2
1B upstrm	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	poor	0	poor	0
1C dwnstrm	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	marginal	3	marginal	4
1C upstrm	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	poor	1	poor	1
1	marginal	5	marginal	5	suboptimal	6	suboptimal	6	poor	2	poor	2
2 dwnstrm	suboptimal	8	suboptimal	8	optimal	9	optimal	9	suboptimal	8	suboptimal	8
2 upstrm	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	poor	1	poor	2
3 dwnstrm	suboptimal	8	suboptimal	8	marginal	5	marginal	5	poor	1	poor	1
3 upstrm	marginal	5	marginal	5	suboptimal	8	suboptimal	8	poor	2	poor	2
4	marginal	4	marginal	4	suboptimal	6	suboptimal	6	poor	2	poor	2
5	suboptimal	6	suboptimal	6	suboptimal	8	suboptimal	8	marginal	5	suboptimal	8
6												
7	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	marginal	4	marginal	4
8A dwnstrm	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	suboptimal	8	marginal	4
8A upstrm	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	suboptimal	6	marginal	4
8	suboptimal	7	suboptimal	7	suboptimal	6	suboptimal	6	poor	1	poor	1
9 dwnstrm	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	poor	2	poor	2
9 upstrm	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	poor	2	poor	2
10	marginal	5	marginal	5	marginal	5	marginal	5	poor	2	poor	2
11	marginal	5	marginal	5	suboptimal	6	suboptimal	6	marginal	3	marginal	3
12	marginal	4	marginal	4	suboptimal	6	suboptimal	6	poor	2	marginal	3

	Habitat Parameter											
	Bank Stability				Vegetative Protection				Riparian Vegetative Zone Width			
	Left Bank		Right Bank		Left Bank		Right Bank		Left Bank		Right Bank	
Site ID	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**	**Condition Category**	**Condition Value**
13	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	poor	1	marginal	3
14	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	marginal	3	marginal	3
15	marginal	4	marginal	3	suboptimal	7	suboptimal	7	marginal	4	marginal	3
16	marginal	5	marginal	5	suboptimal	6	suboptimal	6	poor	1	poor	1
17 dwnstrm	marginal	3	marginal	3	suboptimal	7	suboptimal	7	poor	2	poor	2
17 upstrm	marginal	5	marginal	5	suboptimal	8	suboptimal	8	poor	0	poor	0
18	marginal	3	marginal	3	marginal	4	marginal	4	poor	1	poor	1
19	suboptimal	7	suboptimal	7	suboptimal	7	suboptimal	7	poor	1	poor	1
20	suboptimal	8	suboptimal	8	suboptimal	6	suboptimal	6	poor	2	poor	2
21	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	poor	1	poor	1
22 dwnstrm	suboptimal	6	suboptimal	6	suboptimal	8	suboptimal	8	poor	0	poor	0
22 upstrm	poor	2	poor	2	marginal	4	marginal	4	marginal	3	marginal	3
23	poor	2	poor	2	marginal	3	marginal	3	poor	2	poor	0
24	marginal	5	marginal	5	suboptimal	7	suboptimal	7	poor	1	poor	1
25	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	poor	0	poor	0
26	marginal	4	marginal	4	suboptimal	6	suboptimal	6	poor	0	poor	0
26A	poor	1	poor	1	marginal	3	marginal	3	poor	0	poor	0
27 dwnstrm	marginal	3	marginal	3	marginal	5	marginal	5	poor	1	poor	1
27 upstrm	marginal	3	marginal	3	marginal	5	marginal	5	poor	1	poor	1
28	marginal	5	marginal	5	suboptimal	6	suboptimal	6	poor	0	poor	0
29	marginal	4	marginal	4	suboptimal	6	suboptimal	6	poor	0	poor	0
30 dwnstrm	suboptimal	7	suboptimal	7	suboptimal	7	suboptimal	7	marginal	3	poor	1
30 upstrm	suboptimal	7	suboptimal	7	suboptimal	7	suboptimal	7	marginal	3	poor	1

	Habitat Parameter											
	Bank Stability				Vegetative Protection				Riparian Vegetative Zone Width			
	Left Bank		Right Bank		Left Bank		Right Bank		Left Bank		Right Bank	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
30A dwnstrm	suboptimal	7	suboptimal	7	suboptimal	8	suboptimal	8	poor	0	poor	0
30A upstrm	suboptimal	7	suboptimal	7	suboptimal	8	suboptimal	8	marginal	3	marginal	3
30B dwnstrm	marginal	4	marginal	4	suboptimal	6	suboptimal	6	marginal	3	marginal	3
30B upstrm	marginal	4	marginal	4	suboptimal	6	suboptimal	6	marginal	3	suboptimal	6
30C	marginal	3	marginal	3	poor	2	poor	2	poor	0	poor	0
30D	poor	2	poor	2	marginal	5	marginal	5	poor	1	poor	1
31	marginal	4	marginal	4	suboptimal	6	suboptimal	6	poor	2	poor	1
32	marginal	4	marginal	4	suboptimal	6	suboptimal	6	poor	0	poor	0
32A dwnstrm	suboptimal	7	suboptimal	7	suboptimal	8	suboptimal	8	marginal	4	marginal	4
32A upstrm	suboptimal	7	suboptimal	7	marginal	5	marginal	5	marginal	4	marginal	4
32B	suboptimal	8	suboptimal	8	suboptimal	8	suboptimal	8	poor	1	poor	1
32C dwnstrm	marginal	3	marginal	3	marginal	5	marginal	5	poor	0	poor	0
32C upstrm	marginal	3	marginal	3	marginal	5	marginal	5	poor	2	poor	2
33	marginal	3	marginal	3	suboptimal	6	suboptimal	6	poor	1	poor	1
34	marginal	3	marginal	3	marginal	3	marginal	3	poor	1	poor	1
35	poor	1	poor	2	marginal	3	marginal	5	poor	1	poor	1
36	suboptimal	6	suboptimal	6	suboptimal	8	suboptimal	8	poor	1	poor	1
37 dwnstrm	marginal	3	marginal	3	marginal	4	marginal	4	poor	0	poor	0
37 upstrm	marginal	3	marginal	3	marginal	4	marginal	4	poor	0	poor	0
38	marginal	4	marginal	4	suboptimal	7	suboptimal	7	poor	0	poor	0
39	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	poor	2	poor	2
39A												
40	marginal	4	marginal	4	suboptimal	6	suboptimal	6	poor	2	poor	2

	Habitat Parameter											
	Bank Stability				Vegetative Protection				Riparian Vegetative Zone Width			
	Left Bank		Right Bank		Left Bank		Right Bank		Left Bank		Right Bank	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
41	suboptimal	7	suboptimal	7	suboptimal	7	suboptimal	7	poor	1	poor	1
42	suboptimal	6	suboptimal	6	suboptimal	8	suboptimal	8	poor	1	poor	1
43												
44	marginal	4	marginal	4	suboptimal	6	suboptimal	6	poor	1	poor	1
45	marginal	3	marginal	3	suboptimal	6	suboptimal	6	poor	1	poor	1
46 dwnstrm	suboptimal	6	suboptimal	6	marginal	5	marginal	5	poor	1	poor	1
46 upstrm	suboptimal	6	suboptimal	6	marginal	5	marginal	5	poor	1	poor	1
47 dwnstrm	marginal	3	marginal	3	marginal	4	marginal	4	poor	1	poor	1
47 upstrm	suboptimal	8	suboptimal	8	suboptimal	8	suboptimal	8	poor	1	poor	1
48	poor	2	marginal	5	marginal	5	suboptimal	7	poor	1	poor	1
49	poor	1	poor	1	marginal	4	marginal	4	poor	1	poor	1
50	poor	2	poor	2	suboptimal	6	suboptimal	7	poor	2	poor	2
51	poor	2	marginal	3	suboptimal	6	suboptimal	7	poor	1	poor	1
52	poor	2	marginal	3	suboptimal	7	suboptimal	6	marginal	3	marginal	3
53	marginal	4	marginal	4	suboptimal	7	suboptimal	7	poor	2	poor	2
54	marginal	3	marginal	3	suboptimal	7	suboptimal	7	poor	1	poor	1
55	marginal	5	marginal	5	suboptimal	7	suboptimal	7	poor	1	poor	1
56	marginal	3	marginal	3	suboptimal	8	suboptimal	8	poor	1	poor	1
62	marginal	3	marginal	3	marginal	5	marginal	5	poor	0	poor	0
63	marginal	3	marginal	3	marginal	5	marginal	5	poor	0	poor	0
64	poor	2	poor	2	marginal	4	marginal	4	poor	2	poor	2
65	marginal	4	marginal	4	suboptimal	8	suboptimal	8	marginal	4	marginal	4
66	marginal	5	marginal	4	marginal	5	marginal	5	marginal	4	marginal	4

	Habitat Parameter											
	Bank Stability				Vegetative Protection				Riparian Vegetative Zone Width			
	Left Bank		Right Bank		Left Bank		Right Bank		Left Bank		Right Bank	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
67	suboptimal	7	suboptimal	7	suboptimal	8	suboptimal	8	suboptimal	6	suboptimal	6
68	suboptimal	8	suboptimal	7	suboptimal	7	suboptimal	7	suboptimal	6	suboptimal	8
69	suboptimal	8	suboptimal	8	suboptimal	8	suboptimal	8	poor	2	poor	2
70	suboptimal	8	suboptimal	8	suboptimal	8	suboptimal	8	marginal	4	marginal	4
71	marginal	3	marginal	3	marginal	3	marginal	3	marginal	3	marginal	3
72	marginal	4	marginal	4	suboptimal	7	marginal	4	marginal	5	marginal	3
73	suboptimal	5	suboptimal	6	suboptimal	6	suboptimal	6	marginal	5	marginal	5
74	suboptimal	6	suboptimal	7	suboptimal	6	suboptimal	7	marginal	4	marginal	3
75	marginal	4	marginal	4	suboptimal	6	suboptimal	6	marginal	4	marginal	4
76	marginal	3	marginal	3	marginal	4	marginal	4	optimal	9	optimal	9
77	suboptimal	8	suboptimal	8	suboptimal	8	suboptimal	8	optimal	9	optimal	9
78	marginal	5	marginal	5	marginal	4	marginal	4	marginal	5	marginal	5
79	marginal	5	suboptimal	6	suboptimal	6	suboptimal	6	marginal	5	marginal	5
80	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6
81	suboptimal	6	suboptimal	6	suboptimal	8	suboptimal	8	marginal	5	marginal	5
82	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6
83	marginal	5	marginal	5	marginal	5	marginal	5	marginal	5	marginal	5
84	marginal	4	marginal	4	suboptimal	6	suboptimal	6	marginal	5	marginal	5
No Site ID	suboptimal	8	suboptimal	8	suboptimal	8	suboptimal	8	suboptimal	6	suboptimal	6
85	poor	2	poor	2	poor	2	poor	2	poor	2	poor	2
86	marginal	4	marginal	4	marginal	5	marginal	5	marginal	5	marginal	5
87	suboptimal	8	suboptimal	8	suboptimal	8	suboptimal	8	marginal	5	marginal	5
88	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	marginal	4	marginal	4

	Habitat Parameter											
	Bank Stability				Vegetative Protection				Riparian Vegetative Zone Width			
	Left Bank		Right Bank		Left Bank		Right Bank		Left Bank		Right Bank	
Site ID	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value	Condition Category	Condition Value
89	suboptimal	6	suboptimal	6	suboptimal	7	suboptimal	7	marginal	5	marginal	5
90	marginal	4	marginal	3	marginal	3	marginal	3	suboptimal	6	suboptimal	6
91	marginal	3	marginal	3	marginal	4	marginal	4	marginal	3	marginal	3
92	marginal	5	marginal	5	marginal	5	marginal	5	marginal	4	marginal	4
93	marginal	5	marginal	5	marginal	5	marginal	5	marginal	3	marginal	3
94	poor	2	marginal	4	marginal	3	suboptimal	6	poor	0	poor	0
95	suboptimal	6	marginal	4	suboptimal	6	marginal	5	poor	0	poor	0
96	poor	1	marginal	5	marginal	3	suboptimal	6	poor	0	poor	0
97	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	poor	0	poor	0
98	suboptimal	6	suboptimal	6	suboptimal	6	suboptimal	6	poor	0	poor	0

Mannings n

	Variable/Parameter										
	n_0--Channel substrate (character of channel)		n_1--Bank stability (degree of irregularity)		n_2--Epifaunal substrate (relative effect of obstructions)		n_3--Channel vegetation height		m--Channel sinuosity (degree of meander)		Calculated Manning's roughness coefficient
Site ID	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	
1A dwnstrm	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	poor	1.000	0.045
1A upstrm	earth	0.020	marginal	0.010	suboptimal	0.020	low	0.005	poor	1.000	0.055
1B dwnstrm	earth	0.020	suboptimal	0.005	suboptimal	0.025	low	0.005	poor	1.000	0.055
1B upstrm	earth	0.020	suboptimal	0.005	marginal	0.012	low	0.005	poor	1.000	0.042
1C	earth	0.020	suboptimal	0.005	suboptimal	0.030	low	0.010	poor	1.000	0.065
1	earth	0.020	marginal	0.010	marginal	0.012	low	0.005	poor	1.000	0.047
2 dwnstrm	earth	0.020	suboptimal	0.005	optimal	0.040	low	0.010	poor	1.000	0.075
2 upstrm	earth	0.020	suboptimal	0.005	suboptimal	0.020	low	0.010	poor	1.000	0.055
3 dwnstrm	earth	0.020	suboptimal	0.005	suboptimal	0.020	low	0.005	poor	1.000	0.050
3 upstrm	earth	0.020	marginal	0.010	suboptimal	0.025	low	0.005	poor	1.000	0.060
4	earth	0.020	marginal	0.010	suboptimal	0.025	low	0.010	poor	1.000	0.065
5	earth	0.020	suboptimal	0.005	suboptimal	0.030	low	0.008	poor	1.000	0.063
6											
7	earth	0.020	suboptimal	0.005	suboptimal	0.020	low	0.005	mar. to sub.	1.150	0.058
8A	earth	0.020	suboptimal	0.005	optimal	0.048	medium	0.012	poor	1.000	0.085
8	earth	0.020	suboptimal	0.005	marginal	0.013	low	0.006	poor	1.000	0.044
9 dwnstrm	earth	0.020	suboptimal	0.005	marginal	0.015	low	0.005	poor	1.000	0.045
9 upstrm	earth	0.020	suboptimal	0.005	marginal	0.010	low	0.005	poor	1.000	0.040
10	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	poor	1.000	0.045
11	earth	0.020	marginal	0.010	marginal	0.015	low	0.005	poor	1.000	0.050
12	earth	0.020	marginal	0.010	suboptimal	0.024	low	0.008	poor	1.000	0.062
13	earth	0.020	suboptimal	0.005	suboptimal	0.020	low	0.005	poor	1.000	0.050

	Variable/Parameter										
	n_0--Channel substrate (character of channel)		n_1--Bank stability (degree of irregularity)		n_2--Epifaunal substrate (relative effect of obstructions)		n_3--Channel vegetation height		m--Channel sinuosity (degree of meander)		Calculated Manning's roughness coefficient
Site ID	Condition	Estimate	Condition	Estimate	Condition	Estimate	Condition	Estimate	Condition	Estimate	
14	earth	0.020	suboptimal	0.005	suboptimal	0.020	low	0.005	poor	1.000	0.050
15	earth	0.020	marginal	0.010	marginal	0.025	low	0.005	mar. to sub.	1.150	0.069
16	earth	0.020	marginal	0.010	marginal	0.011	low	0.005	poor	1.000	0.046
17 dwnstrm	earth	0.020	marginal	0.010	suboptimal	0.024	low	0.005	poor	1.000	0.059
17 upstrm	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	poor	1.000	0.045
18	earth	0.020	marginal	0.010	marginal	0.015	low	0.005	poor	1.000	0.050
19	earth	0.020	suboptimal	0.005	marginal	0.010	low	0.005	poor	1.000	0.040
20	earth	0.020	suboptimal	0.005	marginal	0.012	low	0.005	poor	1.000	0.042
21	earth	0.020	suboptimal	0.005	poor	0.000	low	0.005	poor	1.000	0.030
22 dwnstrm	earth	0.020	suboptimal	0.005	suboptimal	0.025	medium	0.010	poor	1.000	0.060
22 upstrm	earth	0.020	poor	0.020	suboptimal	0.025	medium	0.010	mar. to sub.	1.150	0.086
23	earth	0.020	poor	0.020	marginal	0.015	low	0.005	poor	1.000	0.060
24	earth	0.020	marginal	0.010	suboptimal	0.020	low	0.007	poor	1.000	0.057
25	earth	0.020	suboptimal	0.005	marginal	0.010	low	0.005	poor	1.000	0.040
26	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	poor	1.000	0.045
26A	earth	0.020	poor	0.020	poor	0.005	low	0.005	poor	1.000	0.050
27 dwnstrm	earth	0.020	marginal	0.010	marginal	0.013	low	0.010	poor	1.000	0.053
27 upstrm	earth	0.020	marginal	0.010	suboptimal	0.020	low	0.010	poor	1.000	0.060
28	earth	0.020	marginal	0.010	marginal	0.013	low	0.006	poor	1.000	0.049
29	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	poor	1.000	0.045
30 dwnstrm	earth	0.020	suboptimal	0.005	optimal	0.040	medium	0.010	poor	1.000	0.075
30 upstrm	earth	0.020	suboptimal	0.005	optimal	0.040	medium	0.010	mar. to sub.	1.150	0.086
30A dwnstrm	earth	0.020	suboptimal	0.005	suboptimal	0.025	low	0.007	poor	1.000	0.057

	Variable/Parameter										
	n_0--Channel substrate (character of channel)		n_1--Bank stability (degree of irregularity)		n_2--Epifaunal substrate (relative effect of obstructions)		n_3--Channel vegetation height		m--Channel sinuosity (degree of meander)		Calculated Manning's roughness coefficient
Site ID	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	
30 A upstrm	earth	0.020	suboptimal	0.005	suboptimal	0.025	low	0.007	mar. to sub.	1.150	0.066
30B dwnstrm	earth	0.020	marginal	0.010	optimal	0.048	medium	0.010	mar. to sub.	1.150	0.101
30C	earth	0.020	marginal	0.010	marginal	0.013	low	0.005	poor	1.000	0.048
30D	earth	0.020	poor	0.020	marginal	0.015	low	0.005	poor	1.000	0.060
31	earth	0.020	marginal	0.010	marginal	0.013	low	0.005	poor	1.000	0.048
32	earth	0.020	marginal	0.010	suboptimal	0.025	low	0.005	poor	1.000	0.060
32A	earth	0.020	suboptimal	0.005	suboptimal	0.025	low	0.005	poor	1.000	0.055
32B	earth	0.020	suboptimal	0.005	suboptimal	0.025	low	0.005	poor	1.000	0.055
32C	earth	0.020	marginal	0.010	suboptimal	0.030	low	0.005	poor	1.000	0.065
33	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	poor	1.000	0.045
34	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	poor	1.000	0.045
35	earth	0.020	poor	0.020	marginal	0.010	low	0.005	poor	1.000	0.055
36	earth	0.020	suboptimal	0.005	marginal	0.015	low	0.005	poor	1.000	0.045
37 dwnstrm	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	poor	1.000	0.045
37 upstrm	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	mar. to sub.	1.150	0.052
38	earth	0.020	suboptimal	0.005	marginal	0.015	low	0.005	poor	1.000	0.045
39	earth	0.020	suboptimal	0.005	marginal	0.010	low	0.005	poor	1.000	0.040
39A											0.000
40	earth	0.020	marginal	0.010	marginal	0.012	low	0.005	poor	1.000	0.047
41	earth	0.020	suboptimal	0.005	suboptimal	0.030	medium	0.015	poor	1.000	0.070
42	earth	0.020	suboptimal	0.005	suboptimal	0.027	low	0.010	poor	1.000	0.062
43											
44	earth	0.020	marginal	0.010	poor	0.000	low	0.005	poor	1.000	0.035

	Variable/Parameter										
	n_0--Channel substrate (character of channel)		n_1--Bank stability (degree of irregularity)		n_2--Epifaunal substrate (relative effect of obstructions)		n_3--Channel vegetation height		m--Channel sinuosity (degree of meander)		Calculated Manning's roughness coefficient
Site ID	Condition	Estimate	Condition	Estimate	Condition	Estimate	Condition	Estimate	Condition	Estimate	
45	earth	0.020	marginal	0.010	marginal	0.015	low	0.005	poor	1.000	0.050
46 dwnstrm	earth	0.020	suboptimal	0.005	marginal	0.015	low	0.007	poor	1.000	0.047
46 upstrm	earth	0.020	suboptimal	0.005	suboptimal	0.030	low	0.007	poor	1.000	0.062
47 dwnstrm	earth	0.020	marginal	0.010	marginal	0.015	low	0.007	poor	1.000	0.052
47 upstrm	earth	0.020	suboptimal	0.005	suboptimal	0.030	low	0.007	poor	1.000	0.062
48	earth	0.020	poor	0.020	suboptimal	0.025	low	0.010	poor	1.000	0.075
49	earth	0.020	poor	0.020	marginal	0.015	low	0.005	poor	1.000	0.060
50	earth	0.020	poor	0.020	suboptimal	0.020	low	0.005	poor	1.000	0.065
51	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	poor	1.000	0.045
52	earth	0.020	poor	0.020	marginal	0.015	low	0.009	poor	1.000	0.064
53	earth	0.020	marginal	0.010	marginal	0.015	low	0.008	poor	1.000	0.053
54	earth	0.020	marginal	0.010	marginal	0.012	low	0.008	poor	1.000	0.050
55	earth	0.020	marginal	0.010	marginal	0.012	low	0.005	poor	1.000	0.047
56	earth	0.020	marginal	0.010	marginal	0.012	low	0.005	poor	1.000	0.047
62	earth	0.020	marginal	0.010	poor	0.000	low	0.005	poor	1.000	0.035
63	earth	0.020	marginal	0.010	poor	0.000	low	0.005	poor	1.000	0.035
64	earth	0.020	poor	0.020	marginal	0.010	low	0.005	poor	1.000	0.055
65	earth	0.020	marginal	0.010	poor	0.000	low	0.005	mar. to sub.	1.150	0.040
66	earth	0.020	marginal	0.010	marginal	0.010	low	0.005	mar. to sub.	1.150	0.052
67	earth	0.020	suboptimal	0.005	marginal	0.015	low	0.005	mar. to sub.	1.150	0.052
68	earth	0.020	suboptimal	0.005	marginal	0.010	low	0.005	mar. to sub.	1.150	0.046
69	earth	0.020	suboptimal	0.005	marginal	0.010	low	0.008	mar. to sub.	1.150	0.049
70	earth	0.020	suboptimal	0.005	marginal	0.010	low	0.005	mar. to sub.	1.150	0.046

	Variable/Parameter										
	n_0--Channel substrate (character of channel)		n_1--Bank stability (degree of irregularity)		n_2--Epifaunal substrate (relative effect of obstructions)		n_3--Channel vegetation height		m--Channel sinuosity (degree of meander)		Calculated Manning's roughness coefficient
Site ID	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	
71	earth	0.020	marginal	0.010	poor	0.000	low	0.005	mar. to sub.	1.150	0.040
72 dwnstrm	earth	0.020	marginal	0.010	marginal	0.015	medium	0.015	mar. to sub.	1.150	0.069
73	earth	0.020	marginal	0.008	suboptimal	0.020	low	0.005	mar. to sub.	1.150	0.061
74	earth	0.020	suboptimal	0.005	marginal	0.012	medium	0.015	poor	1.000	0.052
75	earth	0.020	marginal	0.010	poor	0.000	medium	0.010	mar. to sub.	1.150	0.046
76	earth	0.020	marginal	0.015	marginal	0.012	medium	0.010	mar. to sub.	1.150	0.066
77	earth	0.020	suboptimal	0.005	optimal	0.050	medium	0.015	mar. to sub.	1.150	0.104
78	earth	0.020	marginal	0.010	poor	0.000	low	0.005	mar. to sub.	1.150	0.040
79	earth	0.020	marginal	0.008	marginal	0.012	low	0.005	mar. to sub.	1.150	0.052
80	earth	0.020	suboptimal	0.005	marginal	0.015	low	0.005	mar. to sub.	1.150	0.052
81	earth	0.020	suboptimal	0.005	marginal	0.012	low	0.005	mar. to sub.	1.150	0.048
82	earth	0.020	suboptimal	0.005	optimal	0.040	low	0.005	mar. to sub.	1.150	0.081
83	earth	0.020	marginal	0.010	suboptimal	0.020	low	0.005	mar. to sub.	1.150	0.063
84	earth	0.020	marginal	0.010	suboptimal	0.020	low	0.005	mar. to sub.	1.150	0.063
	earth	0.020	suboptimal	0.005	suboptimal	0.030	low	0.005	mar. to sub.	1.150	0.069
85	earth	0.020	poor	0.020	marginal	0.010	low	0.005	mar. to sub.	1.150	0.063
86	earth	0.020	marginal	0.010	marginal	0.015	low	0.005	mar. to sub.	1.150	0.058
87	earth	0.020	suboptimal	0.005	suboptimal	0.030	low	0.005	mar. to sub.	1.150	0.069
88	earth	0.020	suboptimal	0.005	marginal	0.012	low	0.005	mar. to sub.	1.150	0.048
89	earth	0.020	suboptimal	0.005	marginal	0.015	low	0.005	mar. to sub.	1.150	0.052
90	earth	0.020	marginal	0.010	marginal	0.015	low	0.005	mar. to sub.	1.150	0.058
91	earth	0.020	marginal	0.010	poor	0.000	low	0.010	poor	1.000	0.040
92	earth	0.020	marginal	0.010	poor	0.000	low	0.010	mar. to sub.	1.150	0.046

	Variable/Parameter										
	n_0--Channel substrate (character of channel)		n_1--Bank stability (degree of irregularity)		n_2--Epifaunal substrate (relative effect of obstructions)		n_3--Channel vegetation height		m--Channel sinuosity (degree of meander)		Calculated Manning's roughness coefficient
Site ID	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	**Condition**	**Estimate**	
93	earth	0.020	marginal	0.010	poor	0.000	low	0.010	poor	1.000	0.040
94 right	earth	0.020	marginal	0.010	poor	0.000	low	0.005	poor	1.000	0.035
94 left	earth	0.020	poor	0.020	poor	0.000	low	0.005	poor	1.000	0.045
95 right	earth	0.020	marginal	0.010	poor	0.000	low	0.005	poor	1.000	0.035
95 left	earth	0.020	suboptimal	0.005	poor	0.000	low	0.005	poor	1.000	0.030
96 right	earth	0.020	marginal	0.010	poor	0.000	low	0.005	poor	1.000	0.035
96 left	earth	0.020	poor	0.020	poor	0.000	low	0.005	poor	1.000	0.045
97	earth	0.020	suboptimal	0.005	poor	0.000	low	0.005	poor	1.000	0.030
98	earth	0.020	suboptimal	0.005	poor	0.000	low	0.005	poor	1.000	0.030

Appendix E

Management Alternative Report

MANAGEMENT ALTERNATIVE REPORT

Multicriteria Evaluation of Management Alternatives for a Degraded Urban Stream

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Chapter I
Introduction

This Management Alternative Report is part of a study of the decision-making process for watershed management. The study was funded by a grant from Region VII of the Environmental Protection Agency (EPA). With the assistance of several graduate students in Engineering at UNL and Public Administration at UNOmaha, Professors John Stansbury and Renee Irvin collaborated to investigate how environmental decision making occurs when community members team with government agency representatives in a multi-disciplinary, multi-stakeholder group. The Management Alternative Report provides stakeholders with information about possible changes in the Papillion (Papio) Creek watershed from several hypothetical management alternatives used in the study.

Community representatives from the Papillion Creek watershed, including residents from Douglas, Sarpy, and Washington counties, will use this Management Alternative Report as a source of information regarding the effects of several management alternatives for the watershed. The decisions that the community representatives will make in evaluating alternatives will not necessarily be implemented, but will serve as a detailed source of information about community preferences in environmental planning. Also, the process by which the community members arrive at a decision will be studied to determine if similar community-based decision making processes can be implemented for this and other urban watersheds in our region and nationwide.

Notes:

1) *This is a study of watershed decision-making methods. It is not an attempt to implement any particular management alternative. However, the tools, organization, and information developed in this study should be useful in future decision-making processes for this and other watersheds.*

2) *The estimates of environmental changes and economic benefits and costs included in this document were based on either existing data, data gathered specifically for this project, and – where the cost of gathering data was prohibitive – best estimates of hypothesized changes in the economic and environmental variables.*

Before describing the four management alternatives for the Papio Creek watershed, this introductory section includes a brief review of the Papio Creek Watershed Management Study (what the entire project entails), a description of goals that watershed management might hope to achieve, and a list of actions that are necessary (technology, regulations, etc.) to achieve the watershed planning goals. Following the Introduction, Chapter II provides a review of decision-making methods in watershed planning. Chapter III presents the management alternatives that the community respondents will evaluate. Chapter IV describes in detail the multi-criteria decision-making methods that this study will use and evaluate. Chapter V provides information about how community members will use and evaluate the decision-making methods at the community forum scheduled for July 6, 2001.

Section A. Papillion Creek Watershed Study

The overall study process for this project is outlined below. Components of the study that have been completed so far are:

1. Identify important issues and goals for management of the watershed.
   Community representatives were surveyed to determine what critical issues existed for the Papillion creek watershed. These are listed in Section B of this chapter.

2. Identify technologies to achieve the watershed goals.
   Dr. Stansbury collected information on actions needed to achieve various watershed management goals. These are listed in Section C.

3. Identify potential management alternatives.
   Community representatives were surveyed to determine their reaction to a preliminary list of management alternatives (combinations of technologies designed to achieve the watershed management goals). The potential management alternatives used for this study are detailed in Chapter III.

4. Predict impacts caused by the management alternatives.
   These impacts included water quality changes, wildlife habitat changes, and economic costs and benefits brought about by the management alternatives. Much of the past year of study was spent gathering data to measure these predicted environmental and economic impacts. The environmental and economic impacts are summarized in Tables 1, 6 and 7.

Components of the Papio Creek Watershed Study that we have yet to complete are:

5. Evaluate a variety of decision-making methods to select the most desirable alternative. Community representatives will be presented with several decision making methods at a community forum scheduled for July 6, 2001 at the Peter Kiewit Institute (please see enclosed letter for more instructions regarding the forum).

6. Select the best decision-making method and use it to evaluate the Papillion Creek management alternatives . After the community representatives choose their preferred decision making method, they will use that method to determine their preferred alternative for environmental management of the Papillion Creek watershed.

7. Disseminate results regarding Papillion Creek watershed stakeholder decision making. Provide a summary of the successes and/or failures of the multi-criteria decision making methods used in the Papillion Creek watershed management study.

Section B. Potential Watershed Goals

Following is a list of potential watershed goals for the Papillion Creek watershed. Note that many of the goals are related to one another – either one goal implies another (for example, good water quality can improve wildlife habitat), or a goal might negatively impact another goal. A glossary is provided at the end of this report, for definition of technical words and phrases.

1. Provide good water quality
    - Adequate dissolved oxygen for native aquatic species
    - Low levels of nutrients to avoid eutrophication
    - Low levels of pesticides and other chemicals to avoid health hazard upon water contact and upon fish consumption
    - Low levels of bacteria to avoid health hazard upon water contact

2. Provide good wildlife habitat
    - Riparian (stream-side and bank)
        - Stream-side areas of vegetation including grasses and trees to provide habitat for birds and small animals
    - Aquatic
        - Stream structure (e.g., meanders, bottom substrate) and cover (e.g., vegetation) to provide habitat for native fish and aquatic species

3. Provide recreational opportunities
    - Hiking, biking (etc.) trails along streams
    - Water sports (e.g., boating in lakes)
    - Fishing
    - Watershed-related park space

4. Provide opportunity/climate for economic development
    - Agriculture
    - Real estate development
    - Other businesses

5. Provide flood control

6. Provide high quality of life
    - Aesthetically pleasing creek
    - Green space

Section C. Potential Technologies

The following are technologies or methods that could be used, alone or in combination, to help achieve the above potential goals for the Papillion Creek watershed.

1. <u>Water quality</u>
    - Combined sewer [sanitary and storm sewers] outflow (CSO) separation
    - CSO storage
    - CSO disinfection
    - Best Management Practices (BMPs) for agricultural land
        - Fence livestock from creek and water bodies
        - Upland improvements: terracing, grassed waterways
        - Buffer strips (grass and trees) along waterways and creeks
        - Fertilizer/pesticide education/management
        - Runoff catchments (e.g., ponds, constructed wetlands) for fields, feedlots

    - Best Management Practices for urban and suburban land
        - Street/parking lot cleaning
        - Fertilizer/pesticide education/management
        - Pet manure control
        - Use of pervious surfaces and retention ponds for stormwater

2. <u>Habitat</u>
    - Riparian
        - Linear parks along creeks
        - Buffer strips along creeks and waterways
        - Forested buffers
        - Natural banks (allow/encourage stream banks to develop natural structure and vegetation rather than having a “bare” levee or cropped land next to stream)
    - Aquatic
        - Restore meanders where stream has been straightened
        - Increase plant cover for aquatic species (both instream and bank)
        - Restore bottom substrate to natural conditions by reducing sediment load
        - Restore hydrology by controlling runoff from agricultural and urban areas

3. <u>Recreation</u>
    - Create reservoirs at appropriate locations
    - Improve water quality
        - Reduce sediment load
        - Reduce nutrient load
        - Reduce bacteria load (agricultural, suburban, CSO)
    - Provide fishing facilities in parks
    - Provide canoeing/boating facilities
    - Create park areas near creeks

4. Economic development
    - Foster agricultural production use of watershed
    - Foster real estate development in watershed
    - Provide recreational opportunities and related businesses
    - Provide nice community for workforce to live (aesthetics, parks, water recreation)
    - Provide flood control

5. Flood control
    - Provide bank stabilization to improve flood flow
    - Develop higher levees to increase flood protection in low areas
    - Build previously planned flood control dams
    - Build storage basins (i.e., low areas that will be intentionally flooded during flood events. These basins could be used for other purposes such as parks at other times.)
    - Build storm water retention facilities for developed areas
    - Build storm water retention facilities for new developments
    - Install buffer strips to reduce runoff and increase infiltration
    - Keep development (urban and agricultural) out of natural flood plains – move development from flood plains
    - Build farm ponds and constructed wetland areas to collect runoff

6. High quality of life
    - Maintain and enhance property values by providing parks, trails, water access
    - Maintain flood control
    - Provide aesthetically pleasing creek areas
    - Provide green space
    - Maintain economic development

Chapter II
Decision-Making Processes in Urbanizing Watersheds

Because this is a study of how multi-criteria decision-making methods can be utilized in a community-based watershed management project, it is important to describe the various kinds of decision-making methods that are used frequently, or could be used in the future.

Section A. Current Decision-Making Processes in Urbanizing Watersheds

There are several forms of decision-making that may be employed in the decision-making process in an urbanizing watershed. Forms of decision-making in an urbanizing watershed might include authoritative decision-making, community-based decision-making, or *ad hoc* decision-making. Each of these might be at work in any watershed at any given time. The following discussion gives some examples of these decision-making forms acting in an urbanizing watershed.

Authoritative Decision-Making

Authoritative decision-making occurs when an agency or agencies have and use the authority to make and enforce decisions regarding the watershed. These decisions can include managing water usage from streams and lakes, managing water quality, or managing land use in the watershed.

There are several examples of authoritative decision-making in our local watersheds today. For example, state water resources agencies (e.g., Nebraska Department of Water Resources), through a system of water rights and water use permits, controls how much water can be extracted by water users from streams, lakes, and groundwater.

The federal and state environmental control agencies (e.g., U.S. Environmental Protection Agency, Nebraska Department of Environmental Quality) have the authority to manage the water quality in streams and lakes. For example, the Clean Water Act (CWA) mandates that these agencies control point source discharges to surface water bodies. These agencies are currently developing ways to manage non-point source pollution (e.g., from agriculture and stormwater runoff) to water bodies through the use of Total Maximum Daily Loads (TMDLs).

Land use in watersheds is often controlled by zoning commissions. In some instances, these commissions may have the authority to determine what types of land use are acceptable for various portions of a watershed. Land use decisions may be made for a variety of economic and social reasons, including water use and water quality in a watershed.

Community-Based Decision-Making

There are several examples of community-based decision-making in urbanizing watersheds. Often community-based decision-making is inspired by some notable economic, ecological, or social resource associated with a watershed that is not being adequately protected by the management processes in place. For example, the Puget Sound watershed in Washington State was experiencing significant environmental degradation caused by urban and agricultural discharges. When it became apparent that the degradation was seriously impacting the fish and shellfish, and, therefore the health of the community, a citizen-led effort ensued to implement management systems to protect the watershed. Similarly, in the Chesapeake Bay watershed, when water quality degraded to the degree that it seriously impacted fish and shellfish in the watershed, community-led efforts forced new management initiatives for the watershed. In both of these (and similar) cases, the decision-making process that evolved has a strong community-based component. That is, decisions are now made with significant input from the range of stakeholders in the community.

Ad Hoc Decision-Making

A major problem with decision-making in watersheds is that watersheds often extend across political boundaries (e.g., state to state, county to county, city to city). In this case, different jurisdictions, often with conflicting interests, are responsible for management of the watershed or of different parts of the watershed. A common result is that no clear authority or management philosophy is developed for the watershed, and decisions are then made for various portions of the watershed in a non-integrated, *ad hoc* way. When there is no clear management vision for the watershed as a whole and there is no clearly identifiable economic, social, or ecological resource to be protected, decision-making is often left primarily to land owners and developers.

Section B. The Papillion Creek Management Environment

The Papillion Creek watershed covers an area of approximately 400 square miles in eastern Nebraska. The watershed covers most of metropolitan Omaha, and surrounding communities. The northern (headwater) half of the watershed is agricultural, while the southern half of the watershed is either urban, suburban, or urbanizing.

The authorities involved with the Papillion Creek watershed include:

- U.S. Army Corps of Engineers (UDACE)
- Papio-Missouri River Natural Resources District (NRD)
- U.S. Environmental Protection Agency (USEPA)
- Natural Resources Conservation Service (NRCS)
- The cities of: Omaha, Ralston, Papillion, and Bellevue and many smaller communities

- Washington, Douglas, and Sarpy counties
- Stakeholders, including farmers, urban landowners, interest groups

The U.S. Army Corps of Engineers has built several small reservoirs for flood control. The Papio-Missouri River Natural Resources District (NRD) has primary management responsibility for the watershed. The primary goal of the NRD is flood control in the watershed. The U.S. EPA and the Nebraska Department of Environmental Quality (NDEQ) have responsibility for water quality in the watershed. These agencies carry out the requirements specified by the Clean Water Act and are currently developing policies regarding non-point pollution and stormwater runoff. The Natural Resources Conservation Service works with the agricultural producers in the watershed regarding land management practices that can have significant impacts on the streams and reservoirs.

Issues and uses for the Papillion Creek watershed include; drainage for the agricultural and urban lands, flood control, water quality, and recreation. Historically and currently, the primary use of the watershed is to drain stormwater from agricultural and urban lands. Significant portions of the streams have been straightened and channelized to enhance this purpose. Flood control, an extension of drainage, is a primary concern in the lower portion of the watershed.

Water quality and recreation have emerged as important issues in the watershed. Water quality issues include loadings of sediment, nutrients, and bacteria to streams and reservoirs. These loadings cause eutrophication (an overabundance of nutrients in the water causing nuisance growth of blue-green algae and reduced dissolved oxygen in receiving water) which creates aesthetic problems, decreases recreational use, decreases fish populations, causes odor problems, and decreases the usability and the life-spans of reservoirs. The unwanted sediments, nutrients, and bacteria can come from several sources, including agricultural runoff carrying sediments, fertilizer, and animal wastes; urban runoff from streets and lawns; and soil erosion runoff from construction sites. An additional water quality issue is the presence of combined sewer outfalls (CSOs) on tributaries of Papillion Creek in Omaha. The CSOs can contribute unwanted nutrients from human waste and bacteria to the streams during storm events.

Recreation in the watershed consists primarily of boating, fishing, swimming, and outdoor activities at the reservoirs and associated parklands. In addition, there is a great deal of hiking and biking along an extensive system of trails located along the Papillion Creek branches. Thus, the Papillion Creek system appears to have a positive effect on the area's quality of life. The effects of the Papillion Creek watershed on commercial activity are not as evident as with recreational use. Businesses do not currently orient themselves toward the Papio Creek system, so there is no additional revenue generated by businesses when they are located near the Creek. For example, businesses along watersheds in some other parts of the country have picture windows or decks facing a body of water. Businesses along the Papio Creek system do not currently orient themselves in this way, and there does not appear to be any current revenue premium due to being located close to a creek or lake.

Decision-making to date in the Papillion Creek watershed can be described by several agencies (e.g., USACE, NRD, NDEQ, counties, cities), with different goals and issues working separately but mostly cooperatively. Recently, many of these agencies have recognized the need to work together more closely to meet the non-point source pollution (stormwater) water quality requirements of the Clean Water Act. It is clear that no individual entity can meet these stormwater requirements by themselves; therefore, a coalition of municipalities and agencies is being developed to address these issues watershed-wide. This new effort in community-based decision-making will bring a new set of challenges. For example, how will the coalition, made up of diverse groups with conflicting goals, develop a consensus regarding management policies? One set of decision-making tools that may be useful in consensus building is multi-criteria decision-making (MCDM) methods. It is the goal of this study to evaluate the use of MCDM tools in a watershed management framework.

Section C. Use of Multi-Criteria Decision-Making (MCDM) Methods

MCDM methods have been developed to assist in decision-making when there are several issues to be resolved and when different stakeholders have conflicting goals regarding those issues. For example, in the Papillion Creek watershed, some stakeholders might want to manage the watershed to minimize flooding. This goal could involve straightening channels and removing impediments to flow such as vegetation. Other stakeholders might want to manage the watershed to enhance the aquatic life. This goal could involve maintaining stream meanders and increasing the vegetative cover in the streams. Clearly, these goals are in conflict. MCDM methods may be one tool to help these stakeholders reach a consensus on the management of the watershed.

MCDM methods are systematic processes that demonstrate trade-offs (compromises) between conflicting issues. They attempt to mimic the process that each of us goes through when making a decision. That is, when we can’t have everything we would like, we evaluate the trade-offs between conflicting needs (e.g., flood control and aquatic habitat) to arrive at the best possible solution for us. An important function of using MCDM methods is that it requires stakeholders to specify their preferences. This can be a major step in consensus building. Many agreements have been subverted because stakeholders have not been forthcoming with their real goals. Once stakeholder preferences are “on the table,” meaningful discussion can take place regarding the solution that could best meet all stakeholders’ needs.

There are several different MCDM methods. Examples which we will evaluate include: Weighted Average Programming, Composite Programming and Multi-attribute Utility Theory. These will be discussed in detail in Chapter IV of this report. It is important to note that MCDM methods are not intended to “make the decisions”. Rather, they are tools that may help the decision-makers and stakeholders evaluate the range of issues surrounding management decisions.

Chapter III
Potential Watershed Alternatives

The following are the watershed management alternatives (combinations of technologies) that have been selected to evaluate the use of multi-criteria decision-making methods to assist decision-making in the management of the Papillion Creek watershed.

Alternative 1: Environmental Focus

This alternative is designed to restore "natural" ecological and hydrological conditions in and near the creek. The technologies are designed to improve water quality, provide wildlife habitat, and reduce peak flows in the creek.

1. Install buffer strips (grasses and trees) on all perennial and intermittent streams. Buffer strips provide land and water habitat and filter sediments, excess nutrients and bacteria from runoff before it reaches the stream.

    a. 100 feet per side for perennial streams
        i. 132 linear miles of stream at 100 feet wide per side (6273 acres)
        ii. costs:
            1. land acquisition and/or easement: 6273 acres @ $3000/acre = $18,819,000
            2. buffer installation: 6273 acres @ $300/acre = $1,881,900

    b. 75 feet per side for intermittent streams
        i. 169 linear miles of stream at 75 feet wide per side (3072 acres)
        ii. costs:
            1. land acquisition and/or easement: 3072 acres @ $3000/acre = $9,216,000
            2. buffer installation: 3072 acres @ $300/acre = $921,600

2. Install planned parks along creek. The parks will provide green space, recreation opportunities, and function as buffer strips.
    a. Tranquility Nature Preserve
        i. 120th and Fort to 156th and Bennington Road
        ii. cost: no additional cost; project is currently planned by city

    b. Cunningham Nature Preserve
        i. 96th and Bennington Road to 96th and Dutch Hall Road
        ii. cost: no additional cost; project is currently planned by city

    c. Nature preserve near Kennard at confluence of NW Branch and Big Papio
        i. cost:
            1. land: 320 acres @$4000/acre = $1,280,000
            2. development: assume $3000/acre = $960,000

3. Install grade control structures to restore hydraulic gradient where natural meanders have been removed (that is, where streams have been channelized and straightened). Restoring the natural hydraulic gradient will slow water in the stream, improving aquatic habitat and decreasing stream-bank erosion.

    a. Assume 20 grade control structures will be installed throughout the watershed. Costs: $30,000 per structure = $600,000

4. Install bank stabilization structures to manage lateral stream migration and reduce sediment load to stream from bank erosion.

    a. Assume 20 bank stabilization structures will be installed throughout the watershed. Costs: $30,000 per structure = $600,000

5. Move levees back to 500 feet per side where development allows. This will provide terrestrial (land) habitat, improve aquatic habitat, and improve flood control by allowing flood water storage.

    a. Assume 7 linear miles of stream treated: 4 miles on the Big Papio between Harrison Street and Highway 370, and 3 miles from 72nd Street to 36th Street on the West Branch.

    b. Costs:
        i. land acquisition and/or easement: 848 acres @ $5000/acre = $4,240,000
        ii. construction: 7 miles @ $1,000,000 per mile = $7,000,000

6. Implement Best Management Practices (BMPs) for agricultural land. Currently, approximately 40% of the agricultural land is in need of further conservation management treatment. BMPs for the watershed land include fencing livestock out of waterways, terracing steep cultivated land, planting waterways to grass, implementing conservation tillage, installing farm ponds to trap runoff and sediment and to increase infiltration, and installing livestock waste control facilities for feedlot operations. These BMPs reduce runoff and reduce loadings of sediment, excess nutrients, and bacteria to the streams.

    a. Fence livestock from all perennial and intermittent streams
        i. assume 50 miles of fencing along streams
        ii. cost: 50 miles @ $10,000/mile = $500,000

    b. Install contour terracing (3,000,000 feet)
        i. cost: 3,000,000 feet @ $1.00/foot = $3,000,000

    c. Install grassed waterways (700 acres)
        i. cost: 700 acres @ $2000/acre = $1,400,000

  d. Implement conservation tillage practices
    i. cost: 50,000 acres @ $30/acre = $1,500,000

  e. Install farm ponds
    i. assume 20 ponds
    ii. cost: $80,000 per pond = $1,600,000

  f. Install livestock waste control facilities
    i. assume four facilities
    ii. cost: 4 facilities @ $10,000/facility = $40,000

7. Implement BMPs for urban and suburban land. These BMPs reduce runoff and reduce loadings of sediment, excess nutrients, and bacteria to the streams.

  a. Implement street and parking lot cleaning
    i. cost: no additional cost; already planned or implemented by city

  b. Implement chemical application education
    i. public service announcements, elementary school presentations
    ii. cost: $10,000/year

  c. Install stormwater retention systems for established developments
    i. current development in watershed equals 90 mi^2
    ii. install stormwater retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of approximately 153,000 ft^3 (e.g., approximately 125 ft x 125 ft x 10 ft deep) will be required.
    iii. cost: assume $100,000 each; 90 mi^2 x 4 x $100,000 = $36,000,000

  d. Install retention systems for new developments
    i. assume additional urban development of 45 mi^2 in the watershed.
    ii. install retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of approximately 153,000 ft^3 (e.g., approximately 125 ft x 125 ft x 10 ft deep) will be required.
    iii. cost: assume $50,000 each; 45 mi^2 x 4 x $50,000 = $9,000,000

8. Install storage/disinfection facilities for CSOs in the Papillion Creek watershed. This will decrease loadings of excess nutrients, organic matter and bacteria to the creek. Cost: $10,000,000

Alternative 2: Development Focus

This alternative represents the prevalent current function of the watershed. The creek system is used primarily as a conduit to remove runoff and flood waters. The use of the land for agriculture and urban development is emphasized.

1. Foster real estate development (no new controls).
    a. Assume additional urban development of 45 mi^2 primarily in Douglas county west and northwest of Omaha

2. Foster agricultural land use (no new controls).
    a. Assume current agricultural land use on land not converted to urban developments

3. Make channel improvements to improve flood control.
    a. Channelize, stabilize, and add levees to Big Papio from Center Street to Fort Street ($7,900,000)

    b. Channelize, stabilize, and add levees to West Branch from 90th Street to Lake Zorinsky outlet ($4,800,000)

    c. Raise established levees to restore 100 year flood protection
        i. established levees are: L Street to confluence with Missouri River for the Big Papio and 90th Street to confluence with the Big Papio for the West Branch
        ii. assume 24 miles @ $400,000/mile = $9,600,000

Alternative 3: Recreational Focus

This alternative is designed to maximize recreational opportunities in the watershed.

1. Build dam 3 (on the Big Papio, near 180th street and Washington, Douglas county line). Cost: $20,000,000

2. Build dam 12 (on West Branch near 216th and West Maple Road).
   Cost: $3,000,000

3. Build dam 13 (on West Branch near 192nd and Blondo).
   Cost: $3,000,000

4. Install linear park system: All linear parks planned by Douglas County plus similar parks in Sarpy and Washington (linear parks and trails for all perennial streams).
   a. Tranquility Nature Preserve
      i. 120th and Fort to 156th and Bennington Road
         (No cost because this Preserve is already planned and budgeted.)

   b. Cunningham Nature Preserve
      i. 96th and Bennington Road to96th and Dutch Hall Road Cost?
         (No cost because this Preserve is already planned and budgeted.)

   b. Nature preserve near Kennard
      i. land cost: 320 acres @ $4000/acre = $1,280,000
      ii. construction cost: assume $1,500/acre = $480,000

   c. Hiker/biker paths along creeks (assume 50 miles of additional trails)
      i. hiker/biker paths to headwaters of: Little Papio, Thomas Creek, Big Papio, West Branch, and North Branch of West Branch
         Cost: $150,000/mile * 50 miles = $7,500,000

5. Implement BMPs for agricultural land to improve water quality. Currently, approximately 40% of the agricultural land is in need of further conservation management treatment. BMPs for the watershed land include fencing livestock out of waterways, terracing steep cultivated land, planting waterways to grass, conservation tillage, installing farm ponds to trap runoff and sediment and to increase infiltration, and installing livestock waste control facilities for feedlot operations.
   a. Fence livestock from all perennial and intermittent streams
      i. assume 50 miles of fencing along streams
      ii. cost: 50 miles @ $10,000/mile = $500,000

   b. Install contour terracing (3,000,000 feet)

        - i. cost: 3,000,000 feet @ $1.00/foot = $3,000,000

    - c. Grassed waterways (700 acres)
        - i. cost: 700 acres @ $2000/acre = $1,400,000

    - d. Implement conservation tillage practices
        - i. cost: 50,000 acres @ $30/acre = $1,500,000

    - e. Install farm ponds
        - i. assume 20 ponds
        - ii. cost: $80,000 per pond = $1,600,000

    - f. Install 4 livestock waste control facilities
        - i. cost: 4 facilities @ $10,000/facility = $40,000

9. Implement BMPs for urban and suburban land.
    - a. Implement street and parking lot cleaning
        - i. cost: no new cost; city is currently implementing this practice

    - b. Implement chemical application education
        - i. public service announcements, elementary school programs
        - ii. cost: $10,000/year

    - c. Install stormwater retention systems for established developments
        - i. Current development in watershed equals 90 mi^2
        - ii. Install retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of 153,000 ft^3 (e.g., approximately 125 ft x 125 ft x 10 ft deep) will be required.
        - iii. Cost: assume $100,000 each; 90 mi^2 x 4 x $100,000 = $36,000,000

    - d. Install stormwater retention systems for new developments
        - i. Assume additional urban development of 45 mi^2 in the watershed.
        - ii. Install retention systems to store increased runoff caused by development for the 10-year flood. For each quarter section developed, a retention volume of 153,000 ft^3 (e.g., approximately 125 ft x 125 ft x 10 ft deep) will be required.
        - iii. Cost: assume $50,000 each; 45 mi^2 x 4 x $50,000 = $9,000,000

Alternative 4: Flood Protection Focus

This alternative is designed to provide a high level of flood control for the watershed. It uses conventional flood control methods such as dams, levees, and channel improvements.

1. Build dam 1 (near Kennard). Cost = $20,000,000

2. Build dam 2 (near Kennard). Cost = $20,000,000

3. Build dam 3 (near 180th street and Washington, Douglas county line).
   Cost = $20,000,000

4. Build dam 4 (near 168th street and Washington, Douglas county line).
   Cost = $15,000,000

5. Build dam 12 (near 216th and West Maple Road). Cost = $3,000,000

6. Build dam 13 (near 192nd and Blondo). Cost = $3,000,000

7. Make channel improvements to improve flood control.
   a. Channelize, stabilize, and add levees to Big Papio from Center Street to Fort Street ($7,900,000)

   b. Channelize, stabilize, and add levees to West Branch from 90th Street to Lake Zorinsky outlet ($4,800,000)

   c. Raise established levees to restore 100-year flood protection
      i. Established levees are: L Street to confluence with Missouri River for the Big Papio and 90th Street to confluence with the Big Papio for the West Branch
      ii. Assume 24 miles @ $400,000/mile = $9,600,000

Chapter IV
Multi-Criteria Decision-Making Methods

This project will evaluate the use of three MCDM methods selected because they are relatively straightforward to use and are potentially applicable to watershed decision-making. Methods we will evaluate are: Weighted Average Programming (WAP), Composite Programming (CtP), and Multiattribute Utility Theory (MAUT). In each of these, the general process is:

- Identify the decision criteria. These are the factors (e.g., water quality, flood protection, recreational opportunities) against which the potential management alternatives will be evaluated.

- Identify preference weightings for decision criteria. Each stakeholder identifies his preferences (weightings) regarding the decision criteria. For example, one stakeholder may select a high preference (importance) for flood control and a low preference for recreational opportunities while another stakeholder would weight recreation higher than flood control.

- Identify available management alternatives. These consist of the range of potential management alternatives that could be implemented for the watershed.

- Determine the condition (value) of each decision criterion for each given management alternative. For example, a management alternative that focuses on flood control by channelizing the streams would likely show a good condition for flood control but would probably show a poor condition for aquatic habitat.

- Normalize the values of the decision criteria. Since the values of the different decision-criteria will likely be in different units (e.g., water quality might be measured in mg/L of dissolved oxygen, and flood protection might be measured in dollars saved), the actual values of the criteria must be converted into a unitless 0 to 1 range so that they can be compared. An example of this normalization process is provided below:

	Dissolved Oxygen Concentration	Normalized Value
Alternative X (best)	10 mg/L	1.0
Alternative Y	2 mg/L	0.2
Alternative Z (worst)	0 mg/L	0.0

	Flooding Dollars Saved	Normalized Value
Alternative Q (best)	$30,000,000	1.0
Alternative R	$10,000,000	0.33
Alternative S (worst)	$0	0.0

- Use the MCDM method to compare the management alternatives given the decision criteria and each stakeholder's preferences.

Weighted Average Programming

Weighted Average Programming (WAP) is a simple weighted (based on stakeholder preferences) average of the decision criteria for each management alternative. This method is commonly referred to as "Compromise Programming", but to distinguish it from the similarly named "Composite Programming", we will refer to it here as "Weighted Average Programming." The mathematical formula for Weighted Average Programming is:

$$Z_A = w_1c_1 + w_2c_2 + w_3c_3 + \dots w_nc_n$$

where:

Z_A = trade-off (compromise) value for alternative A
w_i = preference weighting for decision criterion i
c_i = normalized value of decision criterion i

The calculation is performed for each alternative, and the "best" alternative is identified with the highest trade-off score (Z). In practice, this means that a stakeholder specifies how he or she weights each decision criteria, the weights are entered into a formula set up on a computer, and the computer program automatically calculates the stakeholder's trade-off score.

Note that each stakeholder will have a different set of preference weights, and, will therefore produce different trade-off values for the alternatives. It is likely that some stakeholders will have different preferred alternatives. However, it is also likely that after all of the stakeholders conduct their trade-off analysis, some of the alternatives will emerge showing overall acceptability while other alternatives will show little support among the stakeholder group as a whole. The process is described in more detail below.

Identify and quantify decision criteria.

From the potential goals proposed for this study in the Papillion Creek watershed, decision criteria can be identified. These criteria are measures of how well the goals are met under each proposed management alternative. For example, one of the goals for the watershed was to provide good water quality. Therefore, one decision criterion could be the dissolved oxygen concentration in the water that would result from each management alternative. The identified decision criteria for this study are listed in Table 1. Note that there are decision criteria relating to each proposed watershed goal. Table 1 also shows the estimated value that each decision criterion would have under each of the four proposed management alternatives. In an actual application of these methods, a more accurate determination of the decision criteria values would be required. Also shown in Table 1 are the "best" and worst" values of the decision criteria for the range of proposed alternatives. Finally, Table 1 shows the normalized values of the decision criteria (i.e., the placement of the actual values onto the scale of 0 – 1).

Establish stakeholder preference weighting systems.

Once the decision criteria are identified, stakeholders establish preference weights for the decision criteria. To illustrate the process, three hypothetical stakeholders who span the "range" of potential stakeholders are used:

1. an environmental advocate who values environmental quality and wildlife over other issues;

2. a land development advocate who values economic development and minimization of implementation costs over other issues; and

3. a "moderate" who views all issues as equally important.

The weighting systems for each of the three hypothetical stakeholders are shown in Table 2. Note that the "environmentalist" gives more weight to the environmental issues than the "economic" issues while the "developer" gives more weight to the economic issues than the environmental issues.

Note that the purpose of this study is to evaluate the usefulness of these MCDM methods, so the proposed management alternatives were selected to cover the range of potential alternatives, and the hypothetical stakeholders were selected to cover the potential range of stakeholder positions. Neither the proposed alternatives nor the hypothetical stakeholders are meant to represent any actual proposal or stakeholder group.

Calculate the trade-off values for the management alternatives.

Table 2 shows the normalized values of the decision criteria under each proposed management alternative and the preference weights for the decision criteria. Table 2 also shows the "trade-off" values for each decision criterion using the WAP formula (i.e., the weight multiplied times the normalized value), and it shows the overall trade-off value for each alternative. The alternative with the highest overall trade-off value is the preferred alternative for that stakeholder. It can be seen from Table 2 that the "environmentalist" favors alternative 1; the "developer" favors alternative 2 slightly over alternative 4; and the "moderate" favors alternative 1 slightly over alternative 3. From this evaluation, alternatives 1 and 3 may be emerging as potentially attractive alternatives to the group of stakeholders.

Note that this process will not "select" the "preferred alternative", and it will not end the debate regarding the merits of the various goals, decision criteria, and alternatives. Rather, it provides a vehicle for stakeholders to specify their goals and preferences, and it compares these in a straightforward, fair manner so that the results can be evaluated and discussed by the stakeholder group. The process often can help the stakeholder group narrow the range of potential alternatives and find “consensus” alternatives.

Composite Programming

Composite Programming (CtP) is a modification of Weighted Average Programming. In Composite Programming the decision criteria are placed into groups of similar criteria that are composited into fewer, more general groups. For example, the criteria, boating, fishing, swimming, hiking and biking may be composited into the more general criterion of recreation. Groups are composited until the final trade-off criteria are left (see Figures 1 through 3). The criteria within each group are traded off using the formula:

$$Z_{Ai} = \left[(w_1 c_1)^p + (w_2 c_2)^p + \ldots (w_n c_n)^p \right]^{1/p}$$

where:

Z_{Ai} = trade-off value of the ith group of criteria for alternative A
w_m = preference weight for mth criterion of the ith group of criteria
c_m = decision criteria in the ith group of criteria
p = balancing factor that accounts for especially negative criteria values

The calculation is performed for each criteria group progressively until the final trade-off is made for the alternative. Each alternative is evaluated in the same manner, and the “best” alternative is identified with the highest final trade-off score (Z). The process is illustrated below.

Identify and quantify decision criteria.

The values of the decision criteria under each proposed management alternative are established and are again normalized. The decision criteria and the normalized values are shown in Figures 1, 2, and 3 for the “environmentalist”, “developer”, and “moderate”, respectively. Note that the decision criteria and their normalized values are the same as those used in the Weighted Average Programming example.

Establish stakeholder preference weighting systems.

The preference weights for the decision criteria are shown on Figures 1, 2, and 3. Note that preference weights must be established for each trade-off level in Composite Programming. For example, w1, w2, w3, and w4 in Figures 1, 2, and 3 are the preference weights for the first, second, third, and fourth trade-off levels, respectively. The sum of the preference weights in each trade-off group must equal 1.0.

In addition to the way the decision criteria are composited, the use of p-values distinguishes Composite Programming from Weighted Average Programming. The p values are used to prevent “fatally bad” decision criteria values from being “averaged out” in the analysis. For example, an alternative might have several decision criteria with excellent values and one decision criterion with a completely unacceptable value. In Weighted Average Programming, the completely unacceptable criterion value might be obscured by the excellent values of the other criteria. This would result in accepting an alternative that one really would find “unacceptable” because of the one unacceptable criterion value. In Composite Programming, larger p values give more importance to criteria with either very good or, more importantly, very bad values. These criteria are then not so likely to be “averaged” out with the other criteria values. Typically, the Composite Programming calculation is conducted with p values of 1, 2, and 3 to see how the very good and very bad criteria values affect the outcome.

Calculate the trade-off values for the management alternatives.

The Composite Programming formula is applied for each trade-off level and for each criteria group. For example, water velocity and substrate/cover are traded off using the c1 and w1 values in the CtP formula . Note that for Figures 1, 2, and 3, the p value is 2. Typically the analysis is done for p values of 1, 2, and 3 to see how the results are affected. The result of this trade-off is the river habitat value, Z1. This process is repeated for each criteria group and then for each trade-off level until a final trade-off value (Z4) is developed for each management alternative according to each stakeholder. The highest final trade-off value is the preferred alternative for a stakeholder. From Figure 1, it can be seen that the “environmentalist” prefers alternatives 1 slightly over alternative 3. Figure 2, shows that the “developer” prefers alternative 2, and Figure 3 shows that the “moderate” prefers alternatives 1 and 3 about equally. Again, alternatives 1 and 3 may be emerging as potential consensus alternatives for the range of sample stakeholder preferences.

Multiattribute Utility Theory

Multiattribute Utility Theory is similar to Weighted Average Programming except that instead of using the “values” of the decision criteria in the trade-off, the “utilities” of the criteria are used. The “utility” of a criterion is essentially how one feels about the value of a criterion. For example, three alternatives might have costs of $0.0, $1,000,000, and $50,000,000. The utility of each of these cost criteria is determined on a 0.0 to 1.0 scale. Since a cost of $0.0 is “very good”, it would have a utility approaching 1.0 (the best possible). The utility of the $1,000,000 cost might be considered to have a “medium” utility and be rated 0.5, and the utility of the $50,000,000 cost might be considered “very poor” and given a utility of 0.01 (i.e., approaching zero). Note that the utility values do not necessarily follow the actual costs on a one-to-one basis.

Once the utilities are determined for all of the decision criteria for the alternatives, the trade-off proceeds using:

$$U_A = w_1 \cdot u(c_1) + w_2 \cdot u(c_2) + ...w_n \cdot u(c_n)$$

where:

U_A= overall utility of alternative A
w_i = preference weight for decision criteria i
$u(c_i)$ = utility of decision criteria i for alternative A

The process is described in more detail below.

Identify and quantify decision criteria.

The decision criteria are identified, and their values under each management alternative are established in the same manner as before. The decision criteria are shown in Table 3. However, the values of the decision criteria are not normalized as was done in Weighted Average and Composite Programming. Rather, the utility of the values of the decision criteria are estimated. The utility of the value of a criterion can be stated as "how satisfied" one is with that value. For this example, the utilities of the decision criteria values are estimated from Figure 4. A utility of 1.0 is given to the best possible value of a criteria. In actual practice, this process would be conducted by each stakeholder, and the utilities for each criterion and management alternative would vary accordingly. The utilities for this example are shown in Table 3.

Establish stakeholder preference weighting systems.

The preference weights for the decision criteria are shown on Table 3. The preference weights are the same as established for Weighted Average Programming.

Calculate the trade-off values for the management alternatives.

The MAUT formula is applied for each proposed management alternative for each stakeholder. Table 3 shows the "trade-off" values for each decision criterion using the MAUT formula (i.e., the weights multiplied times the criteria utilities), and it shows the overall trade-off value for each alternative. The alternative with the highest overall trade-off value is the preferred alternative for that stakeholder. It can be seen from Table 3 that the "environmentalist" favors alternatives 1 and 3 equally; the "developer" favors alternative 4, and the "moderate" favors alternatives 1 and 3 equally. From this evaluation, alternatives 1 and 3 may be emerging as potentially attractive alternatives to these three hypothetical stakeholders.

Chapter V
Using MCDM for the Papillion Creek Watershed Management Study

So far, we have shown how the three MCDM techniques work with our examples of three hypothetical individuals; one favoring environmental protection, another favoring development, and a "moderate." Of course, in reality, no individual is likely to have preferences identical to the preferences we've hypothesized for the three sample stakeholders. The following is a description of how we will use the MCDM techniques with actual individuals.

1. Distribute copies of this report to interested community members for review of issues and management alternatives for the Papio Creek watershed. These stakeholders can read up on how the MCDM techniques work and can begin to formulate ideas for their own preference weights for the decision criteria listed in Table 1.

2. Convene a meeting of stakeholders (see enclosed letter for details). During the meeting, John Stansbury and Renee Irvin will demonstrate how individuals' preference weightings are entered into the computer program, then a trade-off score is calculated for each person and for each of the four management alternatives. In essence, the MCDM techniques work somewhat like a voting mechanism, and the trade-off scores reflect our "votes" based on our personal preferences for the decision criteria.

3. Each stakeholder attending the meeting will be assisted in entering their values for the preference weights. That is, if an individual favors recreational opportunities, he or she might enter high preference weight values for the following decision criteria; hiking/biking, fishing/boating, lake habitat, and so on. A blank decision criteria worksheet is provided on the next page, so that each individual can record his or her preference weights.

4. Once each stakeholder enters the preference weights, the trade-off scores are obtained for each of the four management alternatives under the three MCDM techniques:

    a. Weighted Average Programming:
    4 trade-off scores (one for each management alternative)

    b. Composite Programming:
        i. $p = 1$: 4 trade-off scores
        ii. $p = 2$: 4 trade-off scores

    c. Multiattribute Utility Theory:
    4 trade-off scores

Because the Composite Programming technique can be calibrated for p-values of

1 and 2, we will have 2 sets of results for the Composite Programming method. In total, we will have 4 sets of trade-off scores, showing each person's overall trade-off score for the four management alternatives. The highest trade-off score is the best (most preferred) alternative for each stakeholder. Table 4 shows the highest trade-off scores in boldface for the three hypothetical stakeholders.

5. With the data showing everyone's overall trade-off scores, local watershed management decisions can more easily incorporate a wide variety of public input. We won't actually choose "the" preferred management alternative for the Papillion Creek watershed, but we will summarize the results of the MCDM calculations to show community member preferences.

6. Following the summary of the stakeholder preference ratings, we will poll the stakeholders to determine what they thought about each of the three MCDM techniques used in the study. We hope to find out if these techniques could be useful for enhancing community involvement in watershed planning.

The community members who participate in this study are, actually, testing an environmental planning technique that has not been applied in the context of watershed management before. The results of this testing could yield important information about efforts to improve community participation in watershed decision-making nationwide. At the same time, information about stakeholder evaluations of the MCDM methods will be useful in the upcoming planning activities for the Papillion Creek watershed. Finally, information about stakeholder preferences for the Papillion Creek watershed derived from this study will aid our local agencies in their efforts to best manage the watershed for the benefit of the public for years to come.

GLOSSARY

Ad hoc decision-making - Occurs when different jurisdictions, often with conflicting interests, are responsible for decisions. A common result is that no clear authority or management philosophy is developed. Rather than making a decision based on a recognizable protocol, *ad hoc* decisions are based on the circumstances at the present.

Aquatic habitat - Stream structure (e.g., meanders, bottom substrate) and cover (e.g., vegetation) to provide habitat for native fish and aquatic species.

Authoritative decision-making - Occurs when an agency or agencies have and use the authority to make and enforce decisions.

Best Management Practice (BMP) - Standards for a given practice that have demonstrated superior results when utilized.

Bottom substrate – The material (mud, sand, gravel) on the bottom of a water body. The substrate is critical to the well-being of aquatic species.

Buffer strips - Grasses and trees planted along stream banks to reduce runoff and increase infiltration.

Clean Water Act (CWA) - Federal mandate that restricts the kinds and types of discharges to surface water bodies.

Combined Sewer [Sanitary and Storm Sewers] **Outflow (CSO)** – Combined sewers convey both stormwater and municipal waste. During storm events, these structures can overflow and discharge to a local stream

Community-based decision-making - Decisions made with significant input from the range of stakeholders in the community.

CSO – (See "Combined Sewer Outflow").

CWA – (See "Clean Water Act").

EPA – Environmental Protection Agency. (See "USEPA.")

Eutrophication - An overabundance of nutrients that renders a stream polluted by either being too rich for plant growth or characterized by a proliferation of unwanted plant material.

Infiltration – Process where precipitation seeps into the soil and percolates to the groundwater. The rate of infiltration depends on ground cover. For example, native prairie may infiltrate most of a rainfall, while agricultural and urban land infiltrate progressively less of a rainfall. More infiltration leads to smaller floods.

Levee - A raised bank designed to contain flood flows.

Meanders – Curves in a stream, created by the flow of water around natural barriers.

Multi-Criteria Decision-Making Methods (MCDM) - MCDM methods have been developed to assist in decision-making when there are several issues to be resolved and when different stakeholders have conflicting goals regarding those issues. The methods are systematic processes that demonstrate trade-offs (compromises) between conflicting issues. They attempt to mimic the process that each of us goes through when making a decision. (See also: authoritative decision-making, community-based decision-making, and ad hoc decision-making.)

Natural Resources Conservation Service (NRCS) - The NRCS works with agricultural producers in the basin regarding land management practices that can have significant impacts on the streams and reservoirs.

Nebraska Department of Environmental Quality (NDEQ) - Along with the USEPA, the NDEQ has responsibility for water quality in the watershed, for managing Clean Water Act provisions, and is currently developing policies regarding non-point pollution and stormwater runoff.

Non-point – Non-point pollution comes from many small sources and not from a single identifiable point source.

NRD – (See “Papio-Missouri River Natural Resources District”).

Nutrients – Nitrogen and phosphorous are common nutrients in streams. They cause algal growth which in turn depletes dissolved oxygen in the stream, leading to fish kills. The main sources of excess nutrients to Papillion Creek are; fertilizer, animal waste and CSOs.

Papio-Missouri River Natural Resources District (NRD) - NRD has primary management responsibility for the watershed. The primary goal of the NRD is flood control in the watershed.

Riparian habitat - Stream-side areas of vegetation including grasses and trees to provide habitat for insects, birds and small animals.

Runoff – The water from a rainfall that moves overland toward streams and waterbodies.

Substrate – (see “Bottom substrate”)

Total Maximum Daily Loads (TMDL) – The maximum amount (loading) from all sources that a water body can handle without unacceptable impacts. TMDLs are being developed for all “impaired” water bodies, including the Big Papillion Creek. For example, TMDLs may limit the amount of nitrogen discharged to the stream from all sources, including: point source discharges, storm water runoff from urban areas, CSOs, and runoff from agricultural land (fields and feedlots).

U.S. Army Corps of Engineers (USACE) - The USACE is a federal agency responsible for navigable waters of the United States. The USACE has built several small reservoirs for flood control in the Papillion Creek watershed.

U.S. Environmental Protection Agency (USEPA) - Along with the NDEQ, the USEPA has responsibility for water quality in the watershed, for managing CWA provisions, and is currently developing policies regarding non-point pollution and stormwater runoff.

United States Geographical Survey (USGS) - Federal agency responsible for accurate mapping of all areas of the country.

Watershed – The entire land area where water runoff drains into a creek system, which eventually collects into one point. In the Papillion Creek watershed, runoff drains from land in Washington, Sarpy, and Douglas County into various tributaries of the Papillion Creek system. Papillion Creek then runs into the Missouri River. All of the land with water runoff entering the Papillion Creek system is part of the Papillion Creek watershed.

APPENDIX
Environmental and Economic Derivation of Decision Criteria Data

The data shown previously in Table 1 was acquired over the course of a year and a half of study. Some of the values listed come from previously published data sources, while other values were derived by the grant researchers with surveys and other measurement instruments. In cases where direct and indirect sources of data were impossible or prohibitively expensive to acquire, researchers had to use "best-guess" estimates for the decision criteria values. Below is a brief description of the derivation of the decision criteria data.

Lake Habitat

The lake habitat criterion represents the available habitat for aquatic species that rely on non-running water. The lake habitat criterion values are represented by the total surface area (in acres) of lakes in each proposed alternative. Currently, there are approximately 1,000 acres of lake surface area in the Papillion Creek watershed. The lake surface areas for the four potential alternatives range from 1,000 to 3,000 acres.

Water Velocity

The water velocity in the creek is an important factor for aquatic habitat and hydraulic issues. High water velocities wash juvenile aquatic species out of their environment, destroy aquatic habitat cover structures, and cause increased stream-bank erosion. The water velocity criterion is represented by the calculated velocity near the mouth of the watershed for the 2-year flood. The 2-year flood was chosen because that is likely to be the "channel-forming" flow. In other words, high velocities for the 2-year flood are most likely to cause significant changes in the channel.

The water velocity near the mouth of the watershed for the 2-year flood was estimated as follows. The runoff from the 2-year storm (2.75 inches) was estimated using the Soil Conservation Service (now Natural Resources Conservation Service) runoff method. A spatially weighted average curve number was used based on the relative agricultural and urban areas for each given alternative. For the alternatives that mandate stormwater detention, the curve number for urban land was set equal to that for agricultural land (i.e., increased runoff from developed land would be detained, and peak flows would be similar to those expected from agricultural land).

The peak flow near the outlet of the watershed was estimated using the SCS peak-flow equation:

$$q_p = \frac{484 \cdot A \cdot Q}{0.5 \cdot D + 0.6 \cdot T_c}$$

where:

q_p = peak flow (cfs)
A = watershed area (mi^2)
Q = runoff from watershed (in)
D = duration of the rainfall (12 hours)
T_c = time of concentration (h)

$$T_c = \frac{L^{1.15}}{7{,}700 \cdot H^{0.38}}$$

where:

L = length of longest tributary (ft)
H = elevation drop from ridge to outlet of watershed (ft)

The depth of flow was calculated from the peak flow using Manning's equation in an iterative manner. Manning's n values were used to account for differences in stream-bank treatments (e.g., buffer strips) for the various alternatives. For alternatives with no buffer strips or other new stream-bank treatment, Manning's n was set to 0.03. For alternatives with buffer strips specified, Manning's n was set to 0.1. The use of high Manning's n values slows the water for alternatives and consequently raises the water surface elevation. This is important for flood control considerations.

The velocity was calculated from the depth of flow and the cross-sectional flow area using the continuity equation:

$$V = \frac{Q}{A}$$

where:

V = average water velocity (ft/sec)
Q = flow (cfs)
A = cross-sectional area of flow (ft^2).

Substrate Cover

The substrate cover criterion represents the amount and quality of aquatic habitat cover structures in the stream. This is an important variable for aquatic habitat. The substrate structure criterion is represented by EPA's Rapid Habitat Assessment Protocol for Aquatic Habitats. The assessment results in a range from 0 to 1 where a value of 1.0 represents an excellent aquatic habitat, and a value of 0.0 represents essentially no aquatic habitat (e.g., smooth mud bottom).

Riparian Quantity

The riparian quantity criterion represents the amount of habitat available for riparian species (terrestrial and avian species living along the stream). The riparian quantity criterion is a measure of the area of buffer or woodland along the streams for the various alternatives. Currently, there are approximately 2,560 acres of woodland and grassland along the creeks in the watershed. Buffer strips along the entire creek system (as in alternatives 1 and 3) would cover 13,185 acres.

Riparian Connectivity

The connectivity of the riparian habitat is important to riparian species because it allows migration along the stream. Discontinuities in the riparian zone significantly reduce the ability of these species to utilize the habitat. The riparian connectivity criterion is represented as the ratio of length of buffer to total stream length resulting in possible criterion values from 0.0 to 1.0 where 0.0 indicates no connectivity (no riparian zone), and 1.0 represents a completely continuous riparian zone along the creeks in the watershed.

Coliform Bacteria

Coliform bacteria concentrations are an important measure of the water quality in a watershed. Coliform bacteria concentrations represent the degree to which a stream is impacted by animal manure and/or human sewage. Since pathogenic organisms (bacteria and viruses) may also be present where coliform bacteria are present, coliform bacteria concentrations are important indicators as to the potential for a water body to pose health hazards to those who come into contact with the water.

The coliform bacteria criterion is represented by a discharge index. The discharge index represents the fraction of coliform bacteria that are likely to be discharged to the Papillion Creek given the management practices for the various alternative compared to the amount that are being discharged without those management practices. That is, the current discharge rate of coliform bacteria to the creek is considered to be 1.0, and an alternative with management practices that would reduce the discharge by 25% would have a discharge index of 0.75. The discharge index is calculated as:

$$DI = (1-r_1)\cdot(1-r_2)\cdot(1-r_3)\cdot\ldots\cdot(1-r_n)$$

where:

DI = Discharge Index (fraction)

r_n = removal fraction for management practice n (fraction).

Nitrogen

Nitrogen in its several forms is a nutrient that causes increased plant growth in aquatic systems. When these aquatic plants die and decay, they can significantly reduce the dissolved oxygen in the water, which can in turn kill the aquatic animal life. In addition, nitrogen in the form of ammonia is quite toxic to aquatic animal life. Nitrogen in the Papillion Creek typically comes from fertilizers (agricultural and urban), and animal and human wastes. The nitrogen criterion is represented by a discharge index, which is described in the Coliform Bacteria criterion section.

Phosphorus

Phosphorus in its several forms is a nutrient that causes increased plant growth in aquatic systems. When these aquatic plants die and decay, they can significantly reduce the dissolved oxygen in the water, which can in turn harm the aquatic animal life. Phosphorus in the Papillion Creek typically comes from fertilizers (agricultural and urban), and animal and human wastes. The phosphorus criterion is represented by a discharge index, which is described in the Coliform Bacteria criterion section.

Sediment Load

A high concentration of sediment (suspended particles) in the stream water is an indicator of erosion in the watershed. It can cause damage to aquatic species by covering habitat structures in the stream bottom and by decreasing the ability of aquatic species to visually find food (and avoid becoming food). In addition, high concentrations of sediment cause an accelerated rate of sedimentation in reservoirs thus shortening their effective life span. The sediment load criterion is represented by a discharge index. The discharge index method is described in the Coliform Bacteria criterion section.

Dissolved Oxygen

The dissolved oxygen concentration in the stream water is important for the health of aquatic species. The dissolved oxygen concentration depends on several factors such as temperature, turbulence of the stream, plants in the water, and constituents in the water (e.g., organic matter and nutrients) that remove dissolved oxygen. The dissolved oxygen in a stream will typically be between 0.0 mg/L and the oxygen solubility of around 10 mg/L . Recent water quality sampling in the Papillion Creek indicates that the dissolved oxygen concentration in the creek in August is approximately 2.5 mg/L.

The dissolved oxygen criterion was estimated to be 1.0 mg/L (August) for the alternatives that allow further development of the watershed with no concurrent management practices designed to increase dissolved oxygen. The dissolved oxygen criterion was estimated to be 6 mg/L for alternatives that mandate management practices designed to increase dissolved oxygen concentrations (e.g., keeping animal and human wastes and nutrients from the stream).

Flood Protection

The flood protection decision criterion represents the expected annual damage due to flooding in the Papillion Creek watershed. Differences in the values between alternatives account for factors such as: increased development (increased impervious area), channel improvements and levee improvements, flood control reservoirs, and stormwater detention basins. The values used for this report are only estimates and have not been verified.

Implementation Costs

Implementation costs are the total costs of the management practices mandated by each alternative. Costs include estimates for land acquisition and construction of the management practices. Operation and maintenance costs were not included. Impacts to land owners (e.g., for converting agricultural land to buffer strips) were not included as a "cost" because these impacts were assumed to be accounted for in the purchase price. Only one-half of the estimated cost of stormwater detention basins is included in this criterion because it was assumed that half of this cost would be borne by the developer; that cost is included in the "Real Estate Cost criterion". The costs of the management practices as they are applied to the watershed are given in the descriptions of the potential management alternatives. Total costs are given in Table 1.

Real Estate Costs

The real estate cost criterion represents the costs to developers for installing stormwater detention basins. It was assumed that one-half of the cost of these basins would be borne by the developer, and one-half would be borne by the "public" in the form of higher prices for developed property. Detention basins are mandated for alternatives 1 and 3 (environmental and recreational alternatives). The total costs of the detention basins for the entire watershed (including new developments and established developments) is $45 million.

Creekside Activity Index

Creekside activity refers to business activity such as retail and dining establishments orienting toward the water. In some cities (for example, San Antonio TX, Estes Park CO), after enhancement of the urban watershed, businesses began to orient themselves toward the river or creek. For example, restaurants can have picture windows and decks overlooking the water. In this way, the businesses can increase their revenues by capitalizing on a scenic view.

There is some potential, with the environmental (#1) and recreation (#3) management alternatives, for the aesthetics of the Papio Creek system to improve to an extent that some businesses in the Omaha area could benefit from increased pedestrian traffic and retail activity. One possibility, for example, is increased creek-orientation of businesses near 78th and Cass Streets. We posit a modest increase in business activity for those alternatives (for the environmental alternative a 10% increase, and for the recreation alternative a 5% increase). The baseline business activity index is zero for the other two alternatives, and assumes no current creekside orientation or effect on business.

Business Disruption Index

Construction of physical structures and landscaping to improve water quality or flood control efforts have a temporary effect on businesses due to traffic rerouting. However, much of the land immediately adjacent to the creek is far enough away from arterial streets that much environmental and flood remediation can be accomplished with little traffic reduction. Also, construction of dams as proposed in alternative 4 occurs primarily in low-traffic, non-urban areas. Thus, the effects on business disruption are predicted to be minimal. Using the status quo (#2) alternative as a baseline of zero business disruption, we add to the disruption index 5% for alternatives 1 and 4, with a slightly lower disruption level of 4% for the recreation (#3) alternative.

Fishing/Boating

To gauge the frequency of recreational use and economic value of the Papio Creek watershed, a survey was administered. One of the survey questions addressed frequency of annual fishing or boating. Survey responses came disproportionately from avid fishermen, since many of the surveys were distributed at Papio Creek system lakes. The survey responses indicate that, among those who fish, fishing is very frequent (an average of 20 times per year). However, a rather small proportion of area residents fish. Boating, on the other hand, can be a less frequent activity. Even those who own a boat may not actually go out on an area lake more than 5 or 10 times per year. Based on this information, the estimate for current annual total fishing and boating visits for the Papio Creek watershed area is 200,000, and this is the value used for alternative 2.

For the environmental alternative (#1), the expected increase in number of fish and also numbers of species available raises the fishing/boating estimate to 300,000. Alternative 4, due to the construction of dams, is expected to increase boating visits, so fishing/boating becomes 250,000. The recreation alternative (#3) is expected to result in the largest increase in fishing/boating, with a fishing/boating estimate of 350,000.

Hiking/Biking/Skating/Running

Survey responses were difficult to obtain from bicyclists because it was difficult to intercept them when they were en route along a creekside trail. However, it was clear from survey responses that some bicyclists travel along portions of the Papio Creek trail system "every day" (some allowance was given for poor weather conditions). Similarly, many walkers who use the trail system walk several times per week. Thus, numbers of visits are estimated to be much larger for this category than for fishing/boating. However, recreational use in this category is likely to be enhanced by improvements in what the creek looks like after restoration, rather than the actual quality of the water.

Dividing the population of 400,000 people linearly into groups of recreational users of the trail and lake system, we can construct a profile of use like the following:

400,000 people total:		Visits per year
200,000	never	0
100,000	once every 2 years	50,000
50,000	twice/year	100,000
25,000	5 times/year	125,000
12,500	20 times/year	250,000
6,250	40 times/year	250,000
3,125	80 times/year	250,000
1,562	160 times/year	250,000
781	320 times/year ("daily")	250,000
Total visits:		1,525,000

We estimate the baseline use of the watershed (alternative 2) to be 1,500,000 visits per year.

Picnicking/Camping/Other

Picnicking and camping, according to survey responses, is not as frequent of an activity as walking and biking. Families bring their children to lakes when they are young, but tend to do more active pursuits (biking, skating) as the children age. Numbers for picnicking/etc. are therefore estimated to be quite low. Since these types of visitors are more likely to come in contact with the water than "high-speed" visitors, it was estimated that picnickers may be more responsive to improvements in water quality.

Aesthetic Value/ Willingness to Pay

This category describes an estimate of value for non-use value. That is, many of us do not use the Papio Creek system for recreational purposes, yet restoration of the watershed might be important to us for various personal reasons (want the creek to be like it used to be, want to provide the area with an attractive natural resource though we're not active fishermen or walkers, etc.). Also, restoration of the creek may positively impact housing values for houses close to the creek or lakes in the Papio system. In our surveys, we attempted to measure this figure with two different approaches; a straightforward annual "willingness to pay" and increases in housing values.

Survey responses varied widely, with many at “zero” (not willing to pay anything for improvements in water quality) to estimates of several thousand dollars for such an improvement. The current value of the watershed to area residents was estimated to be $24,000,000. Alternative 4 would add a slight premium to housing values due to reduced risk of flooding, plus create some additional damsite lake views, so the value of alternative 4 is estimated to be $26,400,000. The recreation (#3) alternative is expected to enhance housing values very little (note that this category is for non-use value, so recreational issues are not considered here, unless they have an impact on house value); $26,400,000. Finally, alternative 1 is likely to produce the highest willingness to pay for non-use values; $32,000,000.

Regulatory Compliance

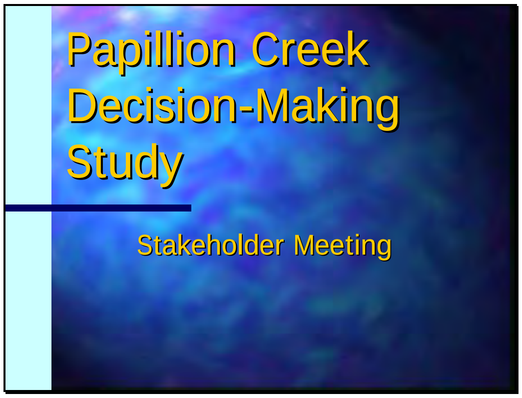
The regulatory compliance criterion represents how well each alternative satisfies current and developing regulations for the watershed. The Clean Water Act sets out water quality criteria for specified uses for individual water bodies. Currently, portions of the Big Papillion Creek do not meet those requirements. In addition, the Clean Water Act mandates that Total Maximum Daily Loads (TMDLs) of various pollutants be developed for such impaired water bodies. That is, maximum daily loadings to the stream of various pollutants such as bacteria, sediments, organic matter, and nutrients will be developed in the future.

The regulatory compliance criterion for each alternative is assigned a value on a scale of 0 to 3 where 3 represents complete compliance with regulations. Potential management alternatives that do not have specific management practices directed at reducing loadings of these pollutants were assigned criterion values of 1. Those management alternatives that have management practices designed to reduce these loadings were assigned a criterion value of 2.

Appendix F

PowerPoint Slides for the Stakeholder Meeting Presentation

Slide 1



Papillion Creek Decision-Making Study

Stakeholder Meeting

Slide 2

Who We Are

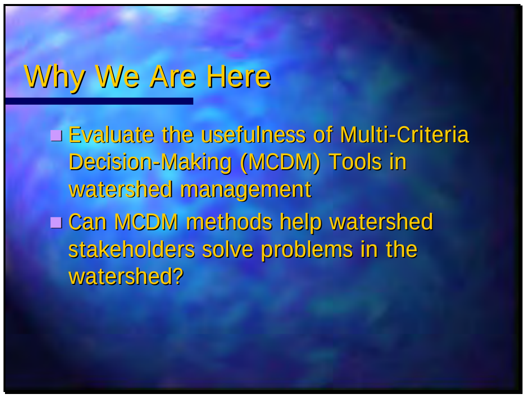
- University of Nebraska Study Group
  - John Stansbury & Reed Colton
    - Civil Engineering
  - Renee Irvin & Chris Swanson
    - Public Administration
- Watershed stakeholders

Slide 3

Relationship to Other Groups

- Independent study of watershed management methods and tools
- Funded by U.S. EPA Region 7
- Coordinating with other groups such as:
  - City of Omaha (storm water management)
  - Papio-Missouri River NRD
  - Papio Creek Watershed Partnership
  - Others

Slide 4



Why We Are Here

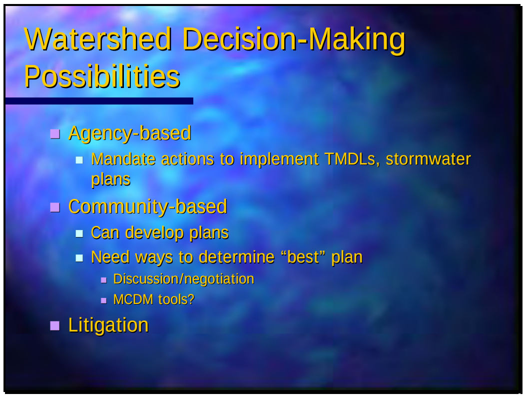
- Evaluate the usefulness of Multi-Criteria Decision-Making (MCDM) Tools in watershed management
- Can MCDM methods help watershed stakeholders solve problems in the watershed?

Slide 5

Reasons for Decision-Making in the Watershed

- Future Activities
  - Stormwater management plan development
  - TMDL implementation?
    - Impaired water bodies in watershed (EPA):
      - Big Papillion Creek
      - Cunningham lake
      - Wehrspann Lake
      - Zorinsky Lake

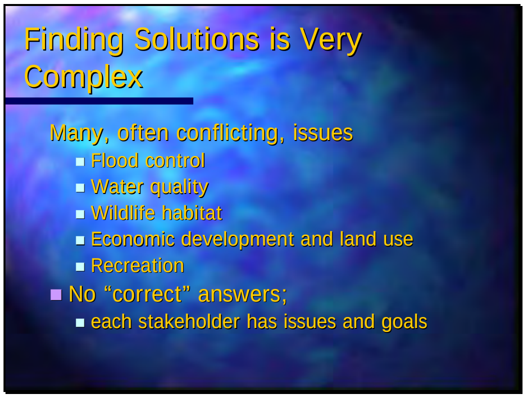
Slide 6



Watershed Decision-Making Possibilities

- Agency-based
  - Mandate actions to implement TMDLs, stormwater plans
- Community-based
  - Can develop plans
  - Need ways to determine "best" plan
    - Discussion/negotiation
    - MCDM tools?
- Litigation

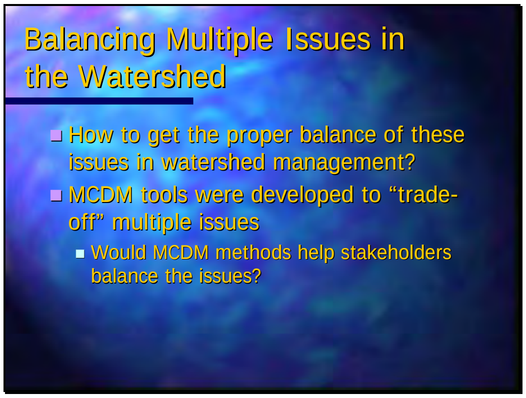
Slide 7



Finding Solutions is Very Complex

- Many, often conflicting, issues
  - Flood control
  - Water quality
  - Wildlife habitat
  - Economic development and land use
  - Recreation
- No “correct” answers;
  - each stakeholder has issues and goals

Slide 8



Balancing Multiple Issues in the Watershed

- How to get the proper balance of these issues in watershed management?
- MCDM tools were developed to “trade-off” multiple issues
  - Would MCDM methods help stakeholders balance the issues?

Slide 9

MCDM Tools

- What they are:
  - Mathematical tools developed to help decision-makers trade off multiple and conflicting objectives
    - For example:
      - flood control wants straight, clean channels,
      - aquatic habitat wants complex channels with lots of cover materials

Slide 10

MCDM Tools

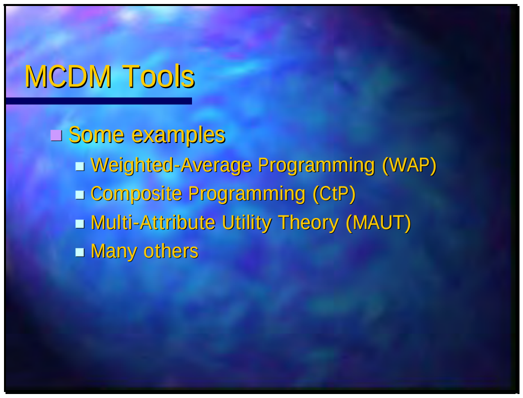
- What they can do
  - Evaluate multiple goals/uses in an objective way
    - Organize and interpret data and issues
  - Help stakeholders identify important issues
  - Make stakeholders disclose goals
  - Allow “all” stakeholders to participate in decision-making
  - Cause evaluation of broad spectrum of issues
  - Show how alternatives compare given different stakeholder preferences and issues

Slide 11

MCDM Tools

- What they can't do
  - Make the decision
  - Determine the “best” solution
    - There isn't one
    - “Best” depends on the stakeholders' views

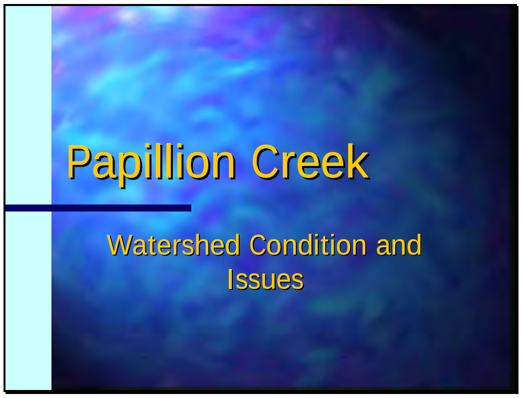
Slide 12



MCDM Tools

- Some examples
  - Weighted-Average Programming (WAP)
  - Composite Programming (CtP)
  - Multi-Attribute Utility Theory (MAUT)
  - Many others

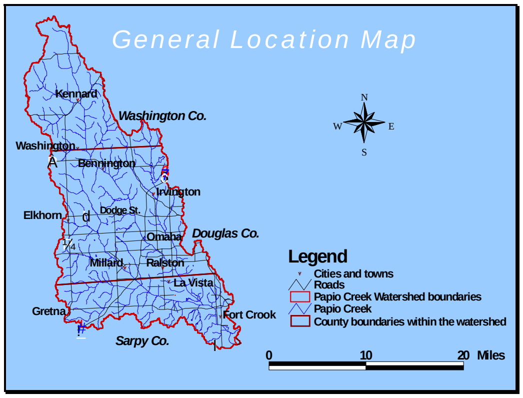
Slide 13



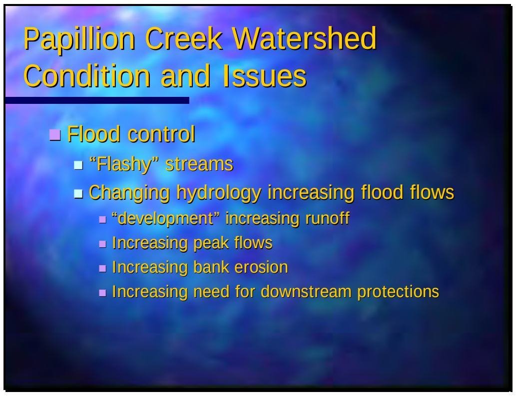
Papillion Creek

Watershed Condition and Issues

Slide 14



Slide 15



Papillion Creek Watershed Condition and Issues

- Flood control
  - "Flashy" streams
  - Changing hydrology increasing flood flows
    - "development" increasing runoff
    - Increasing peak flows
    - Increasing bank erosion
    - Increasing need for downstream protections

Slide 16

Papillion Creek Watershed Condition and Issues (cont.)

- Wildlife habitat
  - Degraded aquatic habitat
  - Narrow, discontinuous riparian habitat

  Causes:
    - Channelization
      - High flows and velocities
      - Eliminates "cover" for aquatic species
    - Land development to creek-side

Slide 17

Papillion Creek Watershed Condition and Issues (cont.)

- Water quality
  - Low dissolved oxygen
  - High BOD (organic material) loading
  - High nutrient loading
  - High bacteria loading
  - High sediment loading
- Sources:
  - Ag runoff, CSOs, urban runoff
- Regulatory actions are coming

Slide 18

Papillion Creek Watershed Condition and Issues (cont.)

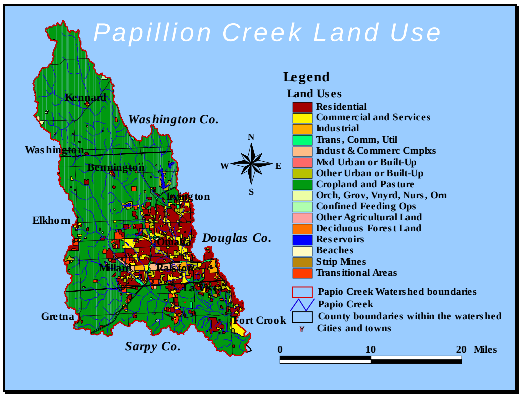
- Recreation
  - Several small lakes
  - Hiking and biking trails

Slide 19

Papillion Creek Watershed Condition and Issues (cont.)

- Economic development
  - "half" ag and "half" urban
  - Much urban development of ag land
  - Little use of creek as economic asset

Slide 20



Papillion Creek Land Use

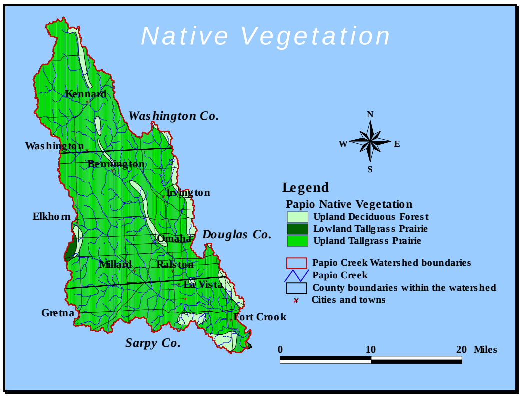
Legend

Land Uses

- 🟥 Residential
- 🟨 Commercial and Services
- 🟧 Industrial
- 🟩 Trans, Comm, Util
- 🟧 Indust & Commerc Cmplxs
- 🟥 Mxd Urban or Built-Up
- 🟨 Other Urban or Built-Up
- 🟩 Cropland and Pasture
- 🟨 Orch, Grov, Vnyrd, Nurs, Orn
- 🟩 Confined Feeding Ops
- 🟥 Other Agricultural Land
- 🟧 Deciduous Forest Land
- 🟦 Reservoirs
- 🟨 Beaches
- 🟫 Strip Mines
- 🟥 Transitional Areas

- Papio Creek Watershed boundaries
- Papio Creek
- County boundaries within the watershed
- Cities and towns

Slide 21



Native Vegetation

Legend

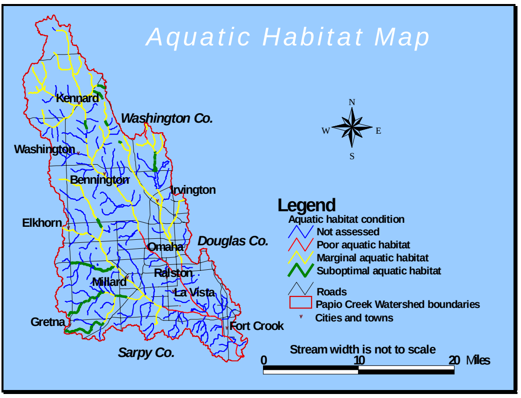
Papio Native Vegetation

- 🟩 Upland Deciduous Forest
- 🟩 Lowland Tallgrass Prairie
- 🟩 Upland Tallgrass Prairie

- Papio Creek Watershed boundaries
- Papio Creek
- County boundaries within the watershed
- Cities and towns

Slide 22

V



Aquatic Habitat Map

Legend

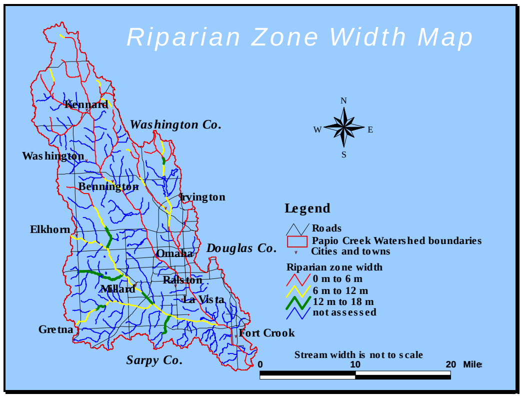
Aquatic habitat condition

- Not assessed
- Poor aquatic habitat
- Marginal aquatic habitat
- Suboptimal aquatic habitat

- Roads
- Papio Creek Watershed boundaries
- Cities and towns

Stream width is not to scale

Slide 23



Riparian Zone Width Map

Legend

- Roads
- Papio Creek Watershed boundaries
- Cities and towns

Riparian zone width

- 0 m to 6 m
- 6 m to 12 m
- 12 m to 18 m
- not assessed

Stream width is not to scale

Slide 24

Big Papio, NW Branch, looking downstream
County Road 23 btwn County Road 30 and County Road P30
June 29, 2000

Slide 25

Big Papio, east branch, upper reach, looking upstream
County Road 24 btwn County Road 27 and County Road 25
June 26, 2000

Slide 26

Big Papio, main reach, looking downstream
Harrison St. and S. 60th St.
June 29, 2000

Slide 27

Big Papio, main reach, looking downstream
Blondo St. btwn N. 83rd and N. 85 Streets

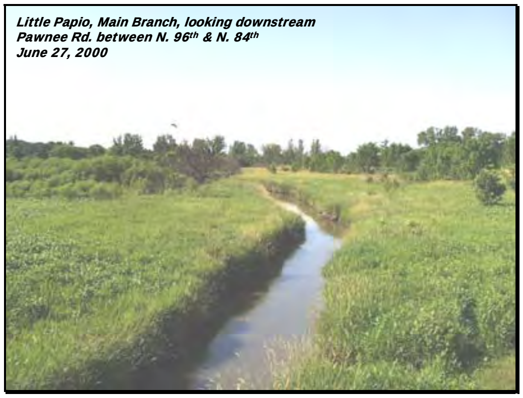
Slide 28

Big Papio, main reach, looking across channel
Pacific St. btwn I-680 and S 105th St

Slide 29

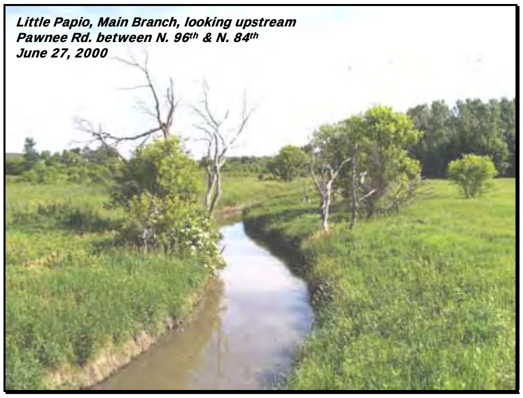
Big Papio, main reach, looking across channel
Pacific St. btwn I-680 and S 105th St

Slide 30



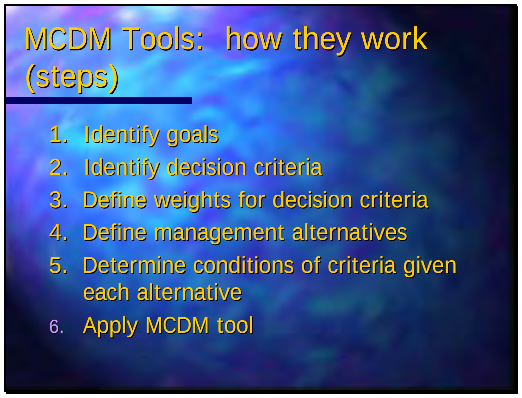
Little Papio, Main Branch, looking downstream
Pawnee Rd. between N. 96th & N. 84th
June 27, 2000

Slide 31



Little Papio, Main Branch, looking upstream
Pawnee Rd. between N. 96th & N. 84th
June 27, 2000

Slide 32



MCDM Tools: how they work (steps)

1. Identify goals
2. Identify decision criteria
3. Define weights for decision criteria
4. Define management alternatives
5. Determine conditions of criteria given each alternative
6. Apply MCDM tool

Slide 33

Watershed Goals

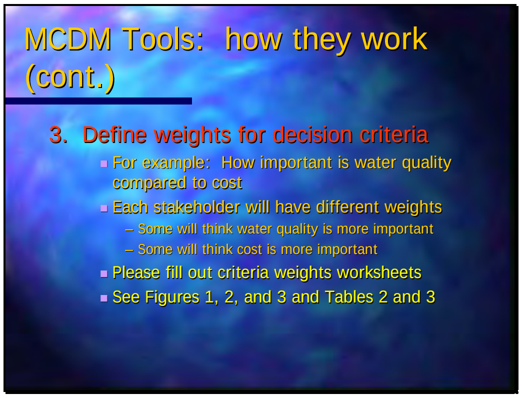
1. Identify goals
   - Provide flood protection
   - Provide good water quality
   - Provide wildlife habitat
   - Provide recreational opportunities
   - Provide climate for economic development
   - Provide opportunity for high quality of life

Slide 34

MCDM Tools: how they work (cont.)

2. Identify decision criteria (measures of goal attainment)
   - Expected annual flood damage
   - Dissolved oxygen in water
   - Cost of alternatives
   - Economic impacts to businesses
   - Aquatic habitat condition
   - Etc.
   - See Table 1 in Report

Slide 35



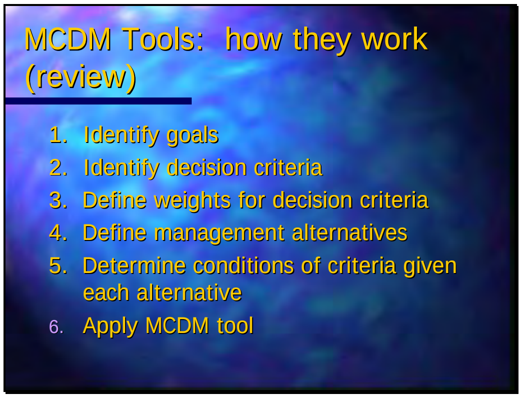
MCDM Tools: how they work (cont.)

3. Define weights for decision criteria
   - For example: How important is water quality compared to cost
   - Each stakeholder will have different weights
     - Some will think water quality is more important
     - Some will think cost is more important
   - Please fill out criteria weights worksheets
   - See Figures 1, 2, and 3 and Tables 2 and 3

Slide 36

Break!!!

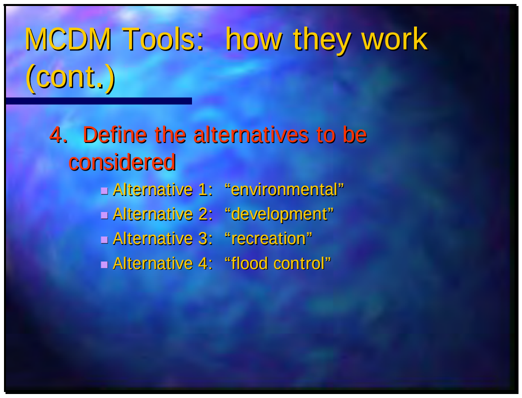
Slide 37



MCDM Tools: how they work (review)

1. Identify goals
2. Identify decision criteria
3. Define weights for decision criteria
4. Define management alternatives
5. Determine conditions of criteria given each alternative
6. Apply MCDM tool

Slide 38



MCDM Tools: how they work (cont.)

4. Define the alternatives to be considered
    - Alternative 1: “environmental”
    - Alternative 2: “development”
    - Alternative 3: “recreation”
    - Alternative 4: “flood control”

Slide 39

Alternative 1: Environmental

- Buffer strips
- Grade-control, bank stabilization
- Move levees back
- Parks/nature preserves
- BMPs for ag and urban land
- Stormwater retention
- Storage and disinfection for CSOs

Slide 40

Alternative 2: Development

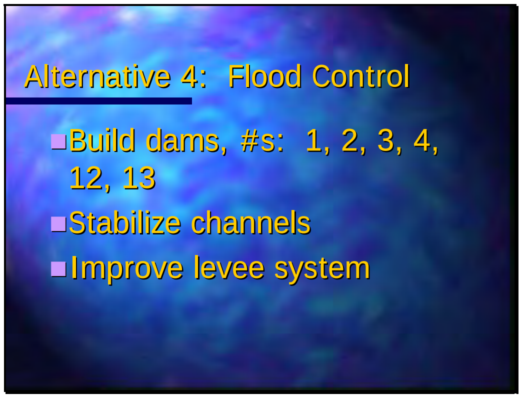
- Maximize land use for:
    - Urban development
    - Agriculture
- Stabilize channels
- Improve levees

Slide 41

Alternative 3: Recreational

- Build dams #3, #12, #13
- Linear parks, more bike paths
- BMPs for ag and urban land
- Stormwater retention

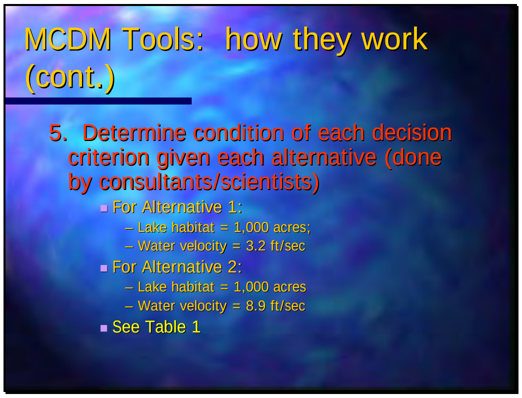
Slide 42



Alternative 4: Flood Control

- Build dams, #s: 1, 2, 3, 4, 12, 13
- Stabilize channels
- Improve levee system

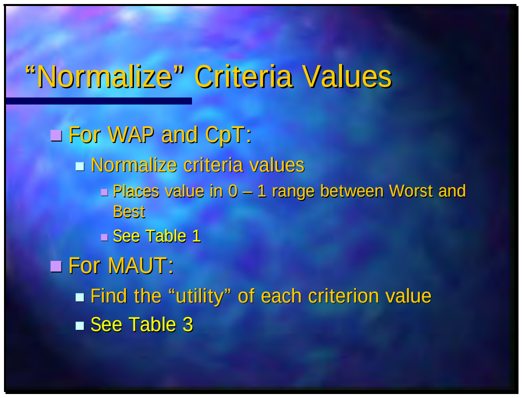
Slide 43



MCDM Tools: how they work (cont.)

5. Determine condition of each decision criterion given each alternative (done by consultants/scientists)
   - For Alternative 1:
     - Lake habitat = 1,000 acres;
     - Water velocity = 3.2 ft/sec
   - For Alternative 2:
     - Lake habitat = 1,000 acres
     - Water velocity = 8.9 ft/sec
   - See Table 1

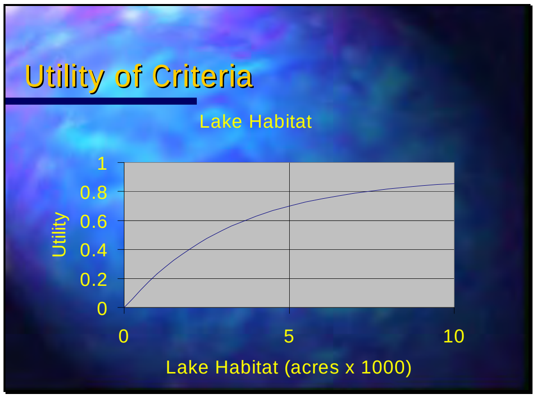
Slide 44



"Normalize" Criteria Values

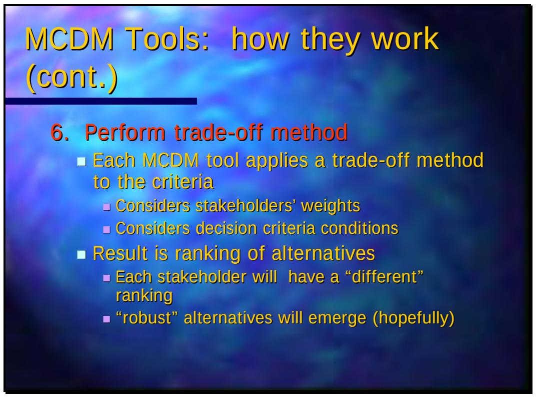
- For WAP and CpT:
  - Normalize criteria values
    - Places value in 0 – 1 range between Worst and Best
    - See Table 1
- For MAUT:
  - Find the "utility" of each criterion value
  - See Table 3

Slide 45



Utility of Criteria

Slide 46



MCDM Tools: how they work (cont.)

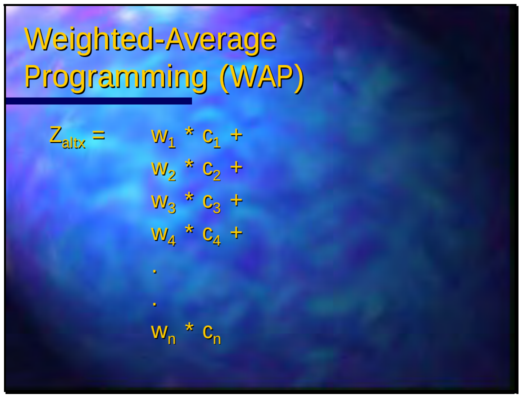
6. Perform trade-off method
   - Each MCDM tool applies a trade-off method to the criteria
     - Considers stakeholders' weights
     - Considers decision criteria conditions
   - Result is ranking of alternatives
     - Each stakeholder will have a "different" ranking
     - "robust" alternatives will emerge (hopefully)

Slide 47

Use of MCDM by Stakeholders

- Review weights to see which criteria are most important to stakeholder group
- Review criteria conditions to see which alternatives best meet goals
- Identify "good" and "bad" alternative components
- Modify alternatives
- Discuss and negotiate to develop "consensus alternative"

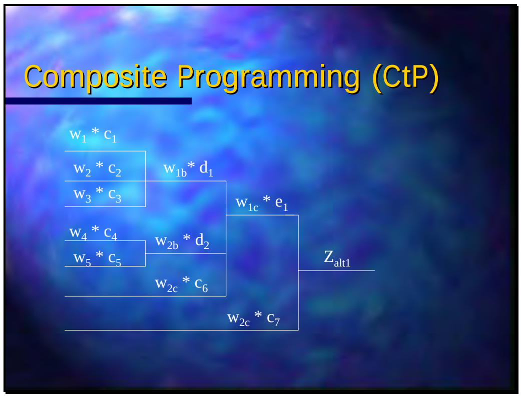
Slide 48



Weighted-Average Programming (WAP)

$$
\begin{aligned}
Z_{altx} = \; & w_1 * c_1 + \\
& w_2 * c_2 + \\
& w_3 * c_3 + \\
& w_4 * c_4 + \\
& . \\
& . \\
& w_n * c_n
\end{aligned}
$$

Slide 49



Composite Programming (CtP)

$w_1 * c_1$

$w_2 * c_2$

$w_3 * c_3$

$w_{1b} * d_1$

$w_{1c} * e_1$

$w_4 * c_4$

$w_5 * c_5$

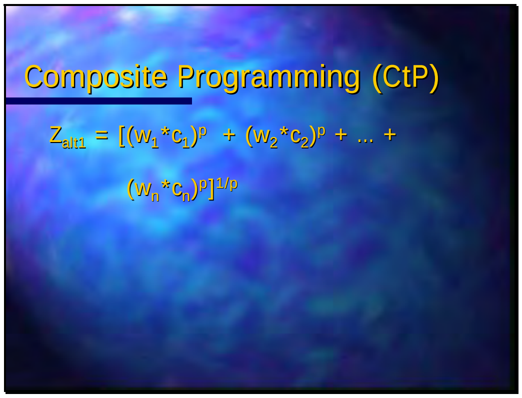
$w_{2b} * d_2$

Z_{alt1}

$w_{2c} * c_6$

$w_{2c} * c_7$

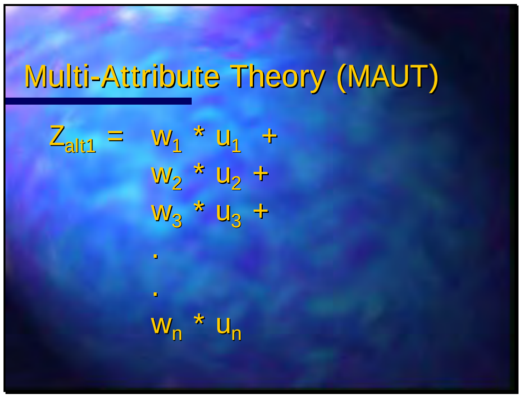
Slide 50



Composite Programming (CtP)

$$Z_{alt1} = [(w_1 * c_1)^p + (w_2 * c_2)^p + \ldots + (w_n * c_n)^p]^{1/p}$$

Slide 51



Multi-Attribute Theory (MAUT)

$$Z_{alt1} = w_1 * u_1 + w_2 * u_2 + w_3 * u_3 + \ldots + w_n * u_n$$

Slide 52

Big Papio, East Fork, Boston Branch, looking upstream
County Road 30, 0.4 miles W. of Hwy 133
June 27, 2000

Slide 53

Little Papio, Main Branch, looking downstream
Dutch Hall Rd. between N. 96th & N. 84th
June 27, 2000

Slide 54

Big Papio, SW Branch, looking upstream
County Road 19 btwn Hwy 30 and County Road 36
June 28, 2000

Slide 55

Big Papio, center branch, upper reach, looking upstream
County Road 18 btwn County Road 25 and County Road 23
June 26, 2000

Appendix G

Stakeholder Meeting Participant Evaluation/Questionnaire

EVALUATION of MULTI-CRITERIA DECISION MAKING METHODS

Thank you very much for taking part in our study. Our final task is to get your opinion on the usefulness of MCDM decision-making as applied to management of a watershed system.

First, please tell us whether you disagree or agree with the following statements:

	Strongly Disagree	**Disagree**	**Indifferent**	**Agree**	**Strongly Agree**
1. Citizen stakeholders should be involved in watershed decision-making.	____	____	____	____	____
2. Citizen stakeholders are likely to remain engaged throughout the decision-making process.	____	____	____	____	____
3. I would be willing to meet twice per month for three years to develop a watershed management plan.	____	____	____	____	____
4. Stakeholders have sufficient understanding of watersheds to participate in the decision making process.	____	____	____	____	____
5. The best format for watershed decision making is:					
a. consensus building among all stakeholder groups.	____	____	____	____	____
b. watershed development without organized planning or decision making.	____	____	____	____	____
c. water resources professionals/ officials making decisions.	____	____	____	____	____

d. Other (please specify):______________________________

____

____

	Strongly Disagree	Disagree	Indifferent	Agree	Strongly Agree
6. The data needed to use MCDM are available or can be reasonably developed.	_____	_____	_____	_____	_____
7. The MCDM methods studied are usable with water quality criteria such as TMDL constraints.	_____	_____	_____	_____	_____
8. The results from the MCDM methods are easy to understand.	_____	_____	_____	_____	_____
9. The results from the MCDM methods are believable.	_____	_____	_____	_____	_____
10. The MCDM methods properly evaluate the selected decision criteria.	_____	_____	_____	_____	_____
11. The MCDM methods mimic "real" decision making.	_____	_____	_____	_____	_____
12. Use of MCDM methods would help identify watershed goals and issues.	_____	_____	_____	_____	_____
13. Use of MCDM methods would facilitate discussion of goals and issues.	_____	_____	_____	_____	_____
14. Use of MCDM methods would improve understanding of goals and issues.	_____	_____	_____	_____	_____
15. Use of MCDM methods would help identification and collection of data needed for decision making.	_____	_____	_____	_____	_____
16. Use of MCDM methods helps illuminate how management alternatives are related to issues.	_____	_____	_____	_____	_____
17. Use of MCDM methods could cause me to change my mind regarding selection of a watershed management alternative.	_____	_____	_____	_____	_____
18. Use of MCDM methods would assist in the watershed decision making process.	_____	_____	_____	_____	_____
19. Use of MCDM methods can help decision makers develop appropriate watershed policies.	_____	_____	_____	_____	_____

	Strongly Disagree	**Disagree**	**Indifferent**	**Agree**	**Strongly Agree**
20. Use of MCDM methods would increase stakeholder participation.	____	____	____	____	____
21. Use of MCDM methods would help build consensus among stakeholders, facilitating compromise among stakeholders favoring competing alternatives.	____	____	____	____	____
22. I think that MCDM methods should be incorporated into watershed decision making.	____	____	____	____	____
23. I think that MCDM methods should be incorporated into the Papio Creek watershed decision making process.	____	____	____	____	____
24. As a stakeholder, I would prefer to use negotiation and discussion with other stakeholders rather than to use MCDM methods.	____	____	____	____	____
25. Watershed management would be better served by simply implementing the most cost-effective Best Management Practices (BMPs) that budgets allow.	____	____	____	____	____
26. In general, citizens don't have the time to get involved in environmental decision making, and they depend on government employees to make those decisions for them.	____	____	____	____	____

27. I would rank the three MCDM methods studied as:

Best **Middle** **Worst**

a. **Weighted Average Programming (WAP)** ____ ____ ____

Reasons:____

____

____

b. **Composite Programming (CtP)** ____ ____ ____

Reasons:____

____

____

c. **Multi-Attribute Utility Theory (MAUT)** ____ ____ ____

Reasons:____

____

____

28. The major benefits of using MCDM methods are:

29. The major drawbacks of using MCDM methods are:

30. Rank the five most important goals for the Papillion Creek watershed (1 = most important, 2 = next most important, etc.):

___ Economic development (land development, agricultural use)

___ Flood control

___ Quality of life (aesthetics, green space)

___ Recreation (hiking, biking, boating, fishing, etc.)

___ Water quality (low nutrients, pesticides, sediment, and organic matter loads)

___ Wildlife habitat (aquatic and riparian)

___ Other (please specify):______________________________

31. The categories that best describe me are (check all that apply):

___ Rural resident

___ Urban/suburban resident

___ Environmental advocate

___ Land development advocate

___ Farmer

___ Planner/decision-maker

___ Business person

___ Government agency representative

___ Recreational use advocate

___ Other (please specify): ____________________

32. **Yes** **No**
___ ___ I have previously used MCDM methods in decision-making or planning applications. If yes, specify method:______________________________

33. **Yes** **No**
___ ___ I have previously used other types of decision-making methods (e.g., optimization methods). If yes, specify method:______________________________

34. Comments and suggestions:

35. If you are interested in participating in more in-depth evaluation of MCDM methods (for example, specifying utility functions for MAUT programming, etc.), please note your name here and detach this page from the rest of the survey:

Yes, I'm interested in evaluating MCDM methods further:

Name: ________________________________

Phone number or email address: ________________________________

Evaluation of Multi-Criteria Decision Making Methods

Survey Results questions 1-26 evaluating MCDM method

Question #	Number of Responses					Average Response	Number of Responses
	Strongly Disagree (1)	Disagree (2)	Indifferent (3)	Agree (4)	Strongly Agree (5)		
1. Citizen stakeholders should be involved in watershed decision-making.				7	8	4.5	15
2. Citizen stakeholders are likely to remain engaged throughout the decision-making process.	2	7	4	2		2.4	15
3. I would be willing to meet twice per month for three years to develop a watershed management plan.		4	2	5	3	3.5	14
4. Stakeholders have sufficient understanding of watersheds to participate in the decision making process.	2	5	6	1	1	2.6	15
5a. The best format for watershed decision making is consensus building among all stakeholder groups.		2		8	4	4.0	14
5b. The best format for watershed decision making is watershed development without organized planning or decision making.	10	2				1.2	12
5c. The best format for watershed decision making is water resources professionals/ officials making decisions.	1	4	2	5		2.9	12
6. The data needed to use MCDM are available or can be reasonably developed.	1	4	2	8		3.1	15
7. The MCDM methods studied are usable with water quality criteria such as TMDL constraints.		1	7	7		3.4	15
8. The results from the MCDM methods are believable.		3	6	3	3	3.4	15
9. The results from MCDM methods properly evaluate the selected decision criteria.		1	6	7	1	3.5	15

10. The MCDM methods properly evaluate the selected decision criteria.		1	5	7	1	3.6	14
11. The MCDM methods mimic "real" decision making.		4	3	5	2	3.4	14
12. Use of MCDM methods would help identify watershed goals and issues.				6	8	4.6	14
13. Use of MCDM methods would facilitate discussion of goals and issues.				5	10	4.7	15
14. Use of MCDM methods would improve understanding of goals and issues.			2	5	8	4.4	15
15. Use of MCDM methods would help identification and collection of data needed for decision making.			4	7	4	4.0	15
16. Use of MCDM methods helps illuminate how management alternatives are related to issues.		1	2	9	2	3.9	14
17. Use of MCDM methods could cause me to change my mind regarding selection of a watershed management alternative.	1	2	6	6		3.1	15
18. Use of MCDM methods would assist in the watershed decision making process.		1	2	10	2	3.9	15
19. Use of MCDM methods can help decision makers develop appropriate watershed policies.		1	3	8	3	3.9	15
20. Use of MCDM methods would increase stakeholder		3	5	6	1	3.3	15
21. Use of MCDM methods would help build consensus among stakeholders, facilitating compromise among stakeholders favoring		2	5	7	1	3.5	15
22. I think that MCDM methods should be incorporated into watershed		2	5	6	2	3.5	15
23. I think that MCDM methods should be incorporated into the Papio Creek watershed decision making process.		1	4	7	3	3.8	15

24. As a stakeholder, I would prefer to use negotiation and discussion with other stakeholders rather than use MCDM methods.		6	2	4	1	3.0	13
25. Watershed management would be better served by simply implementing the most cost-effective Best Management Practices (BMPs) that budgets allow.	4	5	4	2		2.3	15
26. In general, citizens don't have the time to get involved in environmental decision making, and they depend on government employees to make those decisions for them.	1	5	3	5	1	3.0	15

Evaluation of Multi-Criteria Decision Making Methods
Survey Results Citizen Involvement

Question #	Number of Responses					Average Response
	Strongly Disagree (1)	Disagree (2)	Indifferent (3)	Agree (4)	Strongly Agree (5)	
1. Citizen stakeholders should be involved in watershed decision-making.	0	0	0	7	8	4.53
2. Citizen stakeholders are likely to remain engaged throughout the decision-making process.	2	7	4	2	0	2.40
3. I would be willing to meet twice per month for three years to develop a watershed management plan.	0	4	2	5	3	3.50
4. Stakeholders have sufficient understanding of watersheds to participate in the decision making process.	2	5	6	1	1	2.60
20. Use of MCDM methods would increase stakeholder participation.	0	3	5	6	1	3.33
26. In general, citizens don't have the time to get involved in environmental decision making, and they depend on government employees to make those decisions for them.	1	5	3	5	1	3.00

Evaluation of Multi-Criteria Decision Making Methods
Survey Results Citizen Understanding

Question #	Number of Responses					Average Response
	Strongly Disagree (1)	Disagree (2)	Indifferent (3)	Agree (4)	Strongly Agree (5)	
4. Stakeholders have sufficient understanding of watersheds to participate in the decision making process.	2	5	6	1	1	2.60
14. Use of MCDM methods would improve understanding of goals and issues.	0	0	2	5	8	4.40

Evaluation of Multi-Criteria Decision Making Methods						
Survey Results Preferred Decision Making Type						
Question #	Number of Responses					Average Response
	Strongly Disagree (1)	Disagree (2)	Indifferent (3)	Agree (4)	Strongly Agree (5)	
5a. The best format for watershed decision making is consensus building among all stakeholder groups.	0	2	0	8	4	4.00
5b. The best format for watershed decision making is watershed development without organized planning or decision making.	10	2	0	0	0	1.17
5c. The best format for watershed decision making is water resources professionals/ officials making decisions.	1	4	2	5	0	2.92
17. Use of MCDM methods could cause me to change my mind regarding selection of a watershed management alternative.	1	2	6	6	0	3.13
22. I think that MCDM methods should be incorporated into watershed decision making.	0	2	5	6	2	3.53
23. I think that MCDM methods should be incorporated into the Papio Creek watershed decision making process.	0	1	4	7	3	3.80
24. As a stakeholder, I would prefer to use negotiation and discussion with other stakeholders rather than use MCDM methods.	0	6	2	4	1	3.00
25. Watershed management would be better served by simply implementing the most cost-effective Best Management Practices (BMPs) that budgets allow.	4	5	4	2	0	2.27

Evaluation of Multi-Criteria Decision Making Methods

Survey Results Usefulness of MCDM

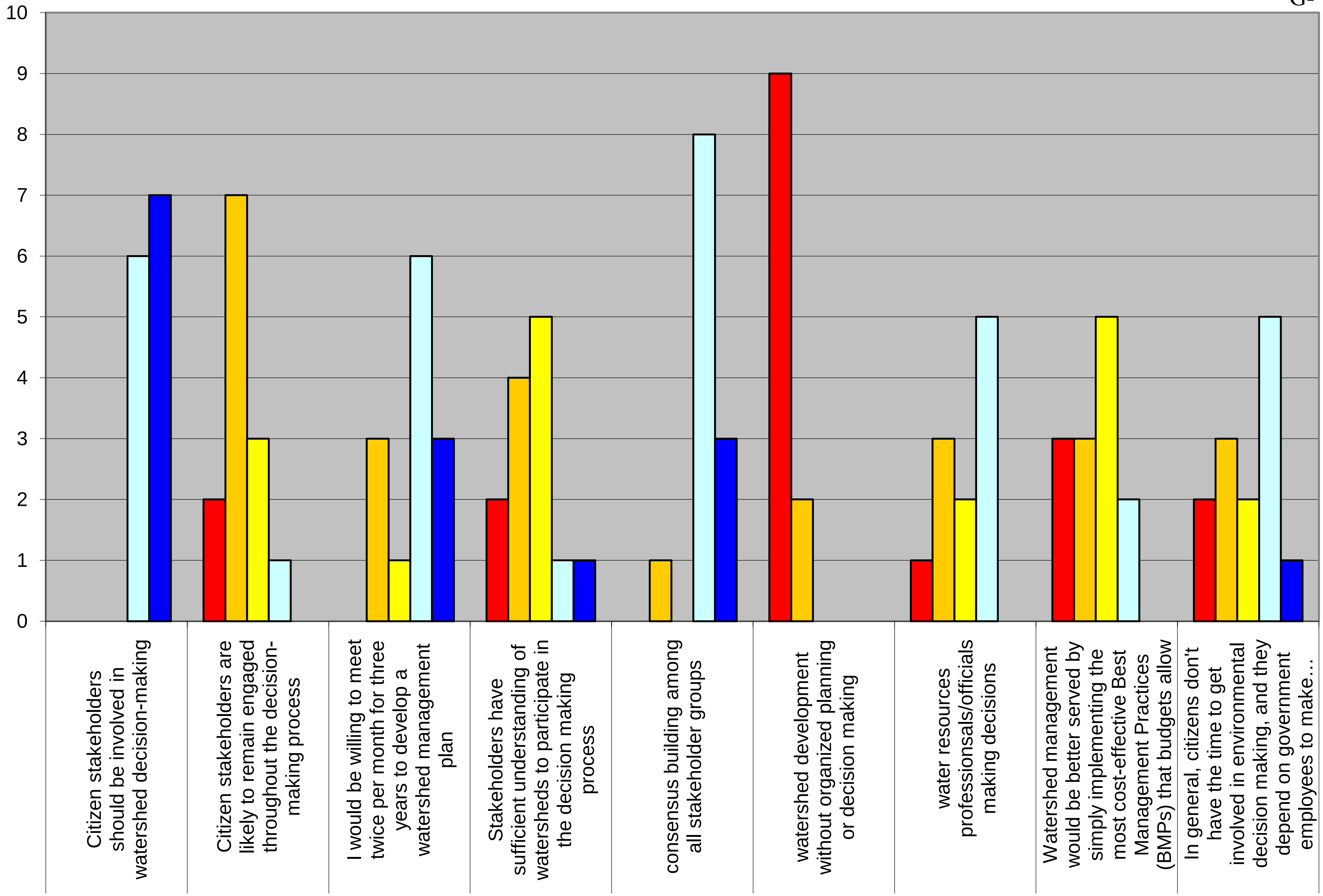
Question #	Number of Responses					Average Response
	Strongly Disagree (1)	Disagree (2)	Indifferent (3)	Agree (4)	Strongly Agree (5)	
6. The data needed to use MCDM are available or can be reasonably developed.	1	4	2	8	0	3.13
7. The MCDM methods studied are usable with water quality criteria such as TMDL constraints.	0	1	7	7	0	3.40
9. The results from MCDM methods properly evaluate the selected decision criteria.	0	1	6	7	1	3.53
10. The MCDM methods properly evaluate the selected decision criteria.	0	1	5	7	1	3.57
11. The MCDM methods mimic "real" decision making.	0	4	3	5	2	3.36
17. Use of MCDM methods could cause me to change my mind regarding selection of a watershed management alternative.	1	2	6	6	0	3.13
18. Use of MCDM methods would assist in the watershed decision making process.	0	1	2	10	2	3.87
19. Use of MCDM methods can help decision makers develop appropriate	0	1	3	8	3	3.87
21. Use of MCDM methods would help build consensus among stakeholders, facilitating compromise among stakeholders favoring competing alternatives.	0	2	5	7	1	3.47
22. I think that MCDM methods should be incorporated into watershed decision making.	0	2	5	6	2	3.53
23. I think that MCDM methods should be incorporated into the Papio Creek watershed decision making process.	0	1	4	7	3	3.80

Evaluation of Multi-Criteria Decision Making Methods Survey Results MCDM and Goal Setting						
Question #	Number of Responses					Average Response
	Strongly Disagree (1)	Disagree (2)	Indifferent (3)	Agree (4)	Strongly Agree (5)	
12. Use of MCDM methods would help identify watershed goals and issues.	0	0	0	6	8	4.57
13. Use of MCDM methods would facilitate discussion of goals and issues.	0	0	0	5	10	4.67
14. Use of MCDM methods would improve understanding of goals and issues.	0	0	2	5	8	4.40

Evaluation of Multi-Criteria Decision Making Methods Survey Results MCDM assisting the learning Process						
Question #	Number of Responses					Average Response
	Strongly Disagree (1)	Disagree (2)	Indifferent (3)	Agree (4)	Strongly Agree (5)	
15. Use of MCDM methods would help identification and collection of data needed for decision making.	0	0	4	7	4	4.00
16. Use of MCDM methods helps illuminate how management alternatives are related to issues.	0	1	2	9	2	3.86
18. Use of MCDM methods would assist in the watershed decision making process.	0	1	2	10	2	3.87

Community-Based Questions

Question		SD	D	I	A	SA
1	Citizen stakeholders should be involved in watershed decision-making				6	7
2	Citizen stakeholders are likely to remain engaged throughout the decision-making process	2	7	3	1	
3	I would be willing to meet twice per month for three years to develop a watershed management plan		3	1	6	3
4	Stakeholders have sufficient understanding of watersheds to participate in the decision making process	2	4	5	1	1
5a	consensus building among all stakeholder groups		1		8	3
5b	watershed development without organized planning or decision making	9	2			
5c	water resources professionsals/officials making decisions	1	3	2	5	
25	Watershed management would be better served by simply implementing the most cost-effective Best Management	3	3	5	2	
26	In general, citizens don't have the time to get involved in environmental decision making, and they depend on gove	2	3	2	5	1


10
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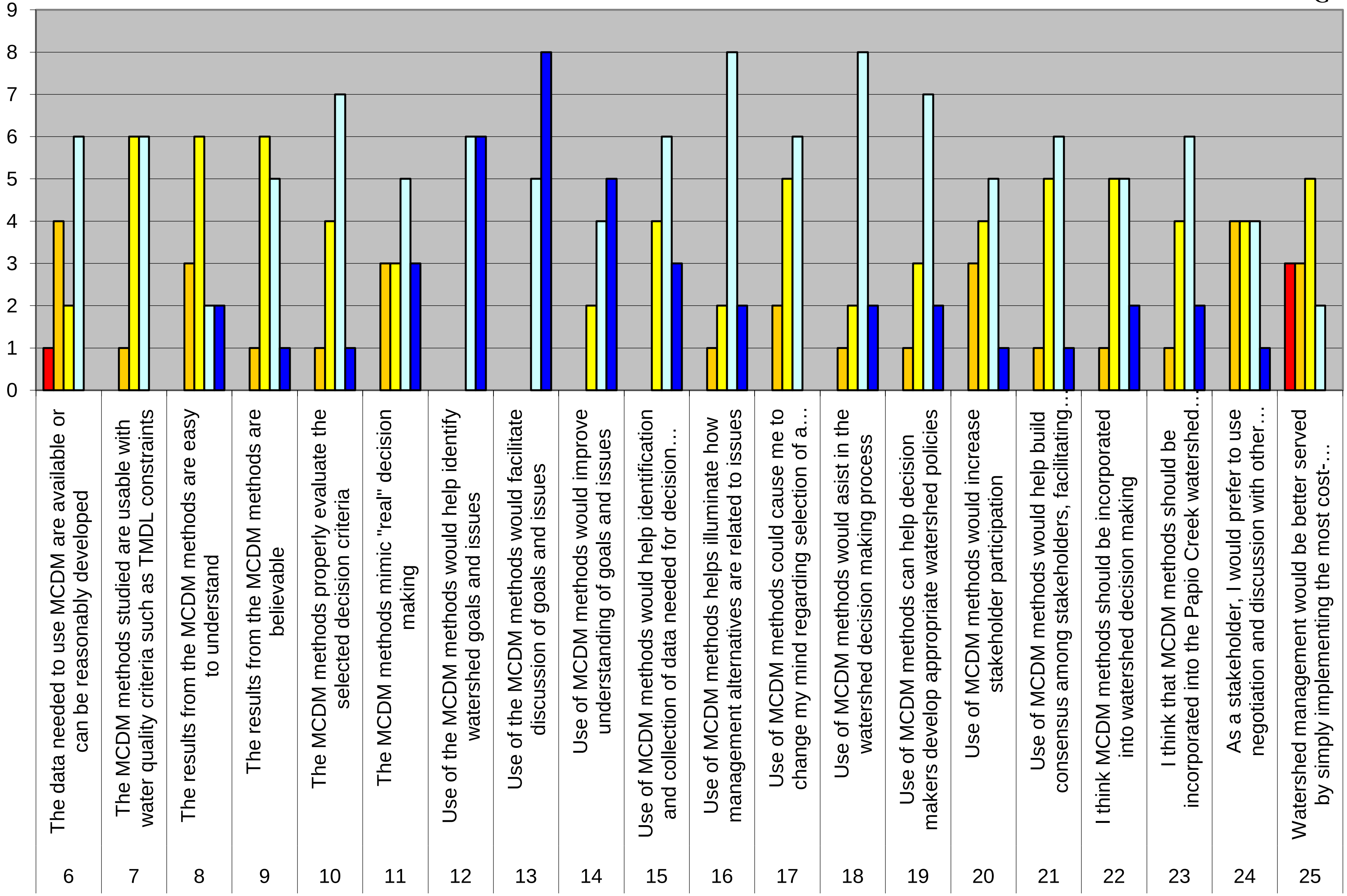
0
Citizen stakeholders should be involved in watershed decision-making
Citizen stakeholders are likely to remain engaged throughout the decision-making process
I would be willing to meet twice per month for three years to develop a watershed management plan
Stakeholders have sufficient understanding of watersheds to participate in the decision making process
consensus building among all stakeholder groups
watershed development without organized planning or decision making
water resources professionsals/officials making decisions
Watershed management would be better served by simply implementing the most cost-effective Best Management Practices (BMPs) that budgets allow
In general, citizens don't have the time to get involved in environmental decision making, and they depend on government employees to make…

Community-Based Questions

Question		SD	D	I	A	SA
1	Citizen stakeholders should be involved in watershed decision-making				6	7
2	Citizen stakeholders are likely to remain engaged throughout the decision-making process	2	7	3	1	
3	I would be willing to meet twice per month for three years to develop a watershed management plan		3	1	6	3
4	Stakeholders have sufficient understanding of watersheds to participate in the decision making process	2	4	5	1	1
5a	consensus building among all stakeholder groups		1		8	3
5b	watershed development without organized planning or decision making	9	2			
5c	water resources professionsals/officials making decisions	1	3	2	5	
25	Watershed management would be better served by simply implementing the most cost-effective Best Management	3	3	5	2	
26	In general, citizens don't have the time to get involved in environmental decision making, and they depend on gove	2	3	2	5	1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The data needed to use MCDM are available or can be reasonably developed
6
The MCDM methods studied are usable with water quality criteria such as TMDL constraints
7
The results from the MCDM methods are easy to understand
8
The results from the MCDM methods are believable
9
The MCDM methods properly evaluate the selected decision criteria
10
The MCDM methods mimic "real" decision making
11
Use of the MCDM methods would help identify watershed goals and issues
12
Use of the MCDM methods would facilitate discussion of goals and issues
13
Use of MCDM methods would improve understanding of goals and issues
14
Use of MCDM methods would help identification and collection of data needed for decision…
15
Use of MCDM methods helps illuminate how management alternatives are related to issues
16
Use of MCDM methods could cause me to change my mind regarding selection of a…
17
Use of MCDM methods would asist in the watershed decision making process
18
Use of MCDM methods can help decision makers develop appropriate watershed policies
19
Use of MCDM methods would increase stakeholder participation
20
Use of MCDM methods would help build consensus among stakeholders, facilitating…
21
I think MCDM methods should be incorporated into watershed decision making
22
I think that MCDM methods should be incorporated into the Papio Creek watershed…
23
As a stakeholder, I would prefer to use negotiation and discussion with other…
24
Watershed management would be better served by simply implementing the most cost-…
25