DISSERTATION

A FACILITATED PROCESS AND ONLINE TOOLSET TO ANALYZE COMPLEX SYSTEMS AND COORDINATE ACTIVE WATERSHED DEVELOPMENT AND TRANSFORMATION

Submitted by

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ABSTRACT

A FACILITATED PROCESS AND ONLINE TOOLSET TO ANALYZE COMPLEX SYSTEMS AND COORDINATE ACTIVE WATERSHED DEVELOPMENT AND TRANSFORMATION

Integrated Water Resources Management (IWRM) coordinates public, private, and nonprofit sectors in strategic resource development, while emphasizing holistic environmental protection. Without more integrated efforts, adverse human affects to water, other natural resources, and ecosystems services may worsen and cause more unintended cross-scale effects. Meanwhile, fragmented jurisdictional controls and competing demands continue to create new obstacles to shared solutions. Lack of coordination may accentuate negative impacts of extreme events, over-extraction, and other, often unrecognized threats to social-ecological systems integrity. To contend with these challenges, a research-based, facilitated process was used to design an online toolset to analyze complex systems more holistically, while exploring more ways to coordinate joint efforts. Although the focus of the research was the watershed scale, different scales of social-ecological problems may be amenable to this approach.

The process builds on an adaptive co-management (ACM) framework. ACM promotes systems-wide, incremental improvements through cooperative action and reflection about complex issues affecting social-ecological systems at nested and overlapping scales. The resulting ACM Decision Support System (DSS) process may help reduce fragmentation in both habitat and social structure by recognizing and encouraging complex systems reintegration and reorganization to improve outcomes. The ACM DSS process incorporates resilience practice techniques to anticipate risks by monitoring drivers and thresholds and to build coordinated coping strategies.

The Bear Creek Watershed Association (BCWA) served as a case study in nutrient management, which focused on understanding and mitigating the complex causes of cultural eutrophication in Bear Creek Reservoir – a flood control reservoir to which the entire watershed drains. The watershed lies in the Upper South Platte River Basin –the eastern mountain headwaters to metropolitan Denver, Colorado in the United States. To initiate Phase I of the ACM DSS process, qualitative data on issues, options, social ties, and current practices were triangulated through organizational interviews, document review, a systems design group, and ongoing BCWA, community, river basin, and state-level participation. The mixed methods approach employed geographic information systems (GIS) for spatial analysis, along with statistical analysis and modeling techniques to assess reported issues and potential options quantitatively. Social network analysis (SNA) was used systematically to evaluate organizational

relationships, transactions, and to direct network expansion towards a more robust core-periphery network structure. Technical and local knowledge developed through these methods were complimented by ongoing academic literature review and analysis of related watershed efforts near and far.

Concurrently, BCWA member organizations helped to incrementally design and test an online toolset for greater emphasis on ACM principles in watershed program management. To date, online components of the ACM DSS include issues reporting, interactive maps, monitoring data access, group search, a topical knowledge base, projects and options tracking, and watershed and lake management plan input. Online toolset development complimented assessment by formalizing what was learned together throughout the ACM DSS process to direct subsequent actions to align with this approach. Since the online system was designed using open source software and a flexible content management system, results can be readily adapted to serve a wider variety of purposes by adjusting the underlying datasets.

The research produced several potentially useful results. A post-project survey averaged 9.3 on a 10-point satisfaction scale. The BCWA board adopted the resulting ACM DSS process as a permanent best management practice, funding a facilitator to continue its expansion. A network weaver to continually foster cooperation, a knowledge curator to expand shared knowledge resources, and a systems engineer to reduce uncertainty and ambiguity and dissect complexity were all found to be critical new roles for successful ACM implementation. Watershed program comparisons also revealed ten qualities that may promote ACM.

The technical analysis of nutrient issues revealed that phosphorus enrichment from phosphorus desorption from fine sediments contributed to cultural eutrophication through several distinct mechanisms, which may be addressed through a wider range of non-point source controls and in-lake management options. Potential affects from floods, wildfires, and droughts were assessed, which has resulted in more coordinated, proactive plans and studies. Next steps include formulating multi-institutional, multi-level academic studies in the watershed, expanding community engagement efforts, and establishing innovation clusters. Multi-disciplinary research needs include studying nutrient exchange processes, piloting decentralized wastewater treatment systems, optimizing phosphorus removal processes, chemically blueprinting nutrient source streams, and developing an integrated modeling framework. At least four additional stages of development are planned to refine and mature the ACM DSS process over time. The ACM DSS process is also being considered for other places and IWRM problem sets.

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I would also like to thank the National Institutes for Water Resources and the Colorado Water Institute for funding development of a *Social Network Analysis Workshop for Water and Natural Resource Management* (http://sna.wateractionnetwork.org). Not only did this opportunity permit me to share a portion of this research directly with students and practitioners in a variety of settings, but the experience provided important lessons that improved the results of this investigation, as well.

Finally, I would like to thank the entire staff of the Colorado Division of Water Resources (DWR) for working with me to redesign the DWR internet and intranet. Michael Blazewicz and Jeff Crane, formerly of the Colorado Watershed Assembly, in partnership with state water-related agencies, helped me create a *Measurable Results* CO Watershed Restoration Project Assessment System. These concurrent opportunities provided additional online collaborative application development experiences, which were adapted to this research.

DEDICATION

To my husband, Fernando, for his unconditional support of this effort

To my teenagers, Alexander and Estrellita, for providing the inspiration and humor to see it through

To you, the reader, for your unique contributions that facilitate social-ecological-technical progress

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DEFINITION OF TERMS

303(d) listed – stream or water body not meeting EPA designated quality standards per state reporting

501(c)3 – nonprofit corporation meeting federal internal revenue service tax-free status requirements

Adaptive Capacity – institutional, organizational, and individual capabilities to make effective decisions, create and implement policy, and achieve projects and programs to address changes in the environment

Adaptive Management – a focus on shared reflection of previous actions to inform proactive next steps

Ambiguity – multiple ways to interpret a situation, results of an action, or risk that complicates decisions

Belief – idea, viewpoint, or attitude held in common that influences the course of action among choices

Bonding Tie – relationship between two people within a cohesive group – family, co-worker, associate

Bridging Tie – relationship between two otherwise unconnected groups –state and federal agencies

Broker – person whom communicates between two groups or persons who would not otherwise relate

Triadic Closure –if A & B and B & C possess strong ties, A & C connect to form a triangular network

Collaboration – groups working together towards shared goals, pooling resources and perspectives

Coalition building – creating formal and informal shared governance between distinct organizations

Co-management – more collaborative decision making inclusive of government and community groups

Common Pool Resource (CPR) Theory – models for managing public goods of limited excludability

Complexity – difficulty in understanding self-organizing, evolving social-ecological interactions

Content Management System (CMS) – storing content in database to auto-generate online information

Cyanobacteria – photosynthesizing bacteria typically responsible for harmful “algae” blooms in lakes

Emergent Property – properties evident in study of the whole that are not apparent in any component

Homophily – a tendency of actors having more characteristics in common to form stronger relationships

Hyporheic Zone – interface of aquifers and rivers, where groundwater and river water mix in sediments

Institution – structure or mechanism of enforcing behavior to conform to shared community practice

Internal Loading – phosphorus released from lake and stream sediments typically during late summer

Knowledge Base (KB) – a database to organize, manage, and retrieve categorized information

LIDAR (from “light” + “radar”) – remote sensing by analyzing reflected light from a laser for mapping

Limnology – freshwater science, the study of bio-chemical-physical interactions in inland waters

Memorandum of Understanding – formal cooperative agreement between two or more organizations

Multimetric Macroinvertebrate Index (MMI) – combines scores to indicate site aquatic condition

Norm – an unwritten social rule, most evident when broken, that directs behavior in a specific situation

Nutrient Loading – actual quantity of nutrients delivered, usually expressed in pounds per year by multiplying the concentration of the nutrient by the volume of water delivered in annual streamflow

Non-Point Source – any pollutant not directly discharged into a stream or water body that still enters it

Public Good – fresh air, clean water, and ecosystem services that cannot be easily kept from public use

Open Source – software produced by the affected user community free for download or online use

Organization – a group organized for a purpose as a named entity with documented rules and positions

Risk Assessment – determining the likelihood of an event occurring and its impacts on practice or goals

Role – a set of expectations society places while one is exercising a particular position: mother or CEO

Resilience Practice – maintaining desired states and transforming systems from undesirable states

Sanction – formal and informal means of social control to gain conformity with social norms

Sensitivity Analysis – determining how altering a variable in a computation or model will affect outputs

Social Capital – ability to access resources and support through ones network of roles and relationships

Social-Ecological Systems – also called human-environmental or socio-ecological systems or SES, nested systems that impact one another through complex interactions that may threaten function of either

Social Learning – fostering multiple perspectives and knowledge types in shared learning environment

Social Network Analysis – analytical tools for uncovering social factors affecting resource governance

Status – various positions one fulfills for which one must exercise a set of prescribed social behaviors

Uncertainty – the inability to fully define and measure stochastic processes and complex interactions

Value – concept of what is desirable, proper, beautiful, good, or right that guides behavior and choices

Vulnerability – inability to recover from a change in the environment, likelihood of failing perturbation

1.0 INTRODUCTION

1.1 Introduction

This research develops a new role in engineering for facilitating adaptive co-management (ACM), which combines incremental, act-and-assess experimentation of *adaptive management* with more flexible approaches to shared governance represented by *co-management* (Pahl-Wostl et al. 2008; Plummer et al. 2012). It creates an expanded role for water resources engineering and research in decision support for watershed program improvement through an ACM-based systems approach to multi-dimensional problem solving under uncertainty. The resulting phased, collaborative decision support systems (DSS) development process is entitled *ACM DSS*. Throughout the facilitated process, engineering tools and methods are introduced to participants to increase the collective technical understanding of each issue and to evaluate potential mitigation options more comprehensively. Systems analysis includes evaluation of the political and social environment required to support change. Results help define how the engineer can more constructively foster innovation in a teaming framework within a wider variety of other disciplines, sectors, and community interests.

1.2 Problem Statement

Humans threaten watershed function by fragmenting habitat, infilling wetlands, altering flows, increasing erosion, overusing natural resources, concentrating nutrients, and contaminating the environment. The 2005 United Nations Millennium Ecosystem Assessment (MEA 2005) reported that changes in policies and practices have not been sufficiently achieved to reverse the resulting degradation in many places. The MEA study was particularly concerned that human induced changes may reflect back on human well-being more abruptly in the future, through plagues, loss of species diversity, collapse of farms and fisheries, and clean water scarcity. Since local decisions collectively affect complex social-ecological systems at regional and global scales, it is particularly important to build local capacity for transformation at the watershed scale (Bierbaum et al. 2012, Glantz et al. 2013). However, even in the United States, fragmented jurisdictions, land ownership, and opposing interests exacerbate these problems and complicate resolution, so the unsustainable trajectory has not been corrected.

In recent years, an interdisciplinary, research-based approach has been steadily gaining acceptance as an alternative development framework. Case-based experimentation has supported further development of this multi-scaled, systems-approach to shared learning and governance. This new approach has many variations that reflect similar concepts, including: Sustainability Science (Komiyama et al. 2011), The Collaborative Learning Approach (Daniels & Walker 2001), Managing for Complexity (PMI 2014), Co-Engineering (Daniell 2012), Ecosystem Management (Meffe 2002), Ecological Engineering Design (Matlock & Morgan 2011), Global Change Research (DeFries et al. 2011), The Institutional Analysis and Development Framework (Ostrom 2005), Social System Design (Banathy 1997), Re-Engineering Community Development (Fabiani & Buss 2008), Participatory Collaborative Modeling (Bourget 2011), Collaborative Resilience (Goldstein 2012), Resilience Practice (Walker & Salt 2012), Adaptation (a.k.a. Adaption) Planning (Carmin et al. 2012), Adaptive Management (NRC 2004), and Adaptive Co-Management (Armitage et al. 2007, Plummer et al. 2012). All of these methods seek collaborative and adaptive paths towards resolution of shared problems. However, relatively little research has focused on how these methods can best be implemented to actually improve watershed program management and cross-sector cooperation.

Shifting from traditional methods to the ACM mindset described in Table 1 is challenging. The ACM DSS process is designed to engage the initial group in reaching out to others, negotiating with regulators, and evaluating each choice more effectively to improve the next. The process must remain iterative to build knowledge and capacity continually to alter current, often entrenched, conditions. Phase I efforts include systems analysis of relationships and transactions to build bridges of cooperation and improve knowledge to apply to subsequent choices through shared, selective experimentation. Political and economic impediments to more integrative approaches must be directly analyzed and addressed across sectors and nested and overlapping structures of governance. Building such knowledge of the social environment is a necessary first step to begin to analyze option packages in a way that results in more targeted next steps with a greater likihood of demonstrating more desirable outcomes from the standpoint of more engaged, diverse community interests.

To illustrate how ACM differs from traditional methods, Table 1 compares the two approaches in terms of several attributes.

Table 1. Contrasts between Traditional Resource Management and Adaptive Co-Management
(adapted from Meffe 2002, Armitage & Plummer 2010; Brunch 2009; Daniell 2012)

Factor	Traditional Management	Adaptive Co-Management
Expanded Resource Valuation	Emphasis on commodity and natural resource extraction, agriculture, mining, and industrial sectors	Balance between commodities, extraction, amenities, and eco-integrity, emphasizing quality; Externalities internalized; Ecosystem services fully valued
Evolving, Adaptive Emphasis	Equilibrium perspective, stability, climax communities, simplifying assumptions	Nonequilibrium, evolutionary perspective, dynamics and resiliency, shifting mosaics, one scale affects nested and overlapping scales in unanticipated ways
Complex Systems Thinking	Reductionism, project-oriented, site specificity, single species/purpose, issue focus, specific optimization	Holistic, multi-scale integration, complex, spatio-temporal contextual view, stepwise action-orientation, complex reactions and interactions
Uncertainty & Ambiguity	Predictability, control, prescriptive, faith in structural solutions, side effects, different viewpoints ignored	Uncertainty and flexibility, experimentation and reflection, focus on monitoring and assessment, diverse disciplines and perspectives embraced
Participatory	Solutions developed by federal resource management agencies, sector-specific technocratic lead	Solutions consider all stakeholders and interests, iterative, incremental coordinated actions focus on improvement rather than one-time solution
Polycentric	Top-down federal agency regulation and decision making dominated development	Vertical and horizontal institutional controls at multiple scales, blend formal and informal governance mechanisms
Cooperative	Confrontation, single-issue polarization, public as adversary, political interventions	Consensus building, multiple issues / scales, power-sharing coalitions, conflict / dispute resolution, networking across sectors, scales, and disciplines
Risk reduction	Planning project-by-project as needed, Risk analysis for one sector / need	Long term forecasting, ongoing planning for system-wide risk reduction and social-ecological resilience
Multi-purpose	Single-purpose projects, regional scale Single-issue corrected, causing others	Diversity of considerations & managed solutions portfolios, Community capacity and trust building

1.3 Research Focus

The central research question is whether ACM can be incorporated into an engineered process to enhance essential features of adaption and cooperation, demonstrated through a case study in watershed-level nutrient management. The resulting *ACM DSS process* was developed to fulfill the following objectives:

- evolve understanding of system characteristics and responses, risks and uncertainties,
- learn from past actions to plan future actions to improve system resilience, and
- forge partnerships for shared governance and coordinated response to unexpected events.

The purpose of development includes serving as a training tool for engineers and scientists pursuing fields related to integrated water resources management (IWRM). The focus in Phase I elaborated through this research is to facilitate more holistic, stepwise analytical assessment of the current situation by teaming with other disciplines to increase the use of combined and clustered engineering and social sciences knowledge and research in subsequent phases of ACM DSS process development.

To test research-based ACM DSS process effectiveness, the study sought to:

- Demonstrate that an interactive online system built collaboratively with the community may foster a sustained ACM focus to enhance community resilience to cope with unexpected events while reducing more vulnerabilities than traditional planning tools appear to have in the past.
- Demonstrate that results serve water resources engineering by providing improved community capacity and institutional coordination to permit more targeted engineering studies and projects.
- Demonstrate how *Social Network Analysis* (SNA) and principles of sociology can increase understanding of the relational social structure surrounding an issue such as nutrient management.
- Demonstrate that statistical analysis of monitoring data reveals temporal patterns of variability and the significance of trends in streamflow, nutrient loading, cyanobacteria blooms, weather, and bracketed point source contributions for improved planning, management, and study focus.
- Demonstrate how GIS delineation of nutrient source issues spatially and in areal extent can more effectively visualize, quantify, and model areas of concern for more site-specific control.
- Employ multidisciplinary research to enhance complex social-ecological systems understanding.
- Acquire and incorporate critical new knowledge from non-academic ways of knowing.
- Discuss the feasibility of scaling-up preliminary results from the watershed to the basin scale.
- Discuss how this process may be applied to other complex, evolving modern day problems.

1.4 Baselines and Metrics

A baseline is a measure of the status of components that may be affected during research implementation to determine how the ACM DSS process apparently affected outcomes. Metrics are measures that can be used against the baseline levels to demonstrate change.

To test ACM DSS process outcomes, the baseline and metrics listed below were exercised:

- ACM DSS Online Toolset

  Baseline: No interactive online system

  Metrics: Modules (tabs), content types, numbers of items, user contributions, perceived utility
- Coping with unexpected events while reducing more vulnerabilities:

  Baseline: No direct efforts sought flood, drought, wildfire, or unexpected event risk reduction

Metrics: Topical knowledge, studies, projects, lessons learned, plans, projects, and relationships or transactions built specifically to gain understanding or seek to reduce unexpected event risks

- More targeted engineering studies and projects

  Baseline: No water resources and environmental engineers were currently involved in ongoing support of the watershed coalition, Bear Creek Watershed Association (BCWA) activities

  Metric: Increase in engineering involvement, analysis, studies, and projects proposed or funded
- Demonstrate how SNA aids understanding of social structure surrounding nutrient issues

  Baseline: No SNA of any nutrient issues existed or of BCWA relationships and transactions

  Metric: Number of nutrient issues analyzed with SNA and resulting metrics of each analysis, Original and final SNA diagrams of BCWA social network and discussion of related findings
- Demonstrate new statistical analysis insight

  Baseline: Only summer and annual average graphs of data at Bear Creek Reservoir (BCR) are reported

  Metric: Online interactive access to annual and monthly average graphs of each stream station,

  Graphs and hypothesis testing of total phosphorus (TP), chlorophyll-a (chl-a), and correlations with other parameters related to occurrence and magnitude of cyanobacteria blooms over time
- Geographic Information Systems (GIS) delineation of nutrient source issues

  Baseline: No GIS analysis of any nutrient issues by BCWA, only Fire Study derived risk assessment layers and overall onsite wastewater treatments systems (OWTS) count estimates

  Metric: Number of interactive online maps developed in the ACM DSS toolset, significance of derived spatial attributes, and the GIS layers developed for use in preliminary non-point source (NPS) modeling
- Employ multidisciplinary research

  Baseline: Limited literary review and expert consultation had been conducted by BCWA

  Metric: Number of experts and fields examined and literary review references that contributed
- Acquire and incorporate critical new knowledge from non-academic ways of knowing

  Baseline: No formal interview process of all BCWA members and participants had been tested, Limited knowledge base beyond a few policies, technical memos, and annual reports

  Metric: Number of issues and options developed through prolonged engagement process, Number of new policies and other new document types and new document purposes

- Discuss the feasibility of scaling-up preliminary results from the watershed to the basin scale

  Baseline: A single case study was investigated in the context of surrounding watersheds

  Metric: Based on South Platte Basin level research and engagement, list steps required to upscale

- Discuss how this process may be applied to other complex, evolving modern day problems

  Baseline: Phosphorus, as the limiting nutrient of concern, was the focus of this research

  Metric: List how the generic process and toolset could be modified to serve other purposes.

1.5 Research Scope

This dissertation phase of the case study only tested the initial framework for its perceived effectiveness, which shall be considered P*hase I* in an anticipated multi-phase ACM DSS development process. Section 4.1.2 discusses a proposed five-phase (approximately five-year) process supported by a *roadmap* in Appendix A. Exhibit 21 scheduling next steps. Beyond the dissertation, the ACM DSS process is designed and promoted community-wide to continue to expand in scope and utility indefinitely.

This study focused on understanding water-related institutions and organizations as the unit of social network analysis. Options may include additional stakeholders and interest groups over time in order to implement specific community actions. The *roadmap* exhibit also reflects the need for such cooperative expansion in later phases.

Although a watershed-scale nutrient management case study was employed to test and refine methods, the ACM DSS process itself and its performance measures were designed to be more generally applicable to a wider variety of water and environmental management problems at multiple scales. For example, the research included investigation of other Upper South Platte basin watersheds and basin-wide efforts for potential extension of the ACM DSS process. Studying the surrounding context also provided insight for case study options development. Literature review and other watersheds not in the Upper South Platte basin were also consulted to expand options and to improve understanding of recurring resource and regulatory issues. These watershed program comparisons also results in several attributes that set more successful watershed management programs apart from less successful ones (Section 4.4.2).

More than thirty years of BCWA water quality monitoring data and related documents were reviewed. Although this research did not intend to develop additional study data during this first phase, it became necessary to analyze deposited flood sediments following a major flood to demonstrate the principles of adaptive management, as describe in Section 3.4.6 with results described in Section 4.2.4.1 and Appendix D. Exhibit 12. Appendix D also highlights technical and social analysis of other significant nutrient issues. The ACM DSS process revealed several new areas for more targeted research described in Section 4.2.5.

1.6 Professional Significance

This research contributes to the field of water resources planning and management and related disciplines in civil and environmental engineering in several substantial ways. Primarily, it provides a flexible set of online watershed program management tools through the phased, collaborative ACM DSS development process that may be adapted to the specific challenges of other watersheds. Beyond the first phase elaborated through this research, it describes how the process may continue into subsequent phases.

Secondly, it encourages engineers to consider SNA and other powerful tools from the social sciences for their own use in research and practice. SNA revealed how to create flexible, inclusive governance structures to enhance natural and water resources stewardship. The case study effectively implemented prolonged engagement as a research technique to capture community knowledge of water resource issues throughout systems development and to expand this capability into the future. This may improve the prioritization and diversity of proposed improvements towards more achievable benefits. It may also encourage faster implementation of the results of academic research and business innovation as an ongoing feedback mechanism. This research recommends ways to encourage collaborative research across disciplines and institutions, which will be tested in subsequent phases.

Thirdly, the case study investigation of the complex problem of anthropogenic nutrient enrichment and cultural eutrophication provides important insight into the complex nature of this problem and a wider range of potential improvement options. Three quantitative assessment tools: GIS, statistical analysis, and social network analysis were used to analyze time, space, and social aspects of each nutrient issue to enhance shared understanding in Phase I. Results indicated additional research needs upon which to focus in subsequent phases of ACM DSS process development. Results will help determine a wider range of more effective non-point source (NPS) nutrient control options to expand BCWA focus from only wastewater discharge compliance to a more systems-wide nutrient management approach.

Finally, through concomitant development of a *Social Network Analysis Workshop for Water and Natural Resources Management*, this project may also provide a new course of study in Integrated Water Resources

Management (IWRM) education for engineering students in high school through graduate school and for professionals in related practice. By presenting ACM DSS process results to federal and statewide professionals in water, wastewater, natural resources, lake and project management, as well as, publishing in diverse journals and conference proceedings, and making the online tools available for other purposes and scales, results should also lead to improved university extension opportunities.

1.7 Dissertation Overview

Chapter 2 includes key concepts used to develop the research design. Chapter 3 describes how the research goals were implemented. Chapter 4 describes principle results with embedded discussion, since exploratory research is difficult to separate into simplified results and discussion sections. Chapter 5 summarizes findings. All references are included in alphabetical order following Chapter 5.

Appendix A lists the related artifacts developed throughout the ACM DSS process that can be used in future ACM DSS process implementation efforts. Appendix B provides a detailed overview of each tool in the ACM DSS online toolset created, tested, and implemented through the collaborative design process. Appendix C describes the case study. Appendix D details the analytical results of each nutrient issue explored using SNA, GIS, statistics, and relevant research to better define each complex, inter-related problem to plan next steps with greater clarity. Appendix E describes survey results from state professional organization conference presentations, including interest in establishing innovation clusters to address specific knowledge gaps in clustered onsite wastewater treatment systems and in-lake management techniques, as well as a collaborative capacity tool that may be employed in subsequent phases. Appendix F lists GIS spatial data layers developed, EPA BASINS results, and USGS Sparrow DSS results comparisons (USGS 2002).

Dissertation-specific usage of terms is listed in the front matter following the table of contents, tables, and figures. A list of abbreviations is found at the end of the document following the references and appendices.

2.0 LITERATURE REVIEW

2.1 Introduction

Ostrom (2011) defined frameworks, theories, and models as nested behavioral concepts to provide different degrees of problem specificity. Paraphrasing her work, frameworks identify the questions and elements that relevant theories should consider to make working assumptions that can then be tested using various models. This case study explored the organizing principles of the ACM conceptual framework. This chapter explains why specific frameworks, theories, models, and analysis tools were chosen for ACM DSS process development.

2.2 Integrated Water Resource Management

Integrated Water Resources Management (IWRM) addresses water management challenges in the context of the entire framework of other interdependent sectors at the human, social, and global scales to promote social equity, economic efficiency, and environmental sustainability (Pena 2011). Since at least the formulation of the Dublin Principles in 1992, a substantive, participatory approach to water development and management has been cited as a core principle of IWRM (ICWE 1992). IWRM fosters policies, legislation, financing, and incentive structures supported by management tools for assessment, planning, prioritization, and information management to enable economic, social, and regulatory mechanisms for change (Global Water Partnership, http://www.gwp.org/The-Challenge/What-is-IWRM/IWRM-Application/).

A working definition of IWRM considers three different dimension of integration: functional, societal, and institutional (Lubell & Edlenbos 2013); functional integration seeks to coordinate competing uses of water, societal integration focuses on public participation and stakeholder collaboration, and institutional integration seeks alignment among nested and jurisdictional levels of resource governance. As full integration is difficult, functional, societal, and institutional fragmentation often impede IWRM efforts (Lubell & Edlenbos 2013). ACM provides methods that may more specifically implement IWRM at various scales by contending directly with limiting factors, especially fragmentation, as the ACM DSS process shall demonstrate. Figure 1 shows some of the complexities IWRM must address.

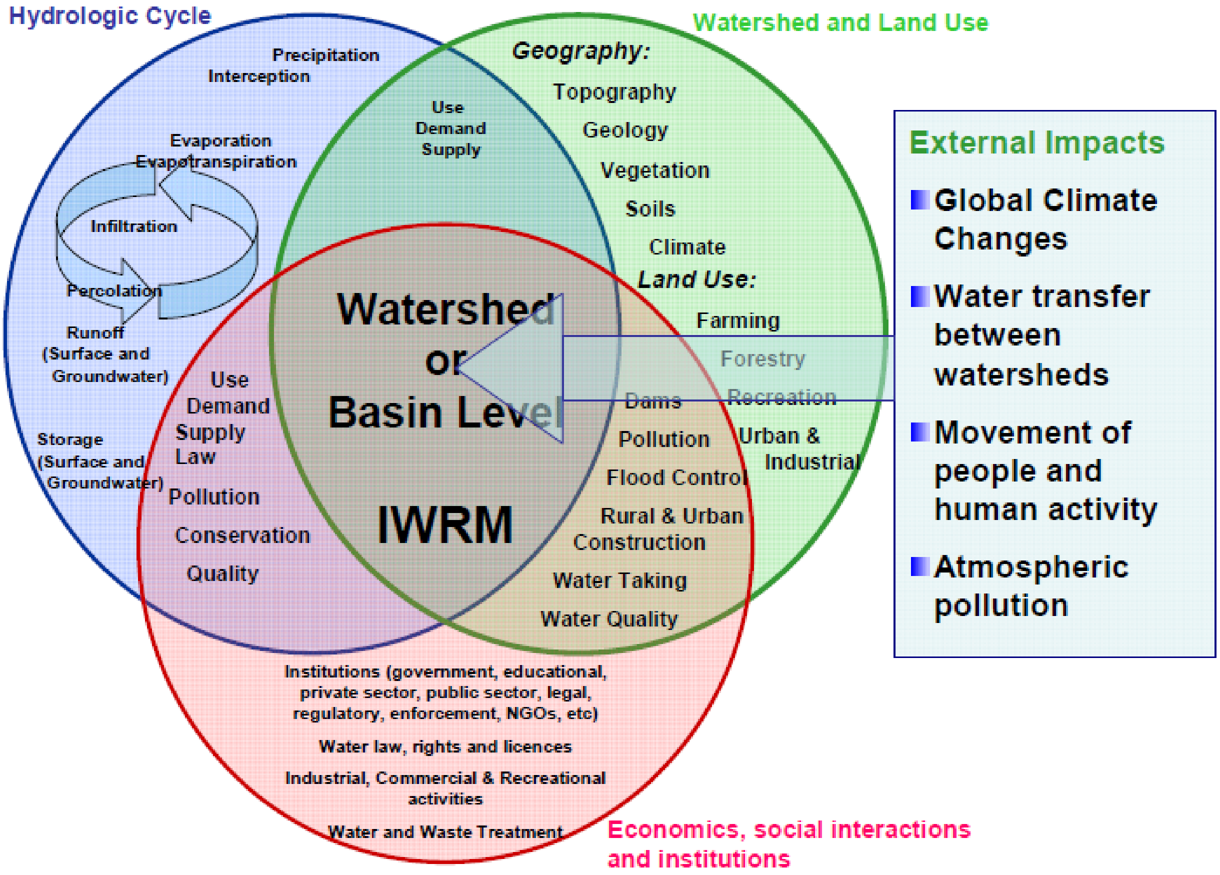


Figure 1. Complex Considerations in IWRM Planning
From United Nations University: *Intro to IWRM* (Creative Commons shared resource)
http://ocw.unu.edu/international-network-on-water-environment-and-health/introduction-to-iwrm/introduction

2.3 Foundations in Adaptive Co-Management

ACM is a complex conceptual framework for implementing IWRM. It includes both adaptive and collaborative theories that are further dissected into several relevant modeling components to use in ACM DSS process elaboration. This research also introduces the concept of resilience in Section 2.3.3 as an integral component of this approach. This level of ACM DSS process design complexity is necessary because of the inherent complexity of the social-ecological systems to be managed as shown in Figure 1.

2.4 Complex Systems Theory

Complex system theory approaches problems through a perspective of multiple, interacting, dynamic nonlinear relationships that are not easily predicted nor controlled (Armitage & Plummer 2010). *Systems thinking* includes processes and interactions that may not be possible to define through reductionist methods into simple variables and feedback mechanisms. It focuses on interactions and amplification among specific component parts to reveal *emergent properties* that are only evident at the systems level (Duru 2013). Such *emergent properties* are scale and boundary dependent and appear to emerge only from the synergistic feedbacks among parts at each nested level of analysis (Daniels & Walker 2001). For example, emergent properties of cultural evolution are new paradigms of knowledge organization and utilization that have enabled humans to alter landscapes throughout the planet over relatively short evolutionary periods (Banathy 2000). Even though systems can be perceived in nested hierarchies in some respects, in other respects, they overlap, and changes at one level may have unexpected effects at other levels. Nonetheless, developing a nested hierarchy of increasing orders of complexity and richness in systems thinking can assist in exploring dynamic processes and scale effects at the appropriate order (unit) of analysis (Sanford 2004). In water resources, at a minimum, systems thinking should consider social and biological interactions, as well as, chemical and physical effects of soil, water, and atmospheric feedbacks.

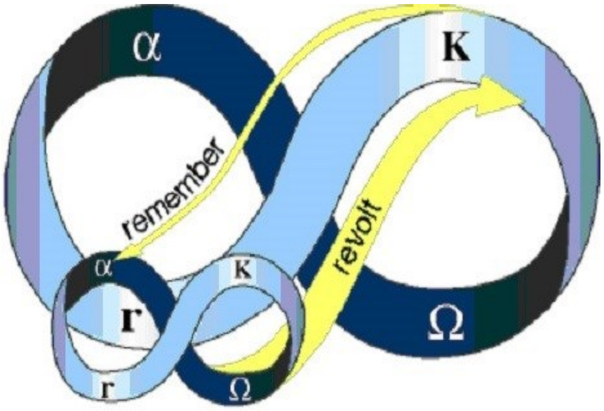


Figure 2. Nested Adaptive Cycles
(used with permission from http://www.resalliance.org/index.php/panarchy)

2.4.1 Adaptive Cycles and Panarchy

A model of an adaptive cycle within a complex system is characterized by a rapid development phase, a typically longer, relatively stable conservation phase, and decay followed by a chaotic reorganization phase of adaption to changes in the socio-ecological-economic setting (Holling & Gunderson 2002).

This model is depicted in Figure 2 as a double-looped curve of development and release. Notice how different scales representing different overlapping systems can intertwine and interconnect in a variety of ways, creating a *panarchy* (Holling & Gunderson 2002b). During the stable, conservation phase, a system may be particularly resistant to change, making it more difficult to ease transition to a new adaptive cycle.

Currently, cultural transmission occurs many times faster than genetic evolution, so focusing on improving flows of information and resources is a proven method of transforming systems today (Banathy 2000). By consciously monitoring critical thresholds and learning to recognize transitional system phases, the ACM DSS process may help watershed program participants more effectively focus on likely options to improve interactions in time and space to promote successful adaption.

2.5 Resilience Thinking

Resilience thinking recognizes that systems are linked, adaptive cycles in time and space impacted by higher and lower scales in the *panarchy* – the myriad, interacting local to global scales resulting in unpredictable change (Holling & Gunderson 2002). Although this case study focused on a single issue – nutrient management at the watershed scale – SNA and other analysis were used to include both federal and state regulatory frameworks, and the overlapping and nested resource management agencies throughout and beyond the watershed that restrict and modulate action opportunities. For this reason, particular attention was devoted to researching how to promulgate what has been learned to adjacent watersheds and to the greater Upper South Platte basin level, and how activities at these scales affected this research.

Resilience thinking also focuses on how to contend with unexpected responses and deep uncertainties such complex interactions generate (Walker & Salt 2012). For this reason, the ACM DSS was designed to continually assess and adjust an entire portfolio of options to address all major sources of nutrient loading, rather than the previous focus on only point wastewater discharges. It also sought to understand political, social, and economic drivers that may be adjusted. By reducing the proximity to dangerous thresholds through a variety of means, while considering variability due to floods and droughts and other stochastic events and trends more directly, over time the ACM DSS process should improve management effectiveness to reduce the deleterious effects of excessive nutrient loading and other undesirable anthropogenic influences throughout the watershed.

2.5.1 Specified vs. General Resilience

Specified resilience includes developing the technical analysis to manage drivers and thresholds discussed in Section 2.4.2. However, often unexpected circumstances and events cause the greatest human-ecological system disruptions. The ability to absorb such unexpected shocks is defined as system *General Resilience*. *Resilience Practice* encompasses human endeavors designed to improve both specified and general resilience systematically (Walker & Salt 2012).

Specified resilience management acknowledges that once a complex system moves from one stable state to another, it cannot easily return, because the driving factors build slowly over time towards a sudden regime shift (Carpenter 1999). Lake trophic status is a prime example of this problem in nutrient management. BCR is eutrophic, and the goal in 1990 was to return the reservoir to a mesotrophic state, characterized by lower nutrient inputs, higher clarity and oxygen levels, and less potentially toxic cyanobacterial blooms (Appendix C-3). Despite reducing nutrient discharges from wastewater treatment facilities (WWTFs) in the 1990's to less than twenty percent of previous levels and installing aerators to oxygenate the reservoir throughout the growing season, BCR continues to exhibit a relatively stable, eutrophic status. The eutrophic regime has likely been exacerbated by increasing watershed urbanization and human effects over time, despite expensive WWTF upgrades and high maintenance costs of ongoing monitoring and control efforts. The fact that the baseline watershed conditions are not static, but rather non-stationary, complicates efforts to improve trophic state (Duarte et al. 2008).

General resilience is addressed by focusing on each event that occurs to develop knowledge and methods to prepare proactively for more extreme or widespread circumstances of that nature in the future. For example, see Section 4.2.4.1, Appendix D. Exhibit 12 for a demonstration of how a September 2013 flood in the case study area led to a variety of adaptive and collaborative measures that may help cope with more extreme events in the future.

Another way to understand general resilience is as an emergent property of a healthy, evolving social-ecological system. The interactions and dynamics among the social structure, the economic scales, and the natural environment are performing in a productive way that does not over-emphasize any aspect that would increase brittle structures than would deter beneficial changes towards evolutionary improvement. A useful analogy may be the social network and environmental factors that allow a human child the health, safety, nutrition, education, and enculturation to become a highly productive member of society. Despite the occasional life setback, the successful adult thrives by a variety of measures. Similarly, a successful watershed program provides the necessary and sufficient conditions to support thriving social-ecological systems. This is the ultimate goal of ACM DSS process implementation.

2.5.2 Managing for Uncertainty

Complexity requires a management approach less focused on command-and-control. Kiker (2012) outlined ways in which the ACM approach to uncertainty differs. He indicates that ACM considers a nested set of vulnerabilities that affect both current and future risks, in addition to shifting human and governance dimensions of the problem. These components are still not sufficient for success, though, if social-ecological system assessment lacks adequate attention to diverse sources and impacts of uncertainty.

Uncertainty is the inability to measure variable processes to project the future. Research in watershed management is by no means a fixed science. Each nutrient source has many physical, chemical, and biological processes interacting that could both be related to root cause, as well as, the emergent properties of their interplay. In other words, driving variables may include complex correlations and attenuating or amplifying feedbacks.

Academic disciplines and their continuous branching into sub-disciplines exacerbate this analytical issue by focusing research resources into limited context, if the resulting knowledge is not reintegrated to address complex systems. It is the goal of the ACM DSS process to attempt to re-integrate more disciplines and *ways of knowing* to improve system understanding of predictable factors. This will help reduce uncertainty to the genuinely unpredictable, rather than arising as much from neglecting requisite knowledge diversity.

2.5.3 Ambiguity Management

Ambiguity management involves coping effectively with the multiple meanings of things. Often no action is taken because of ambiguity, as conflicting research and community values produce opposing courses of action depending on each perspective of system interactions and their relative strengths (Thiry 2011). Shared decision-making cannot be pursued in a complex environment, if even temporary collective certitude to allow action cannot be achieved (Holling & Gunderson 2002). For example, some lake managers apply iron to lake surfaces in an attempt to precipitate phosphorus. Others worry that high iron levels may loosely bind phosphorus, allowing it to solubilize more readily-if sediment conditions should become turbulent or anoxic, thus resulting in an even more unpredictable *internal loading* problem. Ambiguity management uses sense-making and networking to cope with related decision complexity (Thiry 2011). The ACM DSS process is designed to allow participants to develop a sense of shared understanding for this purpose. It also utilizes adaptive management, discussed next, to reduce the risks of uncertain outcomes in decision-making.

2.6 Adaptive Management

Adaptive management is defined as a systematic process for improving management policies and practices by learning from the outcomes of implemented management strategies (Pahl-Wostl et al. 2008). Adaptive management was developed to emphasize managing for the inherent uncertainty in ecosystems described by complex system theory. Actions and polices are considered experiments, because social-ecological systems are too complex to predict outcomes with accuracy; effectively incorporating all relevant factors into decision-making is not possible (Holling 1973 & 1978). Therefore, emphasis focuses on assessment and monitoring of both the decision-making process and action results with ongoing adaptive feedback mechanisms as additional information unfolds (Plummer & FitzGibbon 2007).

By reducing major projects, policies, and decisions into a series of smaller, staged experiments, adaptive management permits ambiguous and uncertain aspects of a problem to be studied to the extent necessary to reach agreement to pursue one or more next steps. The burden of problem solving devolves to many levels and disciplines that can then together reconstruct the pieces into a widely supported, more complex, and nuanced course of action. This incremental, iterative approach may also monitor drivers and thresholds, values and trade-offs, to reduce the risks of unwanted side effects and externalities, while enhancing opportunities for synergy.

2.6.1 Co-management

Co-management is traced to authors focused on its conditions for success (Berkes 1989; Pinkerton 1989). Co-management was developed as an alternative governance structure to top-down bureaucracies in order to manage common pool resources through a formal coalition of linked institutions and organizations with differing roles and responsibilities for the resource at multi-scales (Ostrom 1990, 2005). Governance involves power sharing to make and modify regulations, manage resources, and create policy (Reed & Hubacek 2011).

2.6.1.1 ***Common Pool Resource (CPR) Theory***

Elinor Ostrom won the 2009 Nobel Prize in economic sciences for her research into cooperative, self-organizing commons governed by resource users. She found local Common Pool Resource (CPR) management led to reduced monitoring costs and fewer barriers to information access (Ostrom 2005).

Ostrom (1990, 2001, and 2005) identified eight "design principles" that may lead to self-organizing, more adaptive local common pool resource management:

1. **Clearly defined boundaries**: resources units clearly defined with effective exclusion of external un-entitled parties;
2. **Congruence**: fair rules regarding the appropriation and provision of common resources are adapted to local conditions - institutions *fit* the character of the resource; costs are assigned proportionally in relation to the quantity of resource extracted, used, or diminished;
3. **Collective-choice arrangements**: most resource appropriators can participate in modifying the operational rules governing sustainable resource management or increased enforcement costs or rampant cheating is to be expected;
4. **Effective monitoring**: those monitoring CPR conditions and sanctioned behavior are appropriators themselves or accountable to the appropriators and rule breakers are easily discovered;

5. **Graduated sanctions**: resource appropriators who violate rules are punished relative to the offense and its repetition by the other appropriators directly or by enforcers accountable to the collective;
6. **Conflict Resolution Mechanisms**: cheap, accessible methods to resolve conflicts between appropriators and between appropriators and officials involved in system management exist;
7. **Rights to Organize**: self-determination of the community is recognized by higher-level authorities;
8. **Nested Enterprises**: in the case of larger CPRs, organizations form multiple layers of nested enterprises, with small local common pool resource managing agencies at the base level.

In her later work (Ostrom 2005), four resource attributes (feasible improvement, resource condition indicators, predictability, and manageable spatial extent) and six attributes of appropriators (salience – dependence on resource for livelihood, common understanding, low discount rate, trust, autonomy, and prior leadership and organizational experience) increase likelihood that self-governing associations will form. Ostrom found that positive change would be most likely, if net benefits of resource use in the new system exceeded that of the old system. The gross benefits would thus have to exceed up-front costs of devising and agreeing on new rules, the transaction cost of training and implementation, and the recurring cost of monitoring and system maintenance. The ACM DSS process sought to reduce these three costs to allow benefits to accrue at lower thresholds, thus expanding the range of viable options. However, is should not be ignored that resiliency always comes at a cost, both the direct cost of systems and network modifications, and the indirect costs of opportunities lost, lower system efficiency and yields, needed redundancy, and reserves (Walker and Salt, 2012). Although CPR economic and political theory was built by studying relatively simple, often indigenous, homogeneous systems, this research can be effectively expanded through ACM principles to deal with more complex, heterogeneous systems apparent in the case study.

2.6.1.2 ***Internal Organizational Form***

Related to CPR Theory discussed in Section 2.4.7.2, are complimentary sociological studies in organizational structure that typically correlate with successful natural resources management. Based on local and linking organizational forms studied by Freeman (1992, 2010), Pratt (2010) more fully details how to use the eight principles Ostrom developed for CPR success as criteria for judging ACM:

1. Presence / Absence of distributional share system
    - dependent on fulfillment of organizational obligation,
    - independent of where in system resource access resides or size of appropriator.

2. Presence / Absence of graduated sanctions for common pool resource management
    - appropriators will not contribute maintenance funds if resources are not fairly distributed.
3. Local leadership / Cosmopolitan leadership
    - site-specific knowledge is critical,
    - local leaders have a vested interest in the community,
    - errors are more easily and cheaply discovered and sanctioned locally,
    - local leadership and staff are more responsible to local members,
    - emergencies are dealt with more nimbly as they arise by local managers.
4. High / Low member resource control
    - Local users respond more effectively with local resources under local control,
    - Money is largely kept within the local group rather than sent to higher levels of authority.
5. High / Low member propensity to support local organization
    - Sustenance of democratic rights, due process, and responsiveness high or low.
6. High / Low structuring of linkages between localities and central bureaucratic authorities
    - Power decentralized,
    - Decisions are taken by each organization responsible for each stream segment,
    - No leadership overlap,
    - Conflict is low, autonomy is high, clear accountability,
    - clear understanding of roles and organizational design.
7. Presence / Absence of federal model
    - each organization tier operates its own CPR share system,
    - each organization tier raises own revenues against its shares,
    - each organization tier has own budget to allocate as members wish.
8. High / Low inter-organizational legitimacy
    - each group /tier sees others as legitimate,
    - local management association is still accountable to standards of upstream tier,
    - each tier must monitor and report results upward.

Recognition of these factors for success and what each entails may assist in defining criteria to evaluate options in the ACM DSS process for improving organizational structure for more effective co-management.

2.6.2 Adaptive Co-management

ACM combines the experimental and experiential learning of adaptive management with attention to shared governance structures focusing on horizontal and vertical linkages (Plummer et al. 2012). ACM addresses complex system interactions and uncertainties. Slow, imperceptible, non-stationary trends like increasing global temperatures, unexpected shocks, like regional forest fires, and unexpected evolutionary shifts and other surprises make social-ecological systems difficult to model (Brunch 2009). Technical knowledge, alone, is insufficient to comprehend how any option a community chooses to implement will effect or unexpectedly alter other aspects of a social-ecological system through unaccounted side effects. Instead, all disciplines and stakeholders bring valuable heuristics and non-traditional ways-of-knowing, while producing cooperation and knowledge integration, thus, accruing deeper, broader shared wisdom through time and space and scale (Mostofi-Javid 2011).

In additional to the factors for success shown in Table 2, LoSchiavo et al. (2013) derived five additional lessons from applying ACM for ten years for more systems-focused Florida Everglades restoration. These include:

1. Ongoing funding and support from both legislative and regulatory authorities.
2. Integrating ACM principles into existing institutional frameworks.
3. Establishing pre-restoration ecosystem reference conditions and systems understanding.
4. Characterizing uncertainty and developing management options matrices.
5. Establishing independent review and feedback towards ongoing program improvement.

These lessons reflect important ACM principles that the ACM DSS process attempted to achieve. In particular, this research focuses on providing independent watershed program review (5) to establish systems understanding (3) and to reflect on uncertainties to analyze options with more depth and breadth (4). It also employed SNA to work towards improving regulatory support (1) and collaborative ACM DSS process development to achieve more integration (2).

Table 2. Salient Components of ACM based on Delphi (Plummer & Armitage 2007) and Ethnographic Analysis (Plummer et. al 2012) of Worldwide Adaptive Co-management Theory and Practice

Main Components for ACM Success	**Purpose**
Effective, Local coalition leadership, Organizational / institutional entrepreneurs	Recognize opportunities for change and guide groups through it Coordinate response to change, Ease transitions, Weave network
Shared resource management	Local stakeholders have direct responsibility for managing the resources rather than only external, institutional controls
Social learning, Learning-by-doing	Options are selected and actions are implemented together to build shared wisdom and understanding through experiment
Measuring outcomes, Reflection	Action-oriented monitoring and assessment for better adaption
Improved respect and use of local and cultural knowledge, Emphasis on diversity of opinions	Technical tools and science remain important, but local system understanding and cultural wisdom are also incorporated
Building coalitions and increasing social capital, Increasing communications and trust	More joint meetings, public outreach, contacts, shared vision, shared resources and direct participation in management
Bridging organizations, Brokers	Increase in organizations serving a brokering role linking federal, state, and local agencies and diverse groups and sectors
Institutional arrangements for power-sharing for rule-making and regulatory enforcement	Local organizations and stakeholders have roles in formulating regulations and guiding principles and their enforcement
Ability to solve economic and legal problems	Broad coalition includes economic and legal expertise and links
Actor empowerment, leverage, scope	Stakeholder role expands over time, Users exert influence
Shock resistant, Reduced vulnerabilities	Wider range of diverse actions are considered and actions are implemented to reduce risks and better survive change
Sustainable resource use, Ecosystems health	Reduce ecological fragmentation and increase diversity, reduce over-exploitation, diversify resource dependent portfolios
Appropriate incentives / disincentives	Formal and informal sanctions are developed to improve compliance and enforcement at all scales, places, and purposes

2.6.2.1 ***Social Capital***

The concept of social capital stems from the premise that social networks possess intrinsic value by reducing the costs and difficulty of securing resources, thus increasing economic performance. The norms and trust developed through repeated association at increasing levels of intimacy allows stakeholders to work together more effectively to progressively address more challenges together over time. Figure 3 symbolizes the improved relationships and interactions that ACM may produce, symbolized as a functional machine integrating sectors across the watershed towards shared, complimentary goals.

Guiso et al. (2010) considered social capital too broad a measure, defining *civic capital* as a willingness to cooperate measured as a probability of trust that reduces resource overuse, while improving the ability of a coalition to achieve its goals. By identifying the mechanisms of civic capital accumulation and depreciation, polices may be designed to foster its development and sustainability. The authors also demonstrated that a positive large shock to benefit cooperation can permanently shift equilibrium to a cooperative one – even when the shock is temporary – since values and beliefs have changed, producing long term improvements in more permanent social infrastructure.

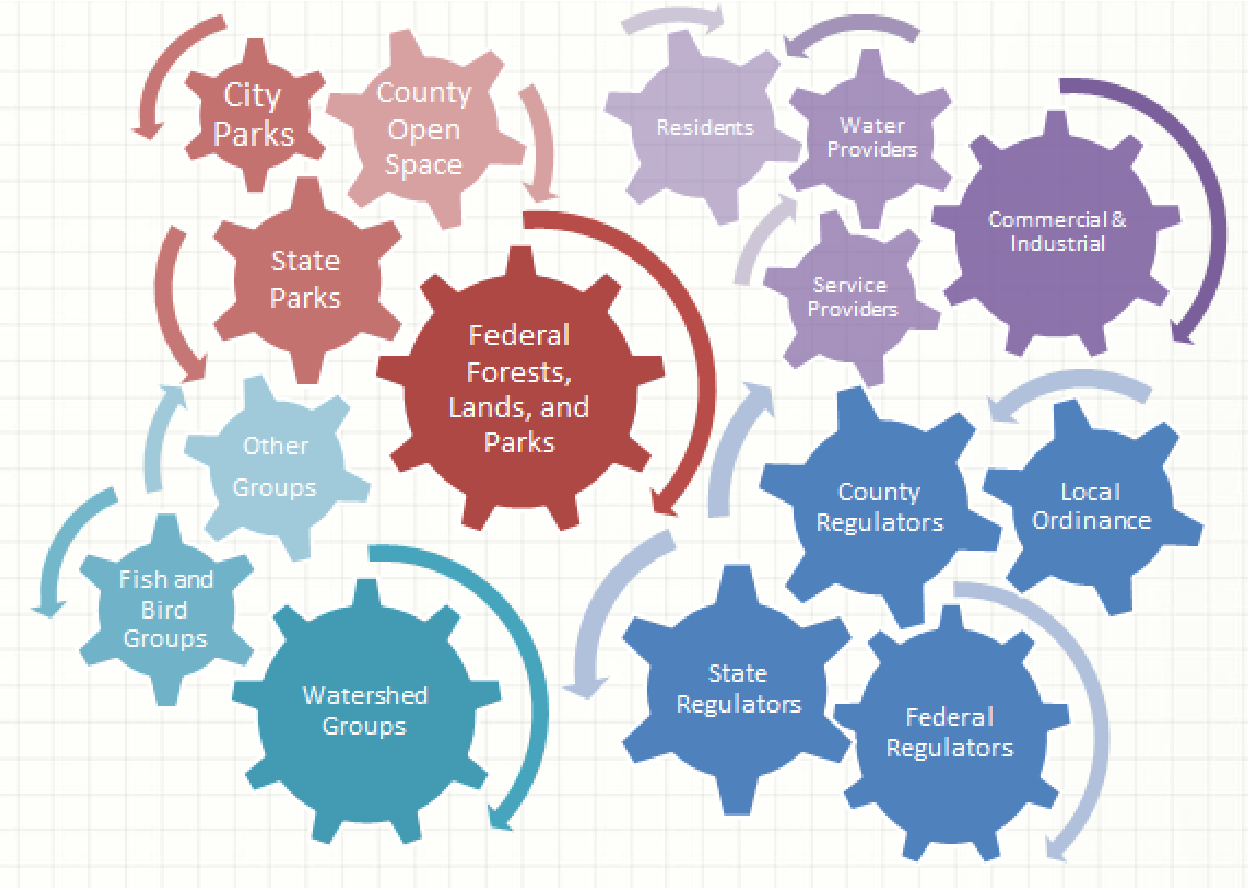


Figure 3. ACM Supports Public, Private, and Non-Profit Sector Integration

Plummer and Fitzgibbon (2007) measure social capital as an increase in bonding and bridging links analyzed through SNA (see Section 2.8.1 and Figure 11). Reed and Hubacek (2011) included advantages derived from network position (SNA measures of centrality), in addition to ratios of bonding and bridging ties in calculating social capital of any particular network actor. In this research, SNA was used to attempt to quantify social capital and related improvement options similarly (Section 2.8, 3.4.1, 4.2.2).

2.6.2.2 ***Social Learning***

Social learning theorizes learning as a feedback process of continual shared experimentation. It also includes choosing subsequent actions based on reflection of which actions performed well or not.

Plummer and FitzGibbon (2007) define five main attributes of social learning:

1. an inclusive, deliberative process;
2. a systems approach to connect humans with their environment;
3. integrating diverse perspectives, knowledge sources, and disciplines;

4. reflecting on collective actions to learn more about system responses to plan future activity better; and
5. double-loop learning, which questions underlying values and assumptions to foster transformation.

Rodela (2012) reviewed ninety-seven natural resources studies that included social learning concepts of experimentation and reflective practice. He found a potential need to integrate different disciplines better and for more emphasis on community-focused monitoring and evaluation of interventions, in particular. To attain these goals, the ACM DSS process is designed to build shared learning, to strengthen a multi-disciplinary academic pipeline to the community, and to promote expansion through the systematic inclusion of additional community groups and institutions over time. This focus should improve the way engineers share complex knowledge through *social interfacing*, which has been repeatedly cited as a primary requirement to improve performance of engineered systems particularly focused on sustainable development through collaboration (Meese & McMahon, 2012). It may help engineers to envision social learning in evolutionary design space, which builds core ideas to consciously set goals and evaluate conditions to apply shared learning in a functional context (Banathy 2000). Although ACM DSS online tools facilitate shared learning, it is important to understand that the ACM DSS *process* recognizes the importance of meetings, activities, and project partnering to negotiate issues across knowledge systems, as Meese & McMahon (2012) found successful collaboratives must develop.

2.6.2.3 ***Adaptive Capacity***

Human behavior, particularly in response to unexpected or extreme events, is reactive to crises. Adaptive capacity, in contrast, is a constant building of theoretical and empirical analysis of the prevailing conditions, incrementally adjusting outcomes to reduce vulnerabilities to recover from shocks and to synchronize with more slowly evolving changes over time (Brunch 2009). Institutions are not typically designed for such adaptive ecosystems governance. Instead, they usually *require reconfiguration* to increase adaptive capacity and to reduce fragmentation through more cooperative alignment with other groups and levels of government. Cheng and Sturtevant (2011) measure collaborative capacity of organizations using factors indicating their ability to organize, learn, decide, act, evaluate, and legitimize in a coalition context. These factors are used to evaluate ACM DSS process success in Section 4.234. Four other factors that may also improve network interactions include recognizing structural problems, building relationships to fill gaps, building ties to knowledge and resources to foster innovation, and having an inspirational facilitator to recharge the network with meaning and purpose (Moore and Wesley 2011). Other factors to increase adaptive capacity may include maintaining evolutionary and complex systems perspectives, learning to live with change and uncertainty, nurturing diversity, combining knowledge types, and increasing self-organizing opportunities to ensure sustainability (Plummer & Armitage 2007, Pratt 2010). A complimentary way to consider adaptive capacity is to measure *absorptive capacity*, which Murray et al. (2011) defines as the capacity of an organization to *recognize the value of new external information, acquire it, assimilate it, transform it, and exploit it*.

The ACM DSS process was designed to focus on capacity building. The facilitator is formally trained in SNA, building, and sustaining practices. The systematic, spiraling engagement process is designed to improve network maturity. Online tools includes a group search tool for continually adding groups by location and type in order to keep track of information, resource, and relationship building opportunities. The knowledge base attempts to make acquired information available to all organizational members, rather than only those who first acquired it, or those attending a particular meeting when it was discussed. The projects, options, and planning tools also focus on generating ideas for new studies from past actions to generate more understanding of social-ecological systems and their uncertainties. New study results provide uncertainty reduction for more effective selection of next steps. The ACM DSS process also encourages more academic review and the inclusion of more professional disciplines in studies and research to improve study design and outcome utility. SNA is used to focus on measuring and fostering collaborative capacity. The spiral model of continual, incremental group expansion ensures that the process remains manageable, while building necessary adaptive capacity that will most directly improve targeted next steps.

2.6.2.4 ***Capacity for Complex Program Management***

In 2014, the Project Management Institute (PMI) developed a guide for managing complexity. It focuses particular on the complexity pertaining to human behavior, systems behavior, and ambiguity in Figure 4 (PMI 2014). The guide provides additional scenarios and mapping tools to navigate complexity in watershed program management, as much as, other complex programs in systems engineering.

Other PMI resources, including the Project Managerment Body of Knowledge (PMBOK) and the Standard for Program Management (PgPM Guide), can help to assess the effectiveness of management capacity in an existing watershed program and offer improvements (PMI 2013 & 2013b). Technical analysis does not often include the importance of management capacity, which often is a key component to determine the ability of a watershed program to meet challenges under growing complexity and uncertainty. The ACM DSS process compares watersheds to develop management evaluation criteria in Section 4.4.

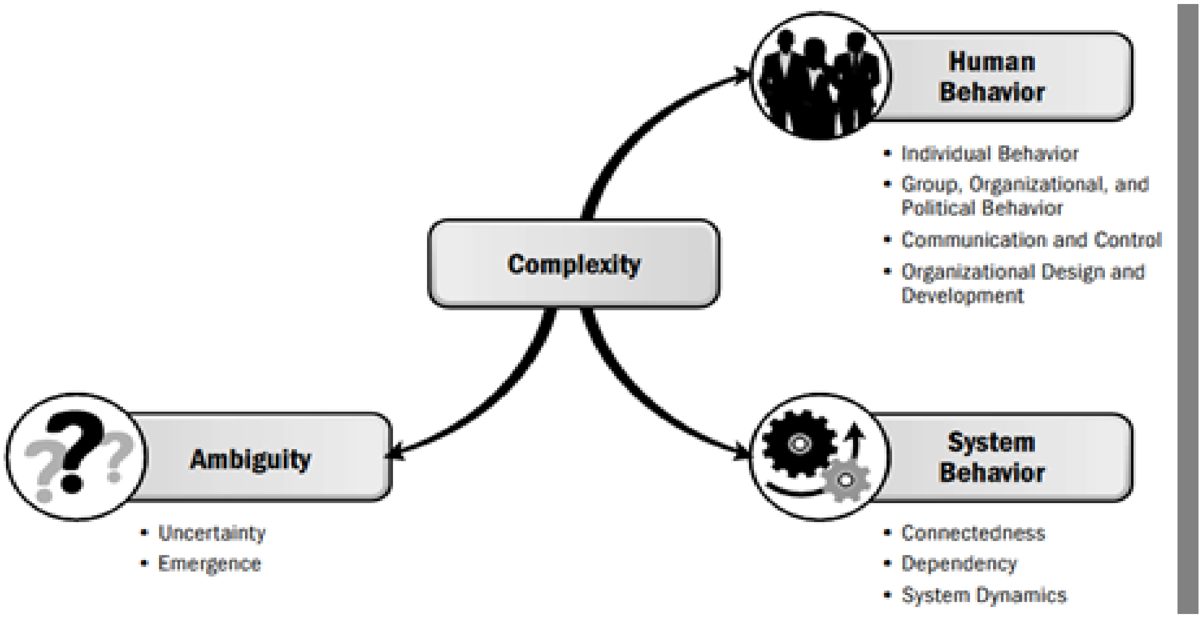


Figure 4. Categories of Complexity and their Causes (PMI 2014)

2.6.2.5 ***Limitations of Adaptive Co-Management***

No alternative management tools and processes represent a panacea, and ACM is not without its detractors. Many efforts to increase adaption and collaboration fail in the face of entrenched value systems focused on extraction, status quo delineations of control, and regulatory inflexibility (Nadasdy 2007). However, metrics should be able to determine if any aspect of the ACM DSS process and its overall implementation can still improve current practice to some degree, while reducing fragmentation. Remaining mindful of common causes for less successful ACM can assist in designing the ACM DSS process to attempt to avoid these issues. Allen and Gunderson (2011) list nine main problems to avoid in ACM:

1. Stakeholders are not substantively included in rule and decision-making.
2. Considering actions as experiments with sufficient evaluation is difficult.
3. Surprises are not embraced as a learning opportunity, but disregarded.
4. Coalitions default to status quo formulas when facing uncertain challenges.
5. Groups tend to exchange and deliberate rather than maintain action orientation.
6. Learning is only worthwhile, if it is applied to improve policies and management.
7. Decision makers are risk averse, preferring not to wrestle with ambiguity.
8. Staid leadership and targeted outcomes are often lacking or one party controls.
9. Planning processes are too time-consuming or results are not effectively enacted.

This list is only a fraction of the issues that can derail effective ACM. However, the ACM DSS process permits progress to be achieved on several aspects of ACM implementation at once, and options can include issues to be addressed as they arise. By focusing continually on achieving small, progressive steps (options), as well as, developing formal projects, the system allows the coalition to gain confidence as smaller, procedural problems and relationship issues are enumerated and corrected. This requires improved levels of trust, since members who express dissatisfaction are often sanctioned by others who benefit from current practices and power structures. However, even if current social structure initially limits freedom to post all issues, having the mechanism to do so in the system and ongoing one-on-one engagement, in addition to group meetings, should permit more diversity of opinion to gain expression over time.

2.7 Decision Support Systems

A variety of research in DSS for IWRM has attempted to support more comprehensive, forward looking decision making, of which a few of many examples follow. A recent evaluation of seven sustainability assessment tools in major developed countries found that they are typically expert-oriented, lacking in local adaptability and participation aspects (Sharifi & Murayama 2013). In 2003, the EPA began developing the SUSTAIN DSS, a simulation-optimization model to evaluate green infrastructure technologies at the watershed-scale, including low impact development (LID) and best management practices (BMPs), but it lacked site-specificity and was difficult to operate and to obtain all needed information (Lee et al. 2012). Community DECISIONS helped a community develop strategies to meet nutrient reduction goals, increasing communications and TMDL planning, but ability to absorb information only during meetings reduced trust, and it did not handle non-technical considerations (Bosch et al. 2012).

Examples that are more successful have a greater focus on stakeholder input and empirical testing. A social multi-criteria evaluation helped compare a degrowth to a pro-growth plan for Barcelona, revealing receptivity to increased rainwater harvesting, demonstrating how DSS can help deal with complexity by determining unconventional alternatives that may still be politically feasible (Domènecha et al. 2011). In another community-based DSS, three models: a farm nutrient budgeting model with local septic tank inputs was used to produce annual nutrient loads, a daily runoff model, and an algal speciation model were integrated to explore alternative eutrophication management scenarios (Norton et al. 2012). An integrated toolset for water quality modeling in the Great Lakes employed a sophisticated multi-disciplinary modeling framework for both *nowcasting* – filling gaps between current observations and forecasting – predicting future observations of lake conditions (Brown 2011). Duru (2013) described an agro-ecological engineering approach to integrate research and field practice knowledge into a shared knowledge system to contextualize and extrapolate knowledge to increase applicability.

2.7.1 Integrated Modeling in later ACM DSS Process Phases

The difference between the first set of less successful DSS compared to the second set of more successful ones included: more participatory input and a greater focus on complex systems and knowledge gaps. The ACM DSS process is designed to provide the foundation for later comprehensive development of more complex, interdisciplinary modeling and management systems.

However, optimization and simulation modeling, though relevant, were too complex and time consuming to include in Phase I of the ACM DSS development process. In the ACM DSS process approach, the modeler must first develop an adequate understanding of the underlying values and direction the community wishes to pursue, institutional and political frameworks, and external factors. The modeler must also first conduct a thorough needs assessment using the previously described analytical tools. Only then can relevant water resources and environmental inputs and outputs be determined to formulate an integrated modeling approach to begin assembling modeling components.

Therefore, a more sophisticated integrated modeling system that adequately reflects the unique social-ecological system complexity of the case study may only be achieved in later ACM DSS process phases. Appendix A. Exhibit 21 demonstrates how Phase I development may be extended to a five-phase ACM DSS staged process, which recommends initiating *Integrated Modeling* in Phase III of development. Based on preliminary results of Phase I, Appendix A. Exhibit 22 diagrams the components the integrated modeling system might include. Patterned after the ACM DSS online system (Appendix B) and its development process (Section 3.3), the Phase III integrated modeling system would also be designed through a parallel collaborative approach. However, the modeling phase would require more academic and subject matter expert participants, in addition to an expanded diversity of ACM DSS Phase I community group participants. In this way, the ACM DSS process does *not* promote complex modeling until community capacity has been adequately developed, exemplifying the rationale for careful adherence to the spiral process of system development described in Section 2.7.2. At that point, the modeler would be better prepared to structure integrative research across disciplines for weaving academic knowledge and tools into the growing system of trusted community knowledge creation (Kragt et al. 2013).

2.7.2 Design Theory

Even though the ACM DSS is systems-oriented, many steps in the process of both ACM DSS process development and designing for the ongoing adaptive learning process itself required simplification, parameterization, and modeling. Unlike theoretical research, social systems design may be considered a multi-dimensional participatory process of disciplined inquiry requiring: *systems thinking, artful design, multiple perspectives, ethical considerations, idealization, creativity, communication, and conversion* (Banathy 1997). After reviewing dozens of models of the design process developed in a variety of fields over the past twenty years that Dubberly (2012) meticulously compiles in his online manuscript *How to Design*, it was found that the ACM DSS development process follows relatively closely to the spiral path model shown in Figure 5.

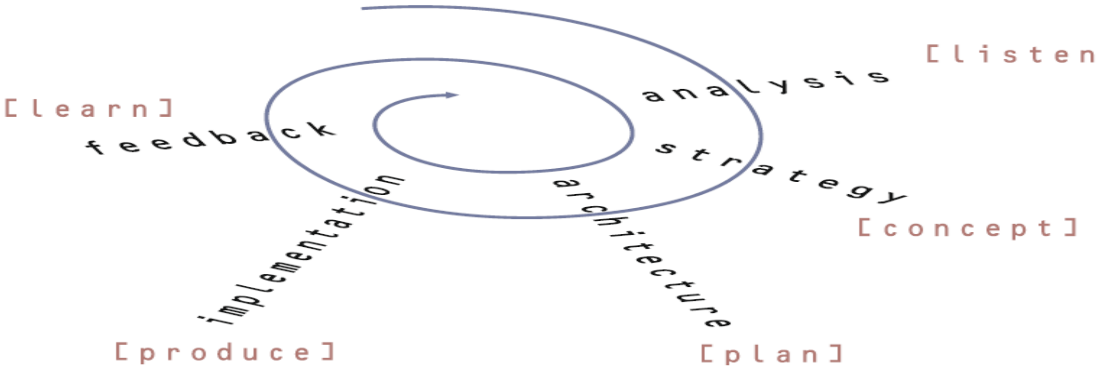


Figure 5. Souza Spiral Path of Repeating Cycles of Design (Dubberly 2012)

The spiral suggests that the relatively messy participatory input and iterative design processes eventually converge to the goal of effective ACM DSS implementation over time. The ACM DSS process spiral model should also be considered to move in an outward spiral towards greater understanding of complex social-ecological systems interactions, while expanding collaboration and participation in each subsequent phase of cooperative development (Figure 6).

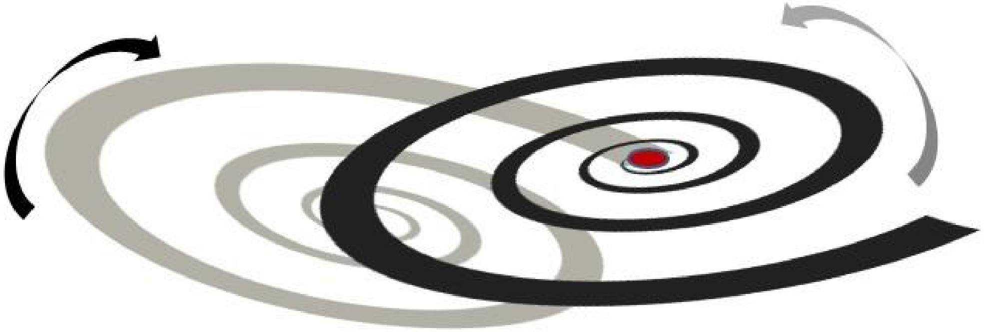


Figure 6. ACM DSS Process Model
(Spiraling out towards more coordinated, concerted efforts while spiraling in towards complex system understanding to improve social-ecological systems interactions incrementally over time with actions interconnected through the online knowledge system)

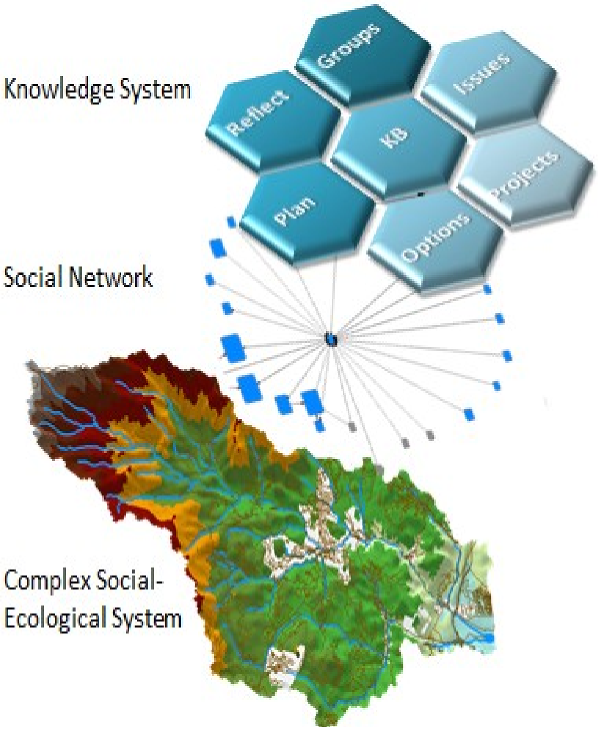


Figure 7. Integrated Systems of Knowledge, Social, and Ecological Processes

Social-ecological systems are complex, as are the human systems in their social networks upon which their future depends. The ACM DSS process must be designed to reflect these relationships and complexity to the extent possible. Figure 7 depicts how this nested structure of knowledge, networks, and social-ecological systems must interconnect. Thus, the ACM DSS process must evolve to serve as a foundation for better managing both human and natural systems by reflecting a similar level of complexity. In other words, the knowledge system must map to the relationships, transactions, and flows in the social network to modulate its structure and permit the participants to interact in ways that provide increasing benefits to the overall social-ecological system and its economic viability.

2.8 Social Network Analysis

SNA determines how entities are organized in relation to one another (Wasserman & Faust 1994). In this research, SNA was used to evaluate existing organizational ties, knowledge and resource exchange, and regulatory frameworks. SNA was employed to assess how the ACM DSS process might improve the structure of relationships, transactions, and flows for improved ACM implementation. Past studies indicate that the presence of social networks can be more important than institutional controls for effective environmental enforcement (Bodin & Crona 2009; Bodin & Prell 2011). Ostrom (2005) explained this phenomenon through game theory as lowering transaction costs, since no longer must an external official attempt to enforce regulations without the local knowledge and relationships needed for uncovering and sanctioning undesirable behavior effectively. Effective exchange is an emergent property of a well-structured network, so systematically evaluating the existing social network to plan targeted improvements is an important way to increase social capital and improve social learning.

2.8.1 Social Network Theory

For the purpose of SNA, relationships and interactions are represented as simple nodes (actor, vertex, or site) and links (tie, edge, or arc). A network boundary defines what nodes and links are included.

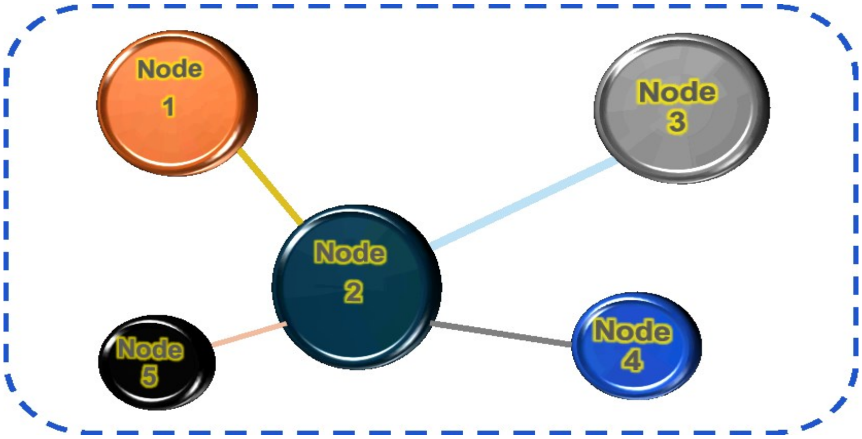


Figure 8. Conceptual Graph of an Ego Network with Four Linked Altars

As an example, the SNA shown in Figure 8 represents an ego network, which depicts a single entity (the ego) and its relationships with others (its altars), in which the thickness of the ties could represent the strength of the relationships and the size of the nodes could depict the relative importance of each entity in the overall network. The dashed line represents the network boundary. In SNA, it is always important to indicate which entities and relationships have been included – and which have not – and how these relationships and characteristics were determined. It is also critical to describe likely errors, as false nodes or missing ties can greatly affect the analysis.

The kernel of SNA is the dyad, two nodes representing two people, organizations, countries, species, etc., which are connected by a link. The link may represent either a relationship (bond) or a transaction (single point in time or continuous flow). The link may be uni-directional (one-way) or bi-directional (both ways), represented by single or double arrows. More than one type of link may also connect two nodes, which can be a particularly effective way to measure strength of relationships. Dyads are used in pairwise relationship studies, such as how different funding relationships affect watershed outcomes.

In addition to the dyad and ego network units of analysis, another important focal point of SNA is triad analysis. A triad is particularly important to organizational research because it is the building block of a social network. An open triad consists of one node that connects to two other nodes that do not connect to each other. SNA demonstrates that networks generally expand by closing these open triads (Prell 2012). This tends to occur because if A is related to both B and C (open triad in Figure 9), A will tend to introduce B and C, and they will begin to interact, as well (closed triad in Figure 9). If not, A may disassociate with B and / or C for not closing the triad, a form of sanctioning. In terms of this study, one way in which an overworked watershed manager might reduce his management burden could be by encouraging organization B and C to work together directly. Then he no longer is required to work as an intermediary. Over time, systematically closing triads can achieve a denser core of principal associations and more outward links to access resources.

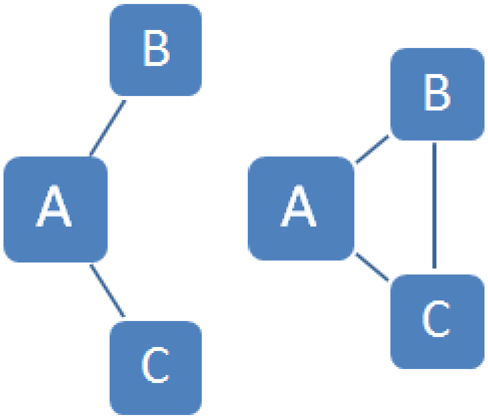


Figure 9. Open vs. Closed Triad

Closing triads helps to create a tighter central core of mutually connected nodes. All nodes that are directly connected to each other through a cluster of closed triads are known as a clique, or more loosely as a subgroup. An n-clique represents a cluster that does not yet possess completely closed triads, but every node is connected to every other node by just a few *hops*. For example, a 3n-clique would connect all members within three links. SNA has led to the important realization that in many situations, there are really only a few choice hops separating one node from almost any other node in the network. This is possible because, even as the number of nodes increases exponentially in the typical population, the average shortest path distance measured in links between one node and any other node only increases *linearly* (Figure 10). This is evident in most social networks due to inherent clustering, which greatly improves overall connectivity compared to random link generators that would produce a more evenly spaced network of nodes and links.

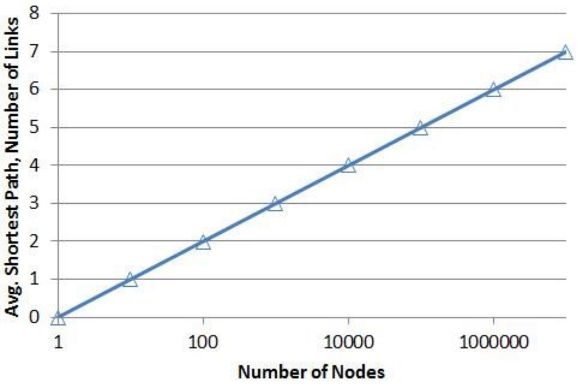


Figure 10. Shortest Path vs. Number of Nodes

This relationship has important implications for watershed management and multi-scaled IWRM. It indicates that by systematically improving even a few key connections between clusters, flow throughout the entire network can be significantly improved. One way SNA can help accomplish this task is by comparing bonding and bridging ties. A bonding tie links members of a subgroup, which was previously noted as already being well connected, allowing the free flow of information and resources. Bonding ties tend to develop particularly among those who share similar characteristics, which is know as homophily (McPherson et al. 2001). In contrast, a bridging tie links members of one subgroup with those of another, or an isolate (disconnected node) to the rest of the network, aiding in the transfer of information between otherwise unconnected network actors. SNA theory can help uncover *brokers*, nodes that play a bridging role, and reveal gaps, where adding a bridging tie between well-connected hubs could greatly increase the connectivity of network overall (Figure 11). It has been postulated that communities with more bridging ties have a greater capacity to organize to address shared concerns (Granovetter 1973 & 1983), though stronger bonding ties may be necessary among organizations to encourage information sharing (Carpenter et al. 2003). Consciously gaining awareness of SNA patterns can help foster both such ties.

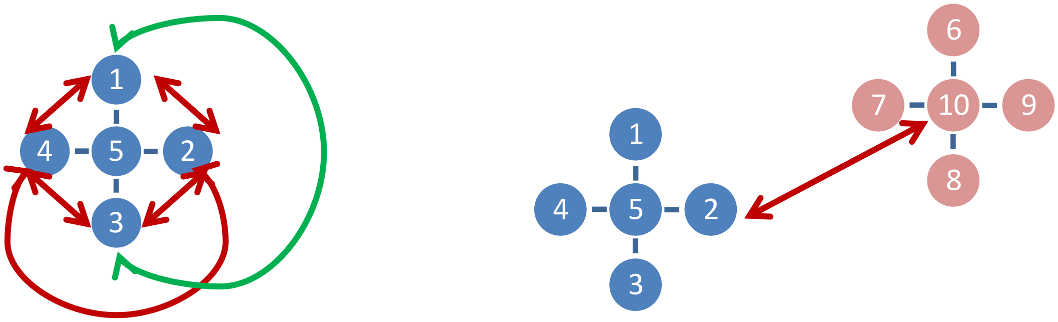


Figure 11. Bonding Tie (left) further connects already associated nodes, while a bridging tie (right) connects otherwise unconnected nodes or subgroups

Building bridging ties does not diminish the importance of bonding ties, though. In fact, the ACM DSS process is based on the strategy of first building strong bonding ties between all BCWA member organizations to enforce cohesiveness and shared knowledge and ongoing learning. A more well-connected BCWA core builds adaptive capacity and collaboration skills to then further strengthen bridging ties with other community groups and government institutions on a regular basis. This hastens network maturity from the hub-spoke stage to the more resilient core-periphery structure by increasing the density of both bonding and bridging ties, which is further discussed in Section 2.10.6.

2.8.2 Levels of Analysis

Bodin and Prell (2011) suggested three levels of SNA: the binary metaphorical approach, the descriptive approach, and the structurally explicit approach. The *binary metaphorical approach* simply determines if network connections between different entities are present or absent, which may be helpful in comparing how successful the ACM DSS process performs in encouraging targeted organizational bonding in Phase I. Analyzing bonding may also help determine which organizations and institutions are already aligned or collaborating effectively and which may need to be more systematically brought into the management or governance context.

The descriptive approach determines if the links are *bonding links* between relatively homogenous entities of the same group, *bridging links* between similar entities from different groups (horizontal linkages), or *linking ties* between two entities from different levels of power and authority (typically vertical linkages from local actors to higher scales in the political hierarchy).

Finally, the *structurally explicit approach* treats the social network more analytically to determine quantitative measures of proximity, centrality, and degree defined explicitly by SNA theory (Wasserman & Faust 1994; Prell 2012; Borgatti et al. 2013). This approach more methodically enumerates and analyzes all nodes and ties within stated boundary conditions and data development method limitations. This approach is most likely to reduce errors in analysis and improve the rate and effectiveness of structural change over ad-hoc methods for network extension and densification. SNA includes agent-based modeling techniques and other tools to uncover patterns, explain outcomes, and help to develop theoretical frameworks to further its utility.

Figure 12 demonstrates some of the network features that can be measured using SNA software for explicit structural analysis. The ACM DSS process uses SNA software to generate many of the measures shown. However, in Phase I, there are so few actors and limited information about each one that calculations may not be of as much value yet as the visualization of the different types of stakeholders and interests involved in each nutrient issue. As each SNA graph grows in complexity, calculations to uncover gaps, clusters, key nodes, and other features will become of increasing importance over time. By including SNA software graphs for each nutrient issue in Phase I ACM DSS process development (Appendix D), SNA updates will be easier to achieve, which is more likely to ensure that SNA will continue to be used with increasing effectiveness in later phases.

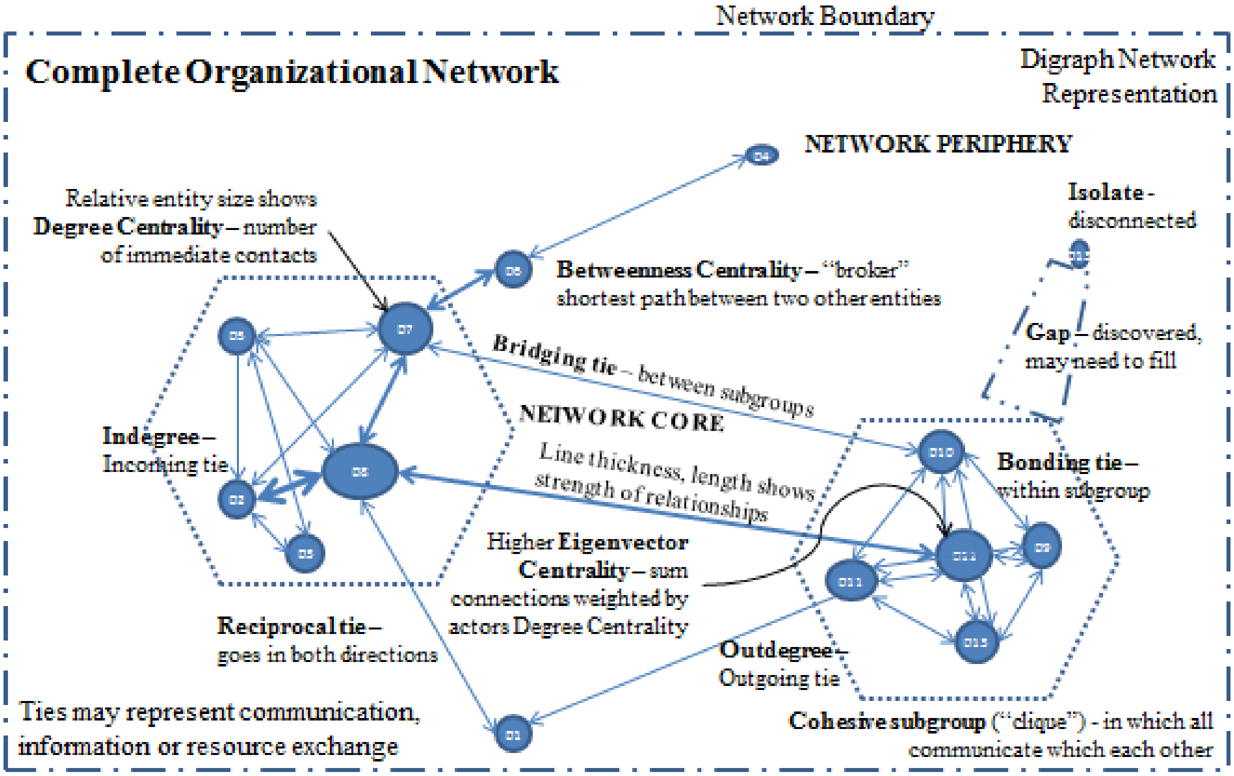


Figure 12. Social Network Analysis Schematic Demonstrating Key Concepts

2.8.3 Affiliation Networks

In addition to SNA using organizations as nodes, organizations can also be analyzed in *two modes* by analyzing coalitions, events, and projects in which they jointly participate to determine network measures. Such *affiliation network analysis* provides three types of structures in two modes of data to consider: organization by event, organizational relations via joint attendance, and relations of events by attraction of common organizations (Wasserman & Faust 1994; Knoke &Yang 2008). Affiliation networks are also known as *two-mode* data, since multiplying the actor-event matrix by its transpose produces one mode of co-occurrences (Borgatti et al. 2013). Ties are synthesized by extent that actors share affiliations, which introduces errors by event size and importance. SNA analysis within the ACM DSS captured organizational affiliations, including project partnering, as a complimentary measure of relationship strength and cooperative capacity.

2.8.4 Knowledge and Resource Exchange Networks

In addition to relationships between organizations or individuals, it is also critical to analyze at the outset, how various organizational actors find, acquire, and internalize new knowledge and information. Knowledge brokering through advanced knowledge bases for storage, search, and retrieval – including the importance of social networks in transferring knowledge – is gaining recognition as a critical research focus, especially at the interorganizational level (Holzmann 2013). Assessing knowledge networks also aids in DSS module design to maximize communication. By linking online portions of the ACM DSS to preferred knowledge supplements derived from interviews, organizational members may increase their usage of ACM DSS tools, thus improving its effectiveness.

Explicit knowledge can be documented and systemized. Tacit knowledge is determined by context and specific actions learned through experience, making it difficult to describe. Cultural and local knowledge, as well as watershed program management skills, are all critical components to managing watersheds well, though their achievement cannot be easily measured (Hordijk &Baud 2011). The ACM DSS is designed to incorporate more tacit knowledge by design, and through social network analysis, turn some knowledge assumed tacit into explicit knowledge that can be codified or at least discussed more broadly. The ACM DSS process also encourages sense-making and networking to develop core values and beliefs in common that may better guide watershed program decisions (Thiry 2011).

2.8.5 SNA Software

Although one could apply ad-hoc SNA theory and research results to improve social network structure, SNA software provides opportunities to more systematically map and manage more complex networks over time. SNA software is effective in visualizing relationships through node and link labeling, coloring, and sizing based on node and link characteristics. It also includes sophisticated functions that can reveal information about the importance of various nodes and ties to the overall structure, including emergent properties. It also helps distinguish cohesive subgroups from less dense areas of the network that may need more attention to improve information flows. There are tools in SNA software to study networks in space and time. In spite of these benefits, most SNA is inexpensive or freely downloadable open-source software. Recently Coursera, a Massive Open Online Course (MOOC) consortium, has begun offering a wide variety of introductory SNA courses free-of-charge. The *Social Network Analysis Workshop for Water and Natural Resources Managers* and the supplementary SNA Workshop website (http://sna.wateractionnetwork.org) with references and links developed as a component of this research is also useful for watershed-specific SNA skills development.

2.8.6 Social Network Maturity Model

Rather than only serving as a descriptive tool, the purpose of SNA in this research, and most natural resource management applications, is to improve the overall network structure in time and space. This includes increasing both horizontal links (cross-sector and between community groups) and vertical links (to connect local, regional, state, and federal governance frameworks) through both bridging and bonding ties. Networks naturally follow a progressive clustering trend in development as they age; however, SNA can help indicate issues in the structure to further improve and speed its development.

To assist in structural analysis, SNA can sometimes be classified into a four-stage maturity model (Krebs & Holley 2006, Zolli & Healy 2012):

1. Small clusters first form by self-organization based on similar roles, location, and homophily.
2. An intentional hub may develop by a network *weaver* focusing on network integration or a naturally developing central cluster of power and influence.
3. More closed triads form through natural network extension processes, or more systematically, as the network weaver teaches others to link to form a denser core and expand bridging ties.
4. Core/Periphery network structure develops as strongly affiliated hubs connect to a constellation of weaker ties for resources and information access from other scales and regions.

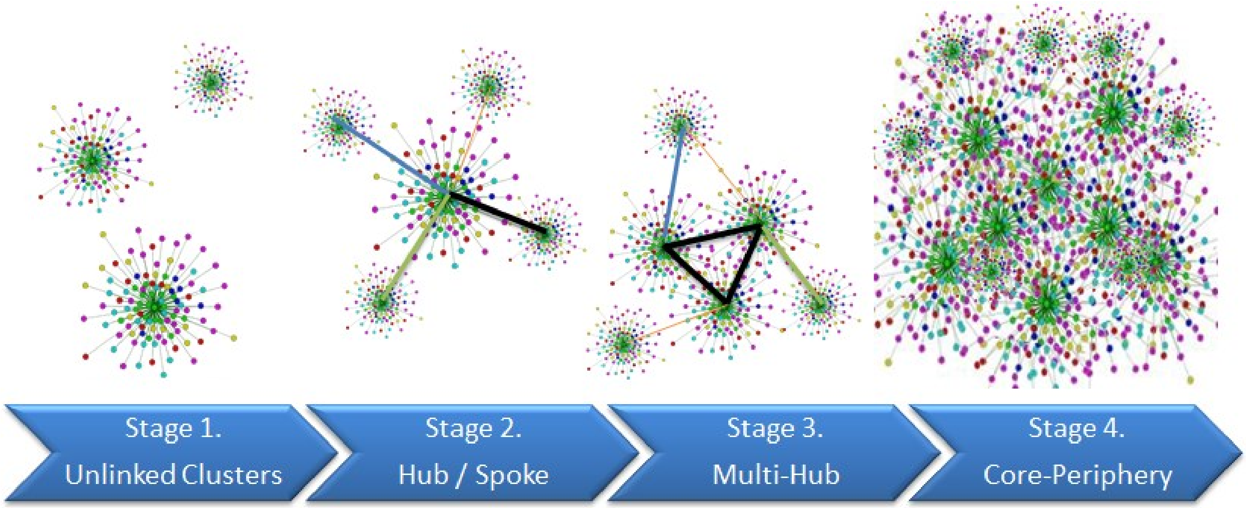


Figure 13. SNA Core-Periphery Structure Four Stage Maturity Model

The term "network weaver" is used specifically to denote the facilitator of deliberate core-periphery structure maturation and the stepwise process is known as "network weaving" (Krebs & Holley 2006, Zolli & Healy

2012). Social network weaving is so named because it parallels the deliberate, fully-absorbed manner in which a spider weaves its web strand-by-strand to create an evolving network pattern.

Healthy network maturity should result in a core-periphery structure as depicted in Figure 13. The dense central core (giant component) includes many redundant connections for multiple paths to information and resources and stable, well-connected relationships. The periphery includes an additional array of resources that are needed less often, but are still adequately connected to remain readily available. There are no obvious gaps in the network that would present an obstacle to network flows. Most real-world networks will not look exactly this way, but the model serves as an ideal to emulate.

2.9 Geographic Information Systems

GIS integrates various data sources as layers into visual products that are identifiable by location on a map (ESRI 2010). Points, lines, and polygons are symbolized with colors, thickness, and labeling to help distinguish relationships among key features. For example, rivers can be represented as lines, lakes as polygons, and wells as points. Grids, also known as *rasters*, are composed of an array of equally spaced cells to show data that has a value everywhere, such as a digital elevation model (DEM) of topography. DEMs can be used to determine watershed boundaries and hydrologic features. In addition to thematic data, like population, grids are also used to represent pixilated images, such as aerial photographs. Images from satellites taken at different time intervals can be compared to detect change. Aerial imagery is often used as a base layer, a backdrop to show how real features appear on the land.

This research used GIS extensively to build interactive maps for the ACM DSS process to improve visualization (Section 3.4.3). GIS was also used to develop input for the EPA BASINS GWLF-E model to estimate the contributions of various nutrient loading sources (Section 3.4.4).

2.10 EPA BASINS GWLF-E Modeling

More detailed spatial analysis of NPS pollution assisted in understanding system complexity and uncertainty. Wastewater dischargers have already reduced phosphorus discharges by over eighty percent with little effect on seasonal TP or chl-a levels or BCR trophic status, which remains stably eutrophic (Appendix C-3). Therefore, it is important to determine other potential sources of nutrients for control to improve BCR water quality to better support all designated uses and watershed-wide water quality.

After reviewing many options, EPA *Better Assessment Science Integrating Point and Nonpoint Sources* (BASINS 4.1) was selected as the modeling platform (EPA 2012c). BASINS 4.1 incorporates several accepted water quality modeling tools and automatically produces some of the needed input data, such as local weather station downloads. Of the tools available in EPA BASINS, GWLF-E was selected as the ACM DSS Phase I screening model, because it directly accepted all the GIS data layers developed, after only requiring attribute additions and modifications to generate mass balance analysis results of relative nutrient loading by source.

In addition to results by nutrient source, GWLF-E also provided results by month and year to compare differences over time based on weather conditions. What was particularly appealing was that the model accepted both horse properties input as animal densities and septic system densities. This permitted direct use of their careful delineation to model their nonpoint nutrient contribution overall, and to verify estimates based on loading factors calculated previously. Point sources, roads, soils, topography, watershed boundaries, and weather data were also used in GWLF-E calculations.

Since GWLF-E was not a routing model, gauged streamflow and sediment transport were not included. However, several models are included in EPA BASINS as extensions, including HSPF, WRMF, and SWAT, which may be used in later ACM DSS process phases of development. EPA BASINS also downloads EPA HUC-8 watershed datasets for model input and provides analysis tools for USGS-supplied datasets. The EPA BASINS Climate Assessment Tool could permit further analysis of climate effects on stationary watershed models. AQUATOX can be used from EPA BASINS to expand contaminant fate and transport modeling, as well (Kinnerson et al. 2009). EPA BASINS is the most accepted watershed-planning tool for TMDL development by both the EPA and state water quality regulatory agencies. This high-level of acceptance of the modeling framework will reduce the burden of regulatory reporting exercises. For all these reasons, EPA BASINS open-source, extensible framework and data-rich resources may serve a variety of BCWA needs well into the future, beyond Phase I ACM DSS process elaboration.

2.11 Statistical Analysis

Resilience Practice requires careful examination of complex causes (Section 2.5.2). Before developing data to use in integrated hydrologic and environmental modeling and to select appropriate software, it was important to begin by developing simple empirical models to gain system understanding. As was found in this research, this exercise may determine that available data and current data collection methods are inadequate to produce necessary model input or even to determine which software tools should be integrated to arrive at desired decisions most effectively. Therefore, statistical analysis is a critical component of the Phase I ACM DSS process to determine drivers and thresholds, correlations, and data needs. Statistical analysis will also help reveal gaps in data, methods, resources, and capacity that will require further study and correction. This important step will help build needed resources and capacity for the watershed program to begin to consider integrated modeling frameworks.

Statistical analysis should only be performed by a highly trained professional. Incorrect data preparation, misunderstanding of the strength or meaning of apparent correlations, or the level of significance of data relationships can mislead subsequent planning and management efforts. It is also sometimes necessary to test an uncertain hypothesis further with additional data collection and study before using preliminary statistical test results as a basis for prioritization or action. Most importantly, ACM is focused on the entire social-ecological system, so important variables that may not yet be collected or considered may be found to be important drivers or system modifiers. For this reason, each action is considered an experiment, which upon assessment, including further statistical analysis, may alter the progression of subsequent choices.

2.12 Creating a Watershed Plan

In 1987, amendments to the Clean Water Act (CWA) established the Section 319 Nonpoint Source (NPS) Management Program to provide federal leadership for NPS control at the watershed, state, and river basin scales (EPA 2012). Ever since, the EPA has taken a leading role in developing IWRM for water quality from the watershed to the river basin scale, with increasing support from federal land management, agriculture, energy, and water management bureaus; states, tribes, and local government utilities; and watershed-related groups. Each state must determine which surface and ground water resources have been impaired and prioritize collaborative assessment and an integrated, adaptive approach to improve management (EPA 2012b). Advanced watershed programs may develop Total Maximum Daily Loads (TMDLs) that include numeric limits on all point and NPS contributions and a margin of safety that should ensure adequate watershed protection. When TMDLs have not yet been developed, the EPA encourages states and watershed groups to develop watershed plans to reduce pollutant loading that causes water quality threats and impairments (EPA 2004). The watershed planning process includes: building partnerships, characterizing watershed issues, setting goals and identifying options, designing an implementation program, implementing the plan, measuring progress and making adjustments, and improving the planning process over time (EPA 2008). A watershed plan must include six required components focusing on water quality as shown in Figure 14. Through this watershed planning process, EPA also emphasizes protecting threatened waters from changing land use, fragmentation, and degradation, rather than simply focusing on restoring those that are already impaired (EPA 2003).

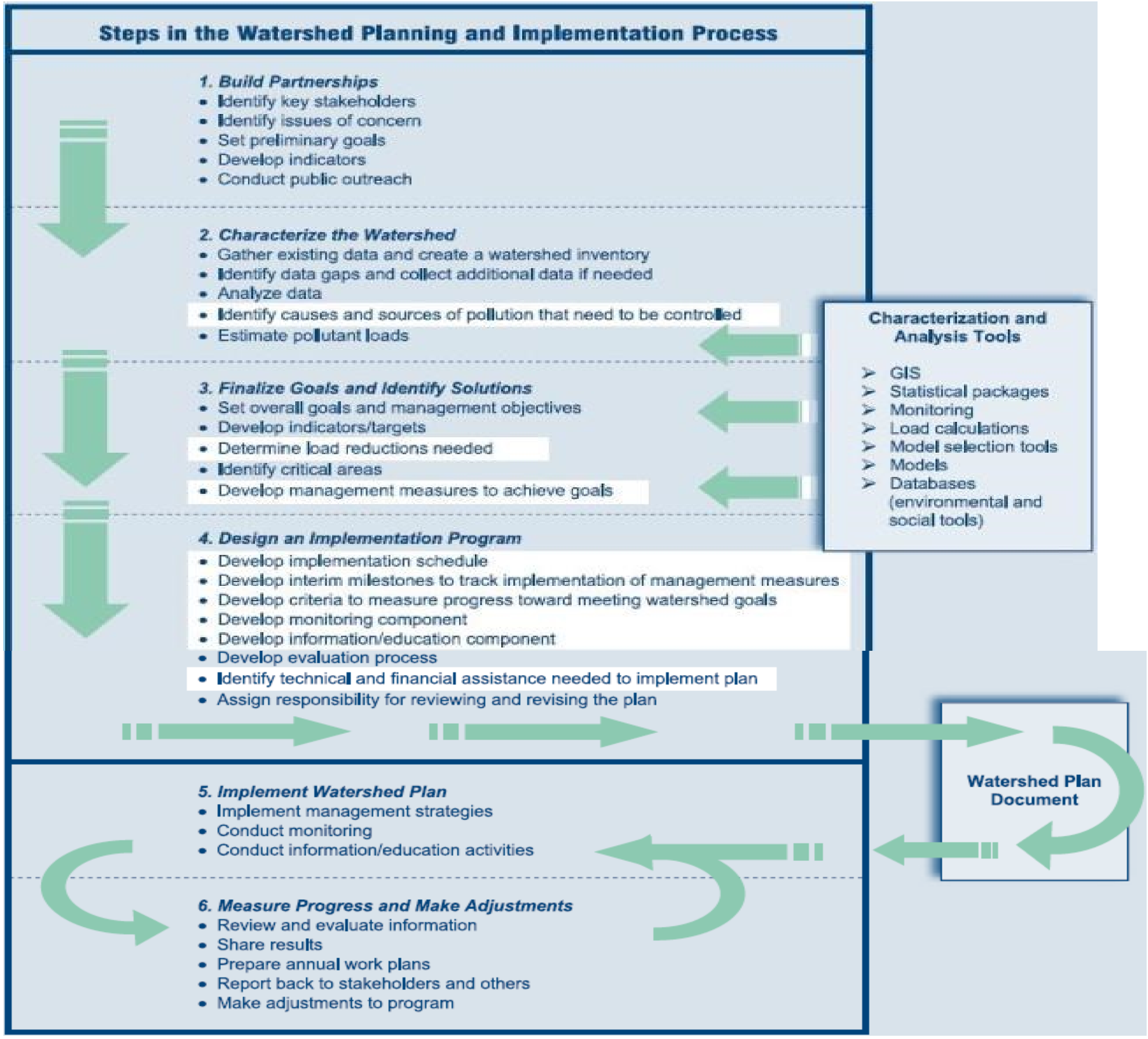


Figure 14. EPA NPS Program - Six Watershed Planning Steps (EPA 2008)

2.12.1 Rapid Biotic and Ecosystem Response

The current EPA watershed planning process emphasis seems to align with recommendations for a community-based, ecosystems-based watershed restoration approach called the Rapid Biotic and Ecosystem Response (RBER), as developed in *Entering the Watershed* (Doppelt 1993). This systems approach to biodiversity focuses on integration of conservation biology, ecosystems science, and geomorphic processes to:

1. Identify, protect, and secure existing healthy eco-diversity in the riverine-riparian landscape.
2. Reconnect fragmented landscapes, focusing on protecting watersheds from the critical headwaters on down, and other measures to integrate already resilient systems, rather than first remediating environmental disaster sites that cannot be easily returned to an eco-functional condition.
3. Only after remaining biodiversity is secured and consolidated should priority shift to *grubstake habitats* – urbanized and commoditized river valleys for which challenges, costs, and restoration periods will be greatest, but which may yield overall benefit in later stages (Dopplet 1993).

The ACM DSS was designed to provide input to the nine-point watershed nutrient-focused water quality plan that meets the EPA NPS program guidelines. It employs the Colorado Nonpoint Source Program watershed plan outline, which meets these EPA goals, as well as, state regulatory requirements to allow results to be submitted to a variety of programs to secure needed funding. Options also attempted to include the three-stage priority RBER approach outlined.

2.12.2 Lake Management Planning

The Lake Management Plan outline employed in the ACM DSS online toolset is based on the Colorado Lake and Reservoir Association (CLRMA) 2012 Lake Management Plan Guidance document, and other state and national sources. The reason both a Watershed Plan and a Lake Management Plan format were needed is that they represent different scales and focus. The watershed plan focuses on watershed-wide point and non-point nutrient source control and other related watershed issues. The lake management plan concerns inputs and outputs and mechanisms causing EPA Section 303(d) listing for both TP and chl-a exceedances at BCR itself that cause eutrophication and other concerns that may affect its recreational and indirect water supply uses (Appendix C-6).

3.0 METHODOLOGY

3.1 Introduction

This chapter describes how the conceptual frameworks, theories, methods, and tools discussed in Chapter 2 were incorporated into the research. It explains how the ACM DSS process was developed collaboratively with the watershed stakeholders. Appendix A lists all artifacts generated that may be used in subsequent ACM DSS process implementations in other watersheds or adapted for other scales or purposes. Appendix B provides details of the online ACM DSS toolset developed through the collaborative process. Appendix C describes the BCWA case study in detail.

Research methods served both exploratory and formative purposes. The problem of watershed-level nutrient management is replete with uncertainty and ambiguity related both to the natural processes and the valuation assigned various causes and effects by diverse individuals and groups (Section 2.5.2 and 2.5.3). Water resources engineering research typically focuses on later phases of design and optimization, allowing others to define assumptions and constraints without probing their efficacy. However, by first demanding a deeper, broader understanding of complexity inherent in the social-ecological environment and its interactions, the ACM DSS process may reveal more dimensions of the problem to enhance specifications for subsequent engineering studies and mitigation projects. In essence, the case study community is materially involved in each step of formative research development, so that an engineering design mindset is better understood and accepted as a component of future visioning and problem unfolding efforts.

3.2 Sequence and Elements of the Research Process

As the research focus was to generate greater systems-wide understanding, a mixed-methods approach took advantage of the strengths of both qualitative and quantitative research methods. Qualitative methods to observe, question, and participate were expected to provide deeper comprehension of the many perspectives on watershed issues and options and a wider range of possibilities for improving adaption and collaboration. Quantitative methods were equally important to focus BCWA members on actual quantities, locations, densities, significance, and interactions among nutrient issues and potential factors that could be controlled to reduce negative impacts. Newing et al. (2011) notes that complex social-ecological systems are being increasingly studied using mixed-methods approaches to achieve such complimentary insights. Without using both methods iteratively throughout the research period, many critical features would have been missed that ensured a more effective ACM DSS facilitated process, more useful analytical results, and a more functional online toolset.

The ACM DSS research and development process consisted of an acclimation period in which the engineering facilitator gained familiarity with the watershed program and issues followed by a period of qualitative assessment and ACM DSS process and toolset collaborative development. Meanwhile, quantitative techniques were used to assess watershed nutrient source issues and needs of the overall watershed program.

The methodology of the research included the creation of a series of online support tools for watershed program decision-making to be used in a phased collaborative process employing the research engineer as the ACM DSS process facilitator. The central research question was whether the ACM DSS process may improve adaptability of watershed-based program management and expand shared governance. This question was explored through development of an interactive online system built collaboratively and tested by BCWA and watershed-wide organizational participants to determine its effectiveness in furthering ACM principles.

Online system components are detailed in Appendix B. The toolset developed as Watershed Online (http://bc.wateractionnetwork.org) illustrates a sequence of interactive tools that are designed to facilitate user-involvement. Tools include: issues reporting, data viewing, interactive maps, group, location and topical search, projects and options tracking, and watershed and lake plan input.

Technical tools were used to assist participants in developing coupled social-ecological systems knowledge, and a greater understanding of remaining uncertainties and ambiguities. Statistical analysis of existing monitoring data was used to study watershed response and water quality trends. GIS was used to delineate nutrient sources spatially to enable visualization and modeling of areas of concern and changes in land use management. Social Network Analysis was used to probe the nature of the social structure surrounding each nutrient management issue defined through interviews and the engagement process.

3.2.1 Characteristics of an Effective Case Study

The research design employed a case study in context, which is detailed in Appendix C. Analysis included the historical context of the watershed, water rights and other site-specific factors, and the history of flooding and construction of the terminal BCR flood control reservoir, which became the focus of nutrient management. Two types of comparative analysis was used to situate the Bear Creek Watershed among its surroundings: studying the six watersheds in the Upper South Platte Basin (including Clear Creek, Cherry Creek, Upper South Platte, Barr-

Milton, Chatfield), and four watersheds with similar Colorado Dept. of Health and Environment (CDPHE) Water Quality Control Commission (WQCC) Control Regulations to reduce nutrient loading in terminal reservoirs (Dillon, Cherry Creek, and Chatfield). Bear Creek, Cherry Creek, and Chatfield Reservoirs are operated as the USACE Tri-Lakes unit to protect the City of Denver from catastrophic flooding. Cross-scale analysis included studying zones of different wastewater treatment providers and OWTS areas, population densities, and landscape-based issue differences throughout the watershed. At higher scales, overlapping jurisdictions, and basin, state, and national scale cumulative nutrient impacts and related regulatory structures were considered.

Appendix C describes the Bear Creek Watershed Association (BCWA) in detail, which served as the case study group to demonstrate development of the ACM DSS process applied to watershed-level surface water quality management. BCWA focuses particularly on monitoring nutrients throughout the watershed. WWTFs serve shopping centers, housing developments, whole towns, or multi-city areas. Small dischargers serve a single campground, hotel, restaurant, or business, but are still regulated under federal programs, if they have potential to discharge more than 2,000 gpd at peak capacity. WWTFs are most affected by tightening regulations and greater monitoring requirements, whereas small dischargers are most affected by having to fund and manage a small treatment facility that does not contribute to their main business. WQCC Regulation 74, the Bear Creek Control Regulation, sets exceedance limits of 32 ug/L TP as the assumed primary limiting factor to cultural eutrophication and 10 ug/L chl-a as a surrogate for cyanobacteria concentrations in BCR. Appendix C-6 describes other regulatory details for context.

It is not possible to conduct an effective watershed-level case study without carefully considering program organization and practices within the context of surrounding watersheds. These regional comparisons provide enough clues to best practices and routine methods that results should be less confined to the single case study, representing a certain level of consensus and transferability. Such a case study method also allows more process-oriented, cross-disciplinary system analysis (Burian 2001). Case studies in IWRM have also demonstrated how lessons learned to enhance institutional and legal reforms can be applied to similar water issues in a variety of settings (Bindra et al. 2014). Contextual study can better determine impacts of the ACM DSS process on the case study watershed considering the six surrounding ones in the same basin as controls. Broader-consensus watershed program practices also informed the ACM DSS process development by demonstrating limitations to current

BCWA performance. Section 4.4 generates results from Upper South Basin watershed program analysis into a list of generalized success factors to maintain broader focus on watershed program essentials.

The ACM DSS process was based on theoretical and conceptual frameworks, theories, models and tools discussed in Chapter 2, to provide a research-based replacement to ad-hoc, slower-paced, less-complex watershed program development. Outcomes were to include a structured, repeatable process and a generic online toolset that could be applied to other watersheds, scales, and resource problems, while simultaneous analyzing complexity of nutrient issues that had not been sufficiently mitigated through a regulatory focus on wastewater point source controls.

3.2.2 Unit of Analysis

The unit of analysis for the case study was organizational members and participants of BCWA, which consists of point wastewater and stormwater dischargers represented by cities, counties, water and sanitation districts, and a few commercial facilities (listed in Appendix A. Exhibit 1. Table A-1). A few additional organizations also participated to a more limited extent, including federal, state, and local nutrient regulators and public landowners, BCWA participants and project collaborators, and others listed in Appendix A. Exhibit 1. Tables A-2 & A-3. No individuals representing themselves were interviewed or otherwise consulted, and no personal information about organizational representatives was recorded. This helped reduce risks to human subjects (Appendix A. Exhibit 3).

3.2.3 Participatory Initiation Phase

In September 2013, the BCWA manager was contacted, who indicated tentative interest in encouraging BCWA to serve as the case study group. This was followed by data and communication exchanges to become more familiar with the BCWA watershed program for nutrient management. The engineering facilitator began to attend all BCWA board and technical review session (TRS) monthly meetings. All meeting discussions were typed as spoken to capture information in context, though no names were recorded for confidentiality. The engineering facilitator also participated in sediment and water quality sampling at BCR and in a few other monitoring activities to become familiar with actual data collection methods.

By waiting nearly six months before beginning interviews, the engineering facilitator was able to first gain greater understanding of the role of each BCWA member organization in nutrient management. This increased the specificity of the interview questions that could be asked of each member organization based on their prior participation in meetings and events. Additional time in document and website review and data analysis also provided key information to improve the value of each interview experience.

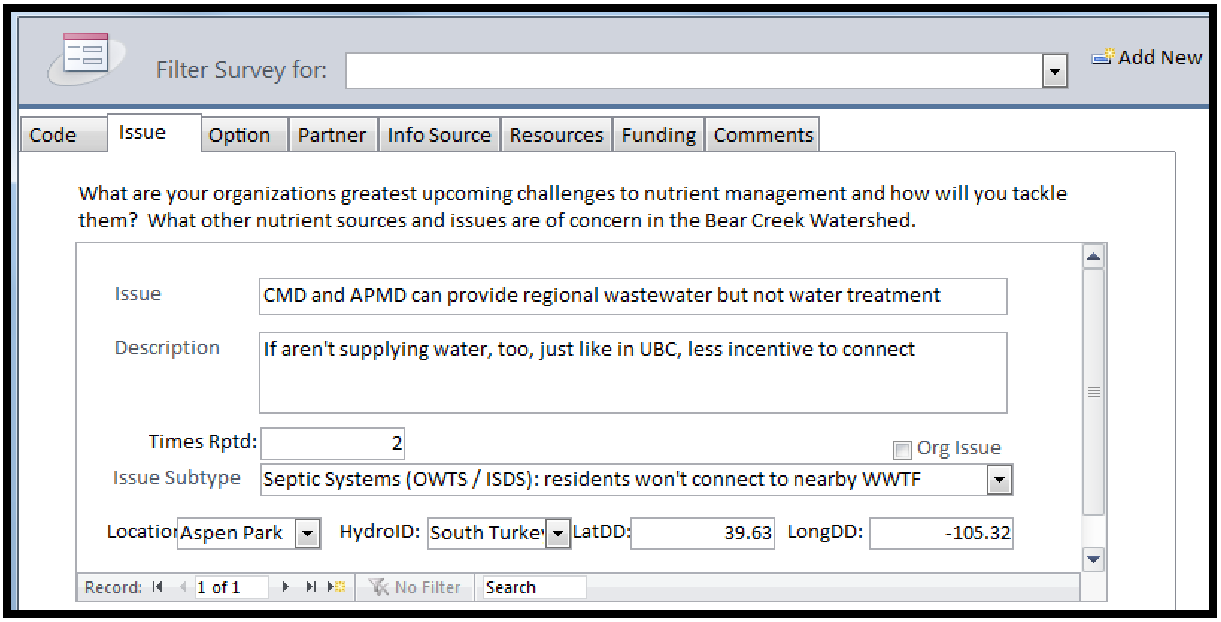
3.2.4 Interviewing Procedures with Ethical Considerations

The ACM DSS process pre-design interviews consisted of semi-structured questions that were gathered as unrecorded, typed shorthand dictation of spoken responses of each organizational representative. DSS pre-design semi-structured questions are listed in Appendix A. Exhibit 6. Additional questions were asked based on prior findings related to specific interests and concerns or each organization in particular.

From the interview notes, specific information was recorded related to:

- Sources of nutrient loading and related watershed issues.
- A range of improvement options to reduce nutrient loading.
- Organizational project partnerships, events, and other documentable ties to other organizations and efforts in the watershed and at both higher (multi-county, basin, regional, state, federal) and lower scales (within their district, county, or city, and among other local groups).
- Organizational sources of funding and project partnerships, volunteers, sources of information, and resources.

This data was entered into a multi-tabbed form developed in a Microsoft Access 2010 database for coding and categorization including: data source, issues, options, partners, information sources, resources, funding, and unclassifiable – but potentially important – comments (Figure 15). Reviewed documents and information gathered from attending both local and statewide water-related events were also included in the database using the same forms.



What are your organizations greatest upcoming challenges to nutrient management and how will you tackle them? What other nutrient sources and issues are of concern in the Bear Creek Watershed.

Issue: CMD and APMD can provide regional wastewater but not water treatment

Description: If aren't supplying water, too, just like in UBC, less incentive to connect

Times Rptd: 2

☐ Org Issue

Issue Subtype: Septic Systems (OWTS / ISDS): residents won't connect to nearby WWTF

Locatio Aspen Park HydroID: South Turke LatDD: 39.63 LongDD: -105.32

Figure 15. MS Access Database Data Coding and Categorization Form

Before an interview, each organizational participant was provided with the *Research Study Summary* from Appendix A. Exhibit 3. The summary clearly explained, per Colorado State University (CSU) RICRO Human Subject ethical standards, exactly how the information was to be used with strict confidentiality considerations. The participant also had the opportunity to ask additional questions of the engineering facilitator both before and after the actual question-set was completed. They were also specifically asked after each interview if they were comfortable with the purposes for which the information would be used.

The engineering facilitator who conducted all interviews and interactive activities completed CSU's *Human Subjects Protection* training (certificate is provided in Appendix A. Exhibit 4). The importance of ethical use of human subjects cannot be over-emphasized. The ACM DSS process is designed to be of ongoing utility to the BCWA for nutrient management and for continued development of the watershed program over time, so building trust and confidence during Phase I implementation was extremely important. By putting in place appropriate controls upfront, there were no known ethical complaints from any of the dozens of organizational participants involved throughout this research.

Although an organizational number was used to associate some interview responses with the organizational respondent in case clarification was necessary, reported summary statistics and findings were compiled from all data irrespective of which research method and source it initially came from to reach consistent, triangulated conclusions.

3.2.5 Post-Design Interviews and Survey

Organizational exit interviews were conducted after Phase I ACM DSS process development had been completed to evaluate how satisfied the participants were with the process and results. A list of Exit Questions is found in Appendix A. Exhibit 7. One question asked if this process built a greater understanding of nutrient source contributions and expanded options for improvement. Another important question was if the ACM DSS process should be further developed for continued use for nutrient management or expanded purposes. Exit interview results were further verified by asking many of the same questions in a confidential survey at a BCWA Board Meeting on 12/11/13 with a point scoring system based on degree of satisfaction or agreement (Appendix A. Exhibit 8).

3.2.6 Ongoing Feedback

If interview results left important questions unanswered or more detail was needed, organizations were contacted for more information; clarification was often conducted face-to-face before or after regularly scheduled BCWA meetings. This feedback process helped ensure maximum understanding of organizational participant needs and plans and the structure and strength of social network relationships, processes, and flows.

3.2.7 Other BCWA Participation

On an ongoing basis, before and / or after regularly scheduled meetings, the BCWA manager also provided additional clarifying information on BCWA policies, documents, and institutional memory. In addition to attending some stream monitoring and lake monitoring, the engineering facilitator also received a flow meter from BCWA to make rough estimates of flow on ungauged tributaries for modeling purposes. By March 2013, the engineering facilitator also began to serve as the BCWA educational coordinator. In this capacity, the engineering facilitator attended all educational seminars and workshops in which BCWA was involved. This provided an opportunity to understand how the watershed group represented itself and water quality issues to the public. It also provided opportunities to discuss the watershed in depth with BCWA member organizations and to learn public perceptions.

3.2.8 Upscaling

The ACM DSS process is particularly applicable to nested systems, allowing what works well at the watershed scale to be reproduced in adjacent watersheds, and possibly integrated into a basin-wide framework. Interviews with managers of each of the surrounding watershed water quality authorities were conducted during the pre-system development interviews to improve the range of options, as well as further consider scaling issues and needs. This allowed the larger basin to be included in the SNA as a knowledge source and social learning link to

BCWA. This additional layer of exchange and collaboration both improved options to consider for local improvement, as well as setting the stage for better basin-wide integration later (Bodin & Prell 2011). It was also critical for context and to evaluate watershed performance and management options among various watershed programs that are discussed in Sections 4.4.

3.3 Participatory Planning and Online Systems Development

Development of ACM-DSS online tools for watershed program management began with needs assessment for systems planning, which was incorporated into BCWA member interviews. Several research techniques were used to validate and verify the information collected:

- Review of watershed group members' websites and documents.
- Attendance at all watershed group meetings from late September 2012 through 2013.
- Involvement in watershed group monitoring, education, and / or project activities.
- Interviews with each member organization of the watershed group.

Based on research, an initial online systems design process schematic was developed (Figure 16) and used to create a Fact Sheet (Appendix A. Exhibit 2) to generate interest in deeper participation among BCWA members.

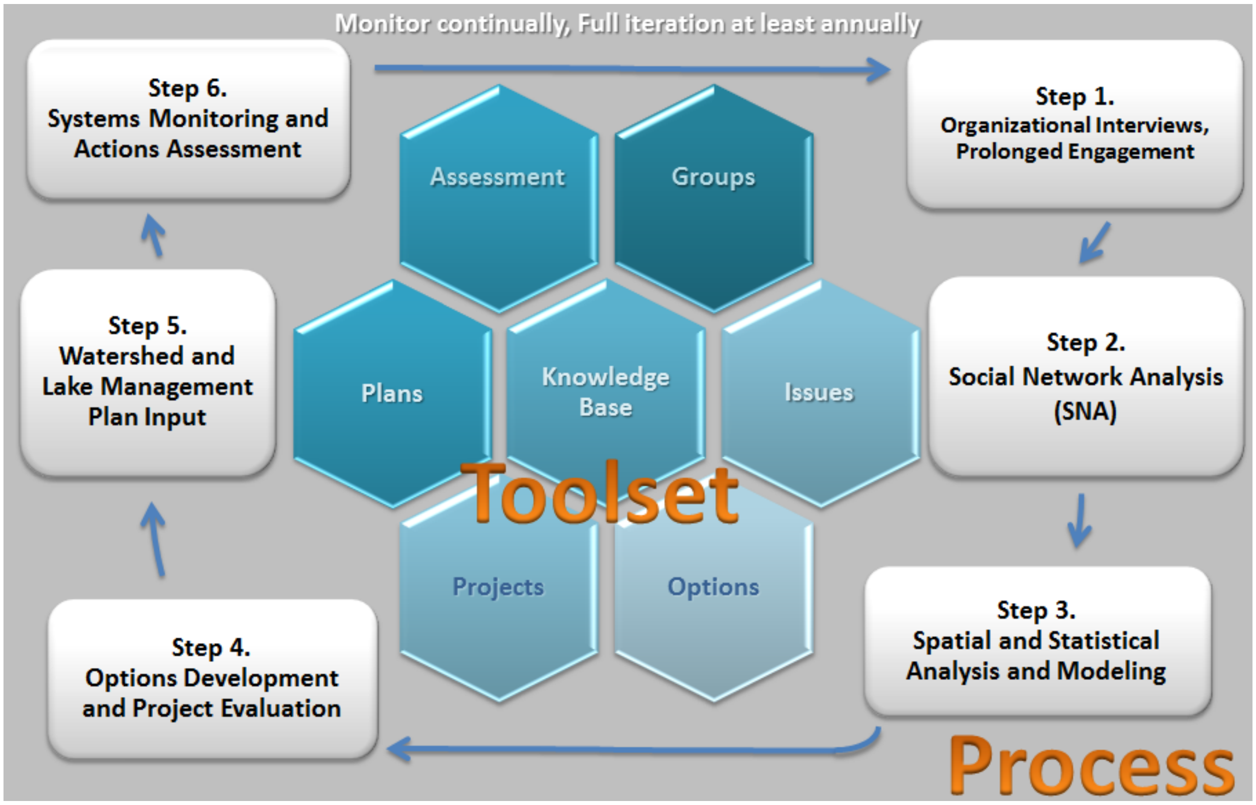


Figure 16. ACM DSS Process and Online Toolset Interactive Development

Watershed group members were further included in ACM-DSS system design in several ways:

- Monthly Design Group at TRS meetings from May through December 2013.
- Usability testing of system functionality by watershed group members.
- Training and practice with ACM DSS system tools.
- Post evaluation interviews and satisfaction surveys in November and December 2013.

The first design group meeting focused on a facilitated discussion of each issue. The second Design Group meeting furthered discussion to include ACM DSS design and the Planning and Prioritization Worksheet (Appendix A. Exhibit 9) to prioritize nutrient source issues, their perceived contributions to the problems, controllability, analysis needs and other related discussion. This also included touching on many of the probing questions developed in Exploratory Questions (Appendix A. Exhibit 10) to enhance double loop learning – to go beyond the issues to probe underlying assumptions.

Criteria were also discussed at subsequent design group meeting to baseline the existing system and to more precisely determine action-oriented options potential (Appendix A. Exhibit 11). Of all the issues and options generated from the interviews, meeting, and discourse (Appendix A. Exhibit 12), favored options were discussed as potential next steps (Appendix A. Exhibit 13).

3.3.1 Usability Testing

By the third Design Group meeting, the first two modules were ready for testing, including issues reporting and interactive data access. Although instructions were provided (Appendix A. Exhibit 15) to self-test the application, in the end, almost all usability testing was conducted in person. Usability testing in person was very effective, because each user was in their own work environment using their exact system set up. This revealed issues related to platform and user operation preferences that would not have been determined otherwise. Users could talk through how they perceived the application and dictate what they wanted changed directly to the developer as they tested each tool. The ACM DSS toolset was designed to require little to no instruction, so if something did not automatically make sense to the user, it was modified to be more self-explanatory. Several buttons were also added by user demand to provide access to BCWA resources, emergency contacts, county mapping tools, and other knowledge sources. Hundreds of changes were made based on usability testing results. Users also completed two Usability Testing Surveys during the in-person analysis (Appendix B. Exhibits 16 and 17). This provided specific information on how the user felt about each tool included, rather than only verbal comments they made as they tested each module in turn. Later design meetings could then focus on refining the tools and discussing progress on issues and options analysis.

3.4 Data Analysis

The purpose of over a year of effort in qualitative systems assessment through collaborative development and testing of the ACM DSS process and toolset was to provide benefits to concurrent and subsequent engineering analysis and modeling. In particular, the ACM DSS process was anticipated to provide a more comprehensive, system-wide focus and foundation for later engineering work. This level of understanding could only be achieved by investigating in-depth how the watershed program operated and the challenges they faced from their local, contextual point of view. Insight was also gained by learning exactly how the complex regulatory frameworks actually interoperated among federal, state, and local levels, and how surrounding watersheds throughout the Upper South Platte Basin performed and interacted.

3.4.1 Social Network Analysis

The SNA unit of analysis for this research was the organization level; thus, interviews and feedback focused on administrative representatives of each BCWA member organization or affiliated group participating in the BCWA or related groups (Appendix A. Exhibit 1). The explanatory value of SNA contributed to the options portfolio selected, rather than strictly basing prioritization on technical analysis. This was achieved by modeling a SNA for each nutrient issue (Appendix D) and BCWA overall (Section 4.2.2) to more systematically identify social network structural features including hubs, gaps, bonding and bridging ties, and subgroups. SNA-based options included those that increased knowledge and resource exchange among participants and those that expanded BCWA connectedness through better collaboration to improve compliance and enforcement. Affiliation (two-mode) data was also collected by project partnership, joint event attendance, and shared coalition membership to supplement and verify the direct relational data. Coalition building incrementally through the spiral model of development (Section 2.7.2) was stressed for its perceived benefit to enable the watershed program to achieve more synergetic relationships.

3.4.1.1 ***SNA Software***

Two different SNA software were used in this research. The first tested was UCINET and NetDraw (Borgatti 2002). UCINET included a rich set of analytical tools for evaluating adjacency matrices of node relationships, node attributes, and link weights. It was used to analyze BCWA as a whole.

GEPHI (Gephi 2013) was used to gain a complex understanding of relationships among both biotic and abiotic factors in BCR, as well as, for analyzing organizational relationships and transactions surrounding each nutrient issue. The time interval tool was also used to document how the engineering facilitator developed relationships with different experts, BCWA members and participants, and regional groups over time. This also demonstrated how the focus on different groups changed over the period, and how the software can help track group dynamics over time.

3.4.2 Statistical Analysis

Chl-a is an indicator of phytoplankton growth, with concern focused on cyanobacterial-based harmful algal blooms (cyano-HABs) in reservoirs. TP is considered a limiting factor in cyano-HABs production. In order to maximize the effectiveness of data already gathered over the decades-long BCWA monitoring program, TP and chl-a were studied statistically to seek relationships and trends. Water quality data were analyzed by stream station, by date and season, and through correlation with other parameters, including streamflow, temperature, sediment load, weather parameters, and BCR water residence time (WRT). Flow and climate trends were also examined to understand patterns of extreme drought (2002) and a flood event (September 2013) for their effects on nutrient concentrations and nuisance blooms.

Although many state requirements focus on summer averages, from an adaptive management standpoint, actual data variability in response to events and prior conditions was a critical consideration. Attention was particularly focused on chl-a and TP exceedances in BCR as the main concern of both Reg.74 and its 303(d) impairment listing to gain better understanding of the potential drivers, thresholds, and feedback mechanisms. (See Appendix C for related case study details) Minitab was the statistical package used for both prediction and graphing, since it is freely available to engineering students at CSU (Minitab 2007). The Minitab Assistant is an efficient tool to graphically analyze, regress, and test hypothesis, while providing comparative graphs and warnings to reduce use and interpretation errors. The advanced Minitab tools could also be used to automatically examine variability by month or seasonal category and through time as a series of graphs for comparison.

3.4.3 Geographic Information Systems

Spatial data sources were developed and analyzed to characterize watershed nutrient issues. The national, state, and local datasets used in thematic mapping, spatial analysis, and modeling are described in Appendix F. Exhibit 1.

Most spatial analysis was conducted in ESRI ArcGIS ArcEditor. ArcToolbox was used to clip national and state data to the watershed boundary. Data often had to be reprojected to a common geographical reference system, so it would align. The State Plane, Colorado Central, meters units was used as the spatial reference system to provide a visual sense of a flat map optimized for this area of the country. This format also worked best in EPA BASINS modeling, which used metric unit-based analysis.

In addition to clipping and projecting, many spatial datasets had to be associated with specific fields in a separate database of attributes. Attributes were also used to group and merge features. Both the spatial and 3-D analyst extensions were used extensively, as described in specific analytical results.

3.4.3.1 ***Determining Topographic and Hydrologic Features***

The USGS National Hydrologic Dataset of streams was clipped and reprojected to obtain all gulches and creeks as lines and water bodies as polygons. Clear Creek County (CCC) and Jefferson County (Jeffco) supplied forty-foot contour lines derived from U.S. Geological Survey (USGS) DEMs. The counties also provided road and parcel data. The roads were used as soft features and the hydrography was used as hard features in the spatial analyst topography tool to make a realistic elevation grid that allowed streams to flow continuously downhill and roads to continue without abrupt elevation changes. Main tributaries to Bear Creek were extracted from lower order streams and labeled by name to serve as a simple base layer for online mapping purposes. Water right diversion canals of significant withdrawals were also added to the stream layer. Colorado Division of Water Resources (DWR) water rights data was related to major diversions, wells, and storage reservoirs to create an online map to improve understanding of priority withdrawals.

3.4.3.2 ***Determining Landuse and Landowner***

Colorado Ownership, Management and Protection Open Space Inventory (CoMap), Denver Mountain Parks (DMP), and Jefferson County Open Space (JCOS) were used to determine the many areas owned by the federal U.S. Forest Service (USFS) at the headwaters, Colorado Dept. of Parks and Wildlife (CDPW) for elk herd protection, and local open space designations. Federal landuse and landcover grids were reclassified to delineate forests, fields, riparian areas, and urban areas for modeling purposes.

3.4.3.3 ***Delineating Locations of Onsite Wastewater Systems (OWTS) and other features***

Spatial analysis was used to classify parcels served by a wastewater provider from those using OWTS for residential and commercial wastewater disposal. In the past, estimates of the number of OWTS were estimated from population data and well data ranging from 6000 to 27,000 (CDM 2011; DrCOG et al. 1990; Geza et al. 2010; Hydros 2011, USACE 2012). However, not all properties that use OWTS use individual wells, and the number of wells and the number of structures do not always coincide. Population-based estimates did not indicate where the OWTS actually existed. Therefore, to begin understanding this potential nutrient source derived from OWTS in space and time, it was important to locate each OWTS and determine its likely age. This was accomplished by delineating areas served by wastewater providers, then extracting out unserved areas that included residential or commercial structures. The results were then shared with each wastewater provider to verify where OWTS still existed within their district, or if they had been converted to sewer-service.

By linking results to a database of properties that Jeffco had developed of permitted OWTS, results could be partially verified. However, not all OWTS in Jefferson County, especially old systems, were required to have a permit, so the analysis also helped the county compile a list of unpermitted systems.

For CCC, a different verification method was used. Only one wastewater provider, the Upper Bear Creek Water and Sanitation District (UBCWSD), existed in this county, so it was relatively easy to obtain a list of their properties served with wastewater. CCC had delineated all buildings by property address because unlike Jeffco, parcels did not often directly coincide with a single property. Therefore, removing the UBCWSD subset from the rest of delineated structures in CCC provided a good estimate of total OWTS in CCC. Although the assessor could not associate the leach field information directly with parcels for verification yet, as Jeffco had, they were able to provide structure age at least.

It was not possible to determine where the septic tank might lie on each parcel. Therefore, a point was placed in the centroid of each OWTS parcel as an estimate of its location. A tedious process was used to move all points on parcels of greater than 10 acres, and most greater than 2 acres, from the centroid to a location closer to the back of the structure, using county supplied imagery. Although this was very time-consuming, it also allowed parcels to be corrected that included two or more structures or parcels with no structures –because the property had been split into two or more pieces. Simultaneously, if a corral, fence, and stable were obvious, then the parcel was designated as a horse property. If the county road did not continue to each structure, a private drive was drawn. The result was included in the unpaved road layer unless it appeared to be paved in county imagery. Paved and unpaved roads were both used in the EPA BASINS GWLF-E model to estimate relative annual nutrient loading by source.

3.4.4 EPA BASINS GWLF-E Nutrient Mass Balance Estimates

Thematic layers including subbasins, soils, landuse, elevation, horse densities and pastures, paved and unpaved roads, streams, point discharges, and urban areas were uploaded into EPA BASINS GWLF-E. Weather data was also downloaded directly for inclusion. After entering a few other standard parameters, the model was run successfully. A few further modifications were made to agriculture constants using the tools provided before choosing to create the output files. Output files were explored by nutrient source, month, and year to estimate proportional, screening level TP contributions by nutrient source.

3.4.5 Traveling the Watershed and Limited Ungauged Streamflow Estimates

After purchasing a new flowmeter, BCWA provided the researcher with an older streamflow gauge to obtain a few streamflow estimates. Two periods at various locations were roughly measured in July 2013 and after the September 2013 flood commenced. In this way, the researcher gained some firsthand understanding of how gulches and smaller streams actually responded to rainfall events. In general, though, the monthly monitoring network of data using more precise BCWA flow meter methods and USGS and DWR gauged stream data described in the annual Quality Assurance Plan for monitoring were preferred data sources. It was also helpful to periodically attend monitoring events and drive through new areas of the watershed not previously visited to obtain a visual understanding of their characteristics. By study end, thousands of miles had been driven.

3.4.6 Exposed September 2013 Flood Sediment Analysis

Following a September 2013 flood, the BCR flood control pool was drawn down quickly from a flood pool high of about 5608 feet MSL back to permanent pool depth of 5558 feet MSL. Eight sediment samples from the dam face, the north dock, Pelican Point, and near the mouths of Bear and Turkey Creeks were analyzed to determine how fine sediments that had been transported to the reservoir might affect trophic status (Appendix D. Exhibit 12). After the sediments had dried around the lake, the thicknesses of additional dried sediments were measured to determine depositional patterns. An inverse-distance-weighted spatial interpolation method was used in GIS to generate an approximate map of sediment deposition to calculate overall volume deposited.

In July 2014, a sample core was extracted from the center of the lake at a depth of about 35 feet. Sediments appeared to have accrued since 1977 to be about 3.5 feet deep before reaching what appeared to be the clay core. This sample was analyzed by the same lab in the same way as the exposed sediment prior for comparison.

3.5 Options Development

Based on both the ACM DSS process described in 3.2-3.3 and the data analysis in 3.4, a comprehensive list of issues and options were developed to expand collaboration and adaption (Appendix A. Exhibit 12). Some preferred results were entered as projects and options in the related ACM DSS tools. A project scoring system was developed with BCWA members to begin to evaluate priorities judiciously as more funding becomes available (Appendix B-8.1). The project-scoring tool was supported by a BCWA board-approved Project Evaluation Process Policy (Appendix A. Exhibit 14).

Options development and ACM DSS evaluation completed Phase I of framework testing and the conclusion of the dissertation research. Subsequent phases will focus on developing more comprehensive models for systems-wide planning, while increasing funding, resources acquisition and community involvement (Appendix A. Exhibit 20 & 21).

3.6 Software Design

Information technology tools included a Content Management System (CMS) to create web content from an online relational database management system (RBDMS), rather than from static web content. CMS also manage user authorization, authentication, and access rights, and provided an extensible framework for modular component design. Component, integration, and usability testing and software development life cycle (SDLC) considerations were also employed throughout the agile, collaborative online software development process. Results are designed for delivery through Software as a Service (SaaS) over any internet connection to ensure that online tools continually support the ACM DSS facilitated process. Each new instance uses functionality of the existing system, but maintains its own set of location and problem specific database tables. Software code is stored in libraries to enable access by reference. In this way, the system remains flexible and generic to support changing needs. More information about system specifics and detailed functionality developed for each module are described in Appendix B.

4.0 RESULTS AND DISCUSSION

4.1 ACM DSS Process Evaluation

In conformance with the stated objectives, Phase I of the ACM DSS process was intended to operationalize ACM principles more effectively by:

- evolving understanding of the complex social-ecological system,
- learning from past actions to plan future actions more effectively, and
- forging partnerships to improve nutrient management and resource governance.

These objectives were achieved by dissecting related needs into a series of Phase I tasks to complete, which based on the stated methods, included the following activity focus in implementation:

1. Develop a process of systematic, prolonged engagement through:
    a) Interviewing BCWA members and participants, federal, state, and local regulators and land managers, community groups, Upper South Platte Basin watersheds and basin-level groups, CSU and other academic experts in watershed and nutrient issues, state professional associations, and water-related businesses and service providers,
    b) Attending all BCWA monthly board meetings and technical review session meetings from September 2012 through October 2014,
    c) Facilitating deep learning and substantive contribution through monthly collaborative ACM DSS toolset design group meetings held during BCWA monthly TRS meetings May through December 2013,
    d) Participating in both stream and lake monitoring to understand methods and controls,
    e) Conducting a study demonstrating ACM act-and-assess experimental design,
    f) Supporting all educational efforts and events as the 2013-2014 BCWA education coordinator,
    g) Following-up after initial interviews with emails, before and after meeting questions, and through other events, opportunities, and communication mechanisms to continue to build stronger relationships with as many participants in as possible over time,
    h) Conducting SNA to evaluate engagement efforts continually to reveal who might be missing or who should receive more targeted follow-up to enhance study results.

2. Continually develop GIS layers, spatial analysis, and spatial modeling techniques to enhance understanding of the location and extent of each potential nutrient-related issue.
3. Analyze monitoring data statistically to reveal significant trends over time and space.
4. Use SNA to understand the human social systems and related resources affecting each issue.
5. Stay involved in state watershed and water-related professional groups and all Upper South Platte Basin watershed and basin-level activities possible for broader context.
6. Research each issue through literature review and discussions with subject matter experts.
7. Collaboratively create, test, and expand the ACM DSS online toolset.
8. Instruct engineers to use SNA through a variety of short course formats to learn methods which might work best in the future to train ACM DSS process facilitators and others.

Results of the first phase of the ACM DSS process include:

1. a suite of collaboratively developed online tools to report issues, projects, options, and plans, access monitoring data, and to store shared knowledge and water-related group information (Appendix B),
2. OWTS, landuse, pastures, fire hazards, ecology, water rights, unpaved roads layer GIS delineations and online interactive maps, with general online static map developments for population, elevation, soils, and vegetation (Appendices B, D, and F),
3. EPA BASINS GWLF-E preliminary mass balance analysis of potential nutrient NPS (Appendix F. Exhibit 2) and comparison with USGS Sparrow DSS results (Appendix F. Exhibit 3),
4. Statistical analysis of monitoring data for potential trends and correlations and engineering calculations to validate and improve monitoring methods (Appendix D),
5. Social Network Analysis of each major nutrient issue and BCWA (Section 4.2.2, Appendix D),
6. Lessons learned from analysis results in context of surrounding watersheds and research studies about nutrient issues and control (Section 4.4, Appendix C, and Appendix D).
7. An SNA Workshop Completion Report describing lessons learned (Herzog et al. 2014).

Results evolved understanding, especially concerning complexity, uncertainty, and ambiguity, by describing how literature review, contextual analysis, and actual study results provided a more expansive problem definition during Phase I development. Results also provided more systematic analysis to improve future, incremental next steps and to expand mutually beneficial partnerships more consistently. A variety of dialogue methods proved to be important to build and reinforce a maturing understanding of ACM and methods to achieve its objectives among participants. Success factors for watershed programs and program managers were developed from watershed program comparisons and literature review (Section 4.4). Nutrient management issues requiring further research were determined in cases in which uncertainty could not be sufficiently reduced (Section 4.2.5).

This chapter focuses on reporting results and discussing how results of Phase I will inform later phases of ACM DSS process development, complimented by materials referenced in the appendices. Appendix B details ACM DSS toolset components. Appendix D contains mixed-methods issues analysis results. Appendix E lists results of state level professional organization surveys, an SNA workshop summary, and collaborative capacity assessment criteria. Appendix F covers GIS and modeling results.

4.1.1 ACM DSS Satisfaction Survey Results

Since survey respondents included most BCWA organizational members who had substantively participated in the ACM DSS process, this evaluation effectively represented satisfaction levels (Appendix A. Exhibit 8. Figure A-1). Overall, the ACM DSS process received 9.3 out of 10 for satisfaction on a scale from very dissatisfied to very satisfied (Appendix A. Exhibit 8. Figure A-2).

BCWA members were also asked to rate how well each ACM DSS online tool by tab fulfilled one or more of its intended purposes and what they thought would be most likely to improve the ACM DSS toolset going forward. All 10 organizational respondents indicated that increasing participation and use would be the key factor in ongoing system success. Nobody indicated that any tool or tab in the online toolset should be added or removed, just that effort would be needed to ensure that the toolset is used to serve its many intended purposes. Per the survey results, each respondent also agreed to continue to update ACM DSS input and share it with others. These responses substantiate explicit concern of participants for continued use and their willingness to continue to participate in system expansion. Post-design survey questions and results are shown in Appendix A. Exhibit 8.

A quarterly progress report format to address the concern for continued development is shown in Appendix A. Exhibit 20. The report is used to facilitate a group discussion at least quarterly to ensure that all related areas of concern are being addressed. In Phase II of ACM DSS process planning, the quarterly report format will be complimented by an online dashboard displaying progress on many of the criteria and success metrics developed by the design group in Appendix A. Exhibit 11.

Responses to the question, *What did you like about being involved in the ACM DSS process?* included:

- seeing different approaches to solving nutrient problems,
- the web-based collaborative environment,
- the evolution of the process with full member inclusion,
- enjoyment of the learning process,
- the overall usability of the resulting system,
- its comprehensive nature,
- the anticipated benefits of having more information available, and
- collaboratively developed resources with improved accessibility in real time.

In usability testing and exit interviews, users also noted that the ACM DSS process could be used for a wide variety of other community needs, not just water quality management. They also felt that BCWA was not the only type of coalition that could benefit from such a system, but also counties, public lands, cities, and other levels of resource and community management. Therefore, in subsequent phases, more components will be made available to the public and for other specific community purposes.

Throughout the ACM DSS process, users expressed satisfaction with the spiral model concept of incremental development (Section 2.7.2). This encourages gradual, continual development using a core group with an increasing level of comfort and success in the system to incrementally build system components and resources and include other trusted participant groups steadily over time. This was specifically designed to overcome the problem of public meetings and other standard stakeholder processes that tend to increase the voice and polarization of a few key players and groups. By focusing instead on building collaborative ties and better access to information and resource flows gradually at the desired pace of the individuals and groups represented, the ACM DSS process has demonstrated an ability to reduce polarization and increased interest in expanded cooperation. Appendix A. Exhibit 20 is an example of an ACM DSS Quarterly Progress Report that reinforces the process by demonstrating incremental progress on all fronts. It allows BCWA members to further shared understanding and brainstorm more next steps together. Most importantly, it recognizes contributors and requires regular nomination of additional group leaders to train in system expansion and further collaboration each quarter. In this way, even if existing members cannot always contribute, the formal training of a diversity of new, targeted members in the ACM DSS process regularly ensures its continued expansion and sharing.

As further demonstration of ACM DSS process support, an official ACM DSS process facilitator was designated for the 2014 calendar year to ensure its continue use and development, even though the research project officially ended in December 2013. In January 2014, the BCWA board also awarded the ACM DSS and Policy 21. *Online Management Process* (Appendix A. Exhibit 19) the *2013 BCWA Golden Trout Award* (Appendix A. Exhibit 18.). This is a significant development. International studies of project outcomes indicate that the greatest measure of success is when project beneficiaries find the perceived objectives so worthwhile that they choose to mainstream the project activities into their own development agendas at their own expense (Glantz et al. 2013). By adopting the ACM DSS process permanently and continuing to pay for its upkeep, BCWA is embracing a more difficult path forward that they already know will require significant and ongoing change towards more adaptive and collaborative practices. However, a glimpse into the possibilities to reduce risks and enhance watershed program effectiveness demonstrates that the ACM DSS process potentially provides benefits worth these significant costs.

Nevertheless, simply having BCWA adopt the ACM DSS process is insufficient to further ACM goals. Over 48 organizational representatives, many that do not represent BCWA active members and participants, have been trained while also conducting usability testing of their comfort in the ACM DSS, after being approved by BCWA board for inclusion. Expanded ACM DSS participation includes county commissioners and various departmental staff, public landowners, state agencies, engineering consultants, students, environmental and community groups, academics, and water utilities. Nevertheless, additional institutions, public and private large landowners, community groups, and citizens must be significantly incorporated into the process over time to ensure enculturation into a new watershed protection mindset. For this reason, the spiral model of continual development (Section 2.7.2) and the five-phase, five-year progressive development *roadmap* (Appendix A. Exhibit 21) must not be neglected simply because Phase I ACM DSS process dissertation research has been completed.

4.1.2 ACM DSS Process – Five-Year Watershed Program Maturity Roadmap

This demonstration case study project only included one full-year of ACM DSS process development in Phase I. However, the ACM DSS process is an expanding, iterative process per the spiral model of development discussed in Section 2.4.2 and the goal of reaching network maturity per Section 2.8.6. Therefore, Appendix A. Exhibit 21 includes a *roadmap* of the ACM DSS process projected over five years towards watershed program maturity in operationalizing ACM principles. It outlines major program events for planning and scheduling, including developing an integrated modeling framework (Appendix A. Exhibit 22), continually building collaborative capacity (Section 2.3.9.3), and gaining further understanding of the complex social-ecological system to more directly affect its evolution (Appendix D). It also strives to develop more core program manager competencies listed in Section 4.4.1 and meet more of the successful features of an effective watershed program described in Section 4.4.2.

4.2 Resulting Metrics

As discussed in section 1.4, baselines and metrics were developed to demonstrate the changes that occurred in response to implementation of the ACM DSS process.

4.2.1 Measurable Benefits of Online Tools

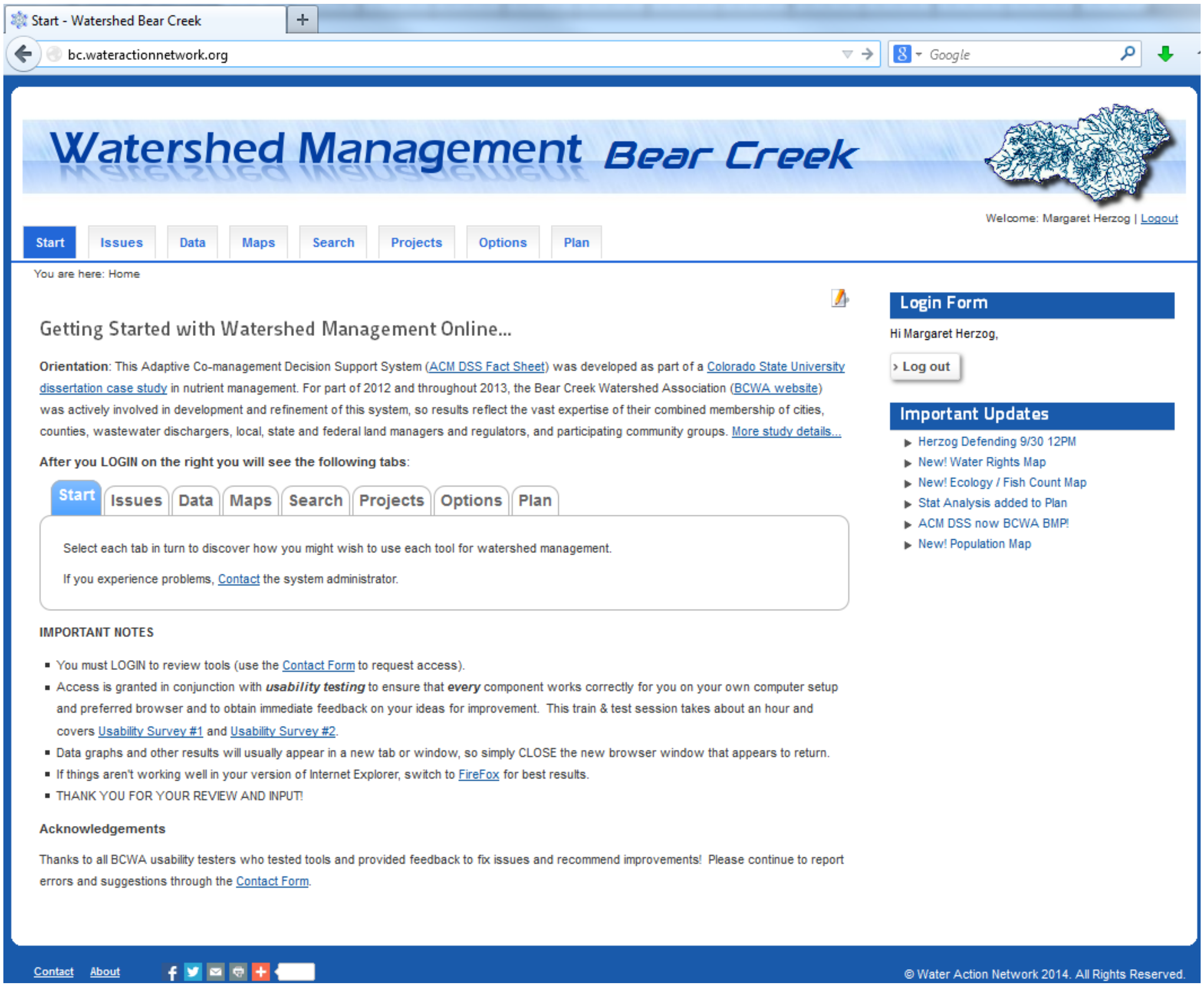
The ACM DSS process employs an online toolset, so that when any tool is no longer useful or requires adjustments, changes are immediately available to all users. By not providing the ACM DSS toolset as an application for download, but as an access-ready, online toolset, it will be easier to maintain quality of each implementation. It will also ensure that as membership in groups change, others can be trained and designated in roles for ongoing ACM DSS process maintenance and systems expansion. In this way, improvement in one instance of the online ACM DSS toolset may also be implemented for other, related purposes to maintain quality and expandability. This helps emphasize ACM DSS process improvement, rather than a disintegrated DSS product.

Although the BCWA had a well-designed public website, which included links to watershed organization documents, it did not previously have an online, interactive, members-only watershed program management system. Figure 17 demonstrates the interface of the new ACM DSS online toolset. Key features of each of the tools are detailed in Appendix B. This section lists key quantitative metrics.

Through the collaborative design process detailed in Section 3.3, eight tabs representing distinct tools in the ACM DSS online toolset were developed (Figure 17). Metrics related to each tools are discussed by tab.

<u>Start Tab</u>: Orientation information, brief instructions for each tool by tab, research references, help, and updates.

<u>Issues Tab</u>: Over 80 issues were reported by BCWA members and participants directly into the issues-by-location tool in 15 different issues categories, each with a different, filterable icon type to show mapped patterns (Appendix B-4). This complimented the extended list of issues and options derived from the prolonged engagement process, which included 57 issue types, subdivided into 202 issue subtypes, and associated with 337 suggested improvement options for future consideration (Appendix A. Exhibit 12).



Getting Started with Watershed Management Online...

Orientation: This Adaptive Co-management Decision Support System (ACM DSS Fact Sheet) was developed as part of a Colorado State University dissertation case study in nutrient management. For part of 2012 and throughout 2013, the Bear Creek Watershed Association (BCWA website) was actively involved in development and refinement of this system, so results reflect the vast expertise of their combined membership of cities, counties, wastewater dischargers, local, state and federal land managers and regulators, and participating community groups. More study details...

After you LOGIN on the right you will see the following tabs:

Select each tab in turn to discover how you might wish to use each tool for watershed management.

If you experience problems, Contact the system administrator.

IMPORTANT NOTES

- You must LOGIN to review tools (use the Contact Form to request access).
- Access is granted in conjunction with ***usability testing*** to ensure that ***every*** component works correctly for you on your own computer setup and preferred browser and to obtain immediate feedback on your ideas for improvement. This train & test session takes about an hour and covers Usability Survey #1 and Usability Survey #2.
- Data graphs and other results will usually appear in a new tab or window, so simply CLOSE the new browser window that appears to return.
- If things aren't working well in your version of Internet Explorer, switch to FireFox for best results.
- THANK YOU FOR YOUR REVIEW AND INPUT!

Acknowledgements

Thanks to all BCWA usability testers who tested tools and provided feedback to fix issues and recommend improvements! Please continue to report errors and suggestions through the Contact Form.

Figure 17. Online, Interactive ACM DSS Toolset - Start Page Showing Tabs Representing Each Tool

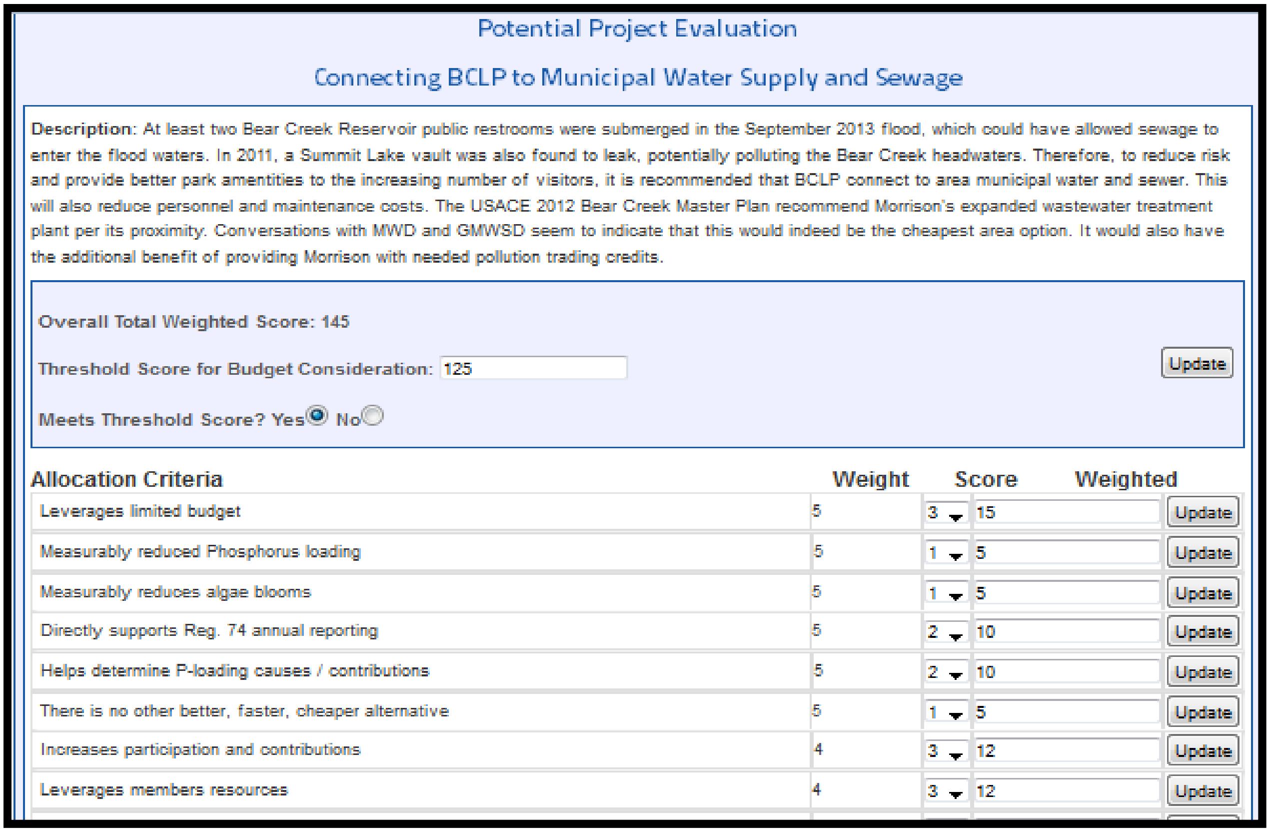
Data Tab: All monitoring data developed in annual reports and studies that could be found from 1990 to the present were added to the online database associated with both dynamic queries and mapped monitoring stations providing linked access to annual and monthly average graphs by water quality constituent. Over 16,500 records were included, fully updated at least yearly, and after each monthly sampling round to the extent possible. Constituents include flowmeter flow calculations, TP, total dissolved and particulate phosphorus, total nitrogen (TN), total suspended solids (TSS), chl-a, ammonia, nitrate, Secchi depth (SD), and monthly temperature indices. The data tab improved monitoring data access for individual BCWA member organizations and participants and for use during group discussions. It also proved critical in planning statistical analysis to determine stream stations for bracketing potential nutrient sources and for selecting appropriate data sets with sufficient data.

Maps: Five interactive maps were developed for landuse, fire hazards, pastures, water rights, and ecology. A general tab included additional information in static maps for population, elevation, soil saturated hydraulic conductivity, and vegetation. All these layers, in addition to several others listed in Appendix F. Exhibit 1, were used to calculate an EPA BASINS GWLF-E mass balance analysis of all major nonpoint nutrient sources throughout the watershed for nutrient control planning and management purposes (Appendix F. Exhibit 2). ACM DSS map tab users also have ready-access to links to both Jeffco and CCC parcel details and other interactive map data provided by these local governments (Appendix B-6.8). More metrics related to GIS analysis are reported in section 4.2.7.

Search Tab: Information from more than 156 organizations within the Bear Creek Watershed or associated through different government agencies or overlapping jurisdictions were included in the Group Search tools. BCWA members and participants are highlighted through a quick search button. Groups can also be accessed by group type or location. Any entity participating in a joint project with other groups will list a link to these projects in their associated group page to emphasize their collaboration and incentivize them to further their partnering efforts (Appendix B-7.1). The topical knowledge base includes more than fifty topics, with more being added each month in association with a new set of BCWA fact sheets recently developed for the new watershed plan and through new studies and ongoing literature review of related nutrient issues and potential controls (Appendix B-7-3).

Projects: With design based on a statewide effort to develop Measurable Results for restoration projects, the Projects tab includes more than 20 proposed projects, several completed projects, and a few in progress related to nutrient issues reduction. Related issues can be associated with a project to demonstrate which issues have been addressed by each one. Project partners added to a project then list the project in their group page as a cross reference incentive, making their group page appear more collaborative over time for cooperative efforts. Project contractors on projects are also recorded. High quality contractors gain more exposure for their effective work, if they demonstrate low costs in relation to effective ongoing assessment results, which also will help develop BMPs.

As shown in Figure 18, an online Project Scoring system was also created through the collaborative systems design group process along with a new policy requiring its use (Appendix A. Exhibit 14). No prior systematic mechanism existed to compare potential projects to prioritize funding and to justify each use of BCWA limited pooled member funds, so this represents another significant program improvement. Projects are scored based on three types of criteria and weighted based on relative importance to BCWA watershed program mission and objectives and annual program emphasis (Appendix B-8.2).



Potential Project Evaluation

Connecting BCLP to Municipal Water Supply and Sewage

Description: At least two Bear Creek Reservoir public restrooms were submerged in the September 2013 flood, which could have allowed sewage to enter the flood waters. In 2011, a Summit Lake vault was also found to leak, potentially polluting the Bear Creek headwaters. Therefore, to reduce risk and provide better park amentities to the increasing number of visitors, it is recommended that BCLP connect to area municipal water and sewer. This will also reduce personnel and maintenance costs. The USACE 2012 Bear Creek Master Plan recommend Morrison's expanded wastewater treatment plant per its proximity. Conversations with MWD and GMWSD seem to indicate that this would indeed be the cheapest area option. It would also have the additional benefit of providing Morrison with needed pollution trading credits.

Overall Total Weighted Score: 145

Threshold Score for Budget Consideration: 125

Meets Threshold Score? Yes ● No ○

Allocation Criteria	Weight	Score	Weighted
Leverages limited budget	5	3	15
Measurably reduced Phosphorus loading	5	1	5
Measurably reduces algae blooms	5	1	5
Directly supports Reg. 74 annual reporting	5	2	10
Helps determine P-loading causes / contributions	5	2	10
There is no other better, faster, cheaper alternative	5	1	5
Increases participation and contributions	4	3	12
Leverages members resources	4	3	12

Figure 18. Online Potential Project Scoring Tool to Analyze Merit and Prioritize Funding

<u>Options Tab</u>: Although only 30 options have been recorded to date, the system is being simplified with a user dashboard to allow each organizational participant to better track their options separately. After this has changed, participants will be encouraged in their individual annual interviews to retry to use this tool more often to record every call, cost estimate, and other small activity they spend time and / or resources in project, study, or policy development or ongoing assessment. In this way, final BMPs will more fully reflect full life cycle costs and required efforts, since options link to the project, policy, or study to which they pertain for cost and resource analysis purposes.

<u>Plan Tab</u>: More than 70 linked items were added to the watershed and BCR lake management plans including pertinent studies, technical memos, research links, and other resources for plan development. Recently, BCWA expanded on this concept to create a completely dynamic watershed plan on their public website at http://bearcreekwatershed.org/Watershed%20Plan.htm. To date, the new BCWA watershed plan includes documents listed in Table 3, most of which had not been generated before the ACM DSS process began in 2012:

Table 3. Change in Each BCWA Document Type Since ACM DSS DSS Process Began

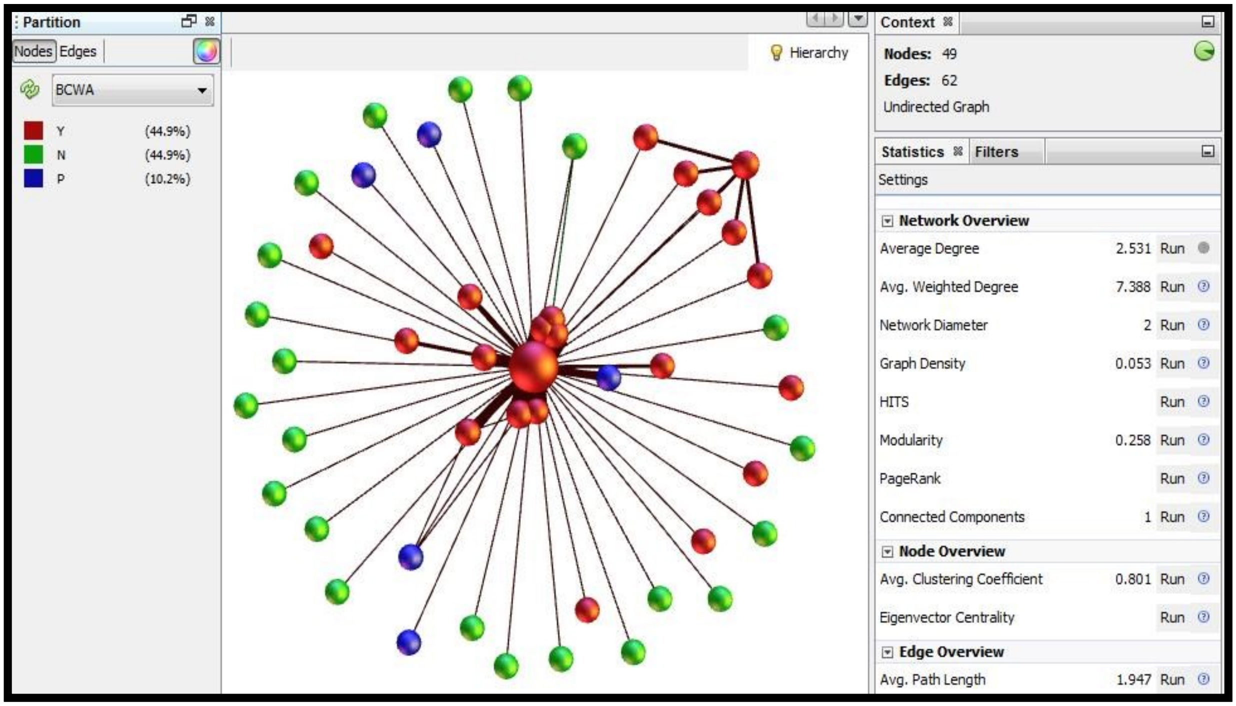
Document Type	Baseline	Current	Change
Brochures	1	4	3
Policies	10	34	24
Information Sheets	0	18	18
Fact Sheets	0	43	43
Maps	10	31	21
Technical Memos	11	31	20
Watershed Plan	0	Complete!	Milestone

The development of a BCWA Watershed Plan is a significant result catalyzed by the ACM DSS process. Without a formal watershed plan, BCWA was not able to apply for certain federal and state grant programs and even some private foundation funding sources. Now that a watershed plan is in place, donors are likely to feel more confident that money provided to the watershed will be used and documented well, further legitimizing and accelerating adoption of ACM. The plan is complimented by the sophisticated ACM DSS toolset, which serves as an online watershed program management system that tracks each project and prioritizes funding through the online scoring system and formal annual project evaluation process.

4.2.2 Social Network Analysis Metrics

Before the ACM DSS process implemented SNA to work towards improving social structure and targeting core-periphery network structure specifically and systematically, less attention had been paid within BCWA to involve each member and participant specifically and substantially in decision making or reaching out regularly to outside organizations to expand general resilience through cooperation.

Figure 19 depicts BCWA in SNA software before research began: members are shown in red, participants in blue, and external support in green. Although boundary analysis was limited, in general, it correctly demonstrates the strong hub-spoke character of BCWA. The central hub represents the BCWA full-time manager. The two small, close clusters represent the two organizational groups managing Evergreen Lake and BCR, which provide staff time to support both lake and watershed-wide monitoring. This six-member core was also most responsible for decision-making and technical analysis. Even though each member organization has many other ties, only the primary ones that they share with BCWA are shown. About half of BCWA resources were obtained from outside its membership, including: federal and state agencies and statewide organizations, other watersheds, and technical expertise.



BCWA

🟥	Y	(44.9%)
🟩	N	(44.9%)
🟦	P	(10.2%)

Nodes: 49
Edges: 62
Undirected Graph

Network Overview

Average Degree	2.531	Run
Avg. Weighted Degree	7.388	Run
Network Diameter	2	Run
Graph Density	0.053	Run
HITS		Run
Modularity	0.258	Run
PageRank		Run
Connected Components	1	Run

Node Overview

Avg. Clustering Coefficient	0.801	Run
Eigenvector Centrality		Run

Edge Overview

Avg. Path Length	1.947	Run

Figure 19. GEPHI SNA of BCWA Network Structure, Pre-Project

Figure 21 demonstrates the significant difference achieved by addition of a trained network weaver, the engineering researcher / ACM DSS process facilitator. By systematically focusing on developing a relationship with each BCWA organizational actor depicted in Figure 19, and more local, state, and federal landowners in the watershed, community groups, and academic experts consecutively over time (Figure 20), the addition of this temporary hub greatly increased connectivity and reach (Figure 21).

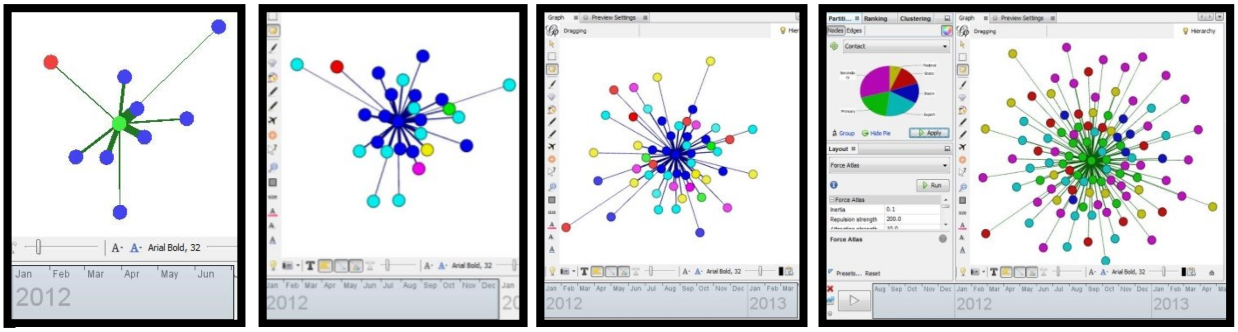
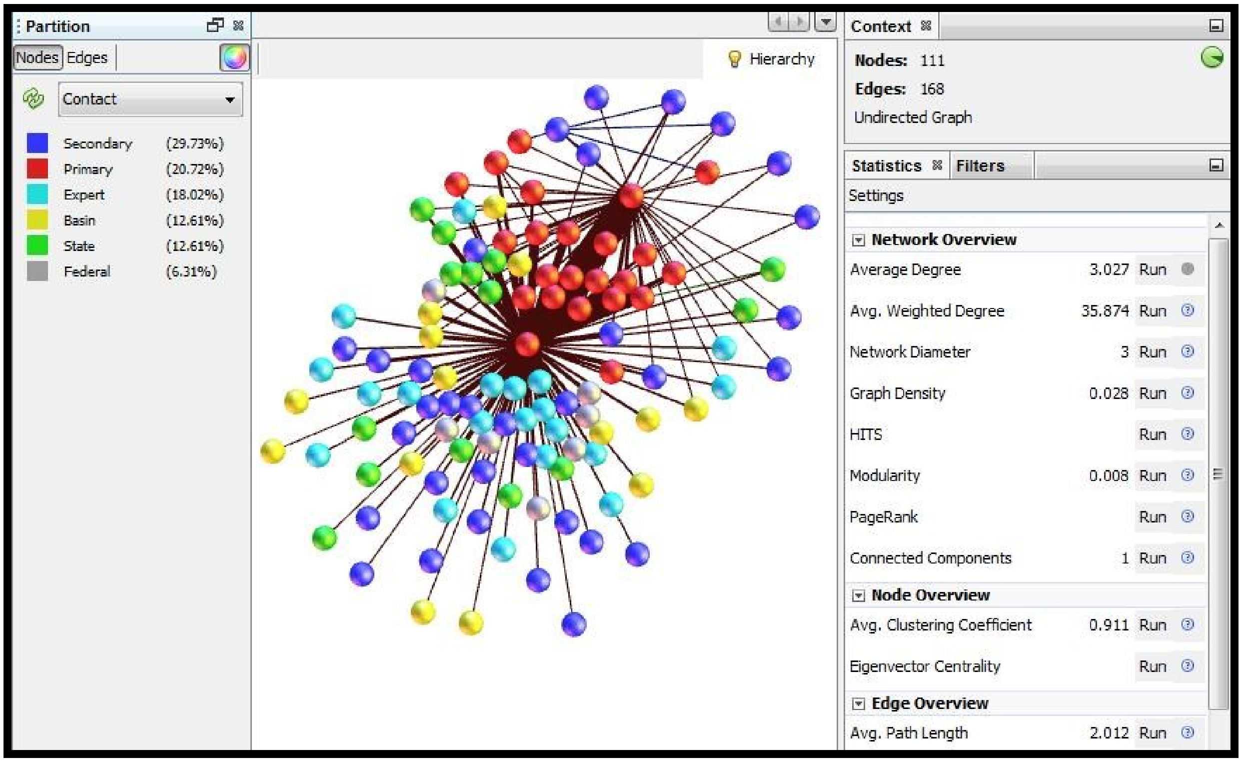


Figure 20. Continual Expansion of Connections by Network Weaver 2012-2013
(nodes with thicker ties in closer proximity to the central hub, the network weaver, interact most often)



🟦	Secondary	(29.73%)
🟥	Primary	(20.72%)
🟦	Expert	(18.02%)
🟨	Basin	(12.61%)
🟩	State	(12.61%)
⬜	Federal	(6.31%)

Nodes: 111
Edges: 168
Undirected Graph

Network Overview

Average Degree	3.027
Avg. Weighted Degree	35.874
Network Diameter	3
Graph Density	0.028
HITS	
Modularity	0.008
PageRank	
Connected Components	1

Node Overview

Avg. Clustering Coefficient	0.911
Eigenvector Centrality	

Edge Overview

Avg. Path Length	2.012

Figure 21. Improved Network Structure through Addition of a Trained Network Weaver

Unfortunately, in the case of most research projects, upon project completion, this temporary hub simply vanishes, leaving little gained. The network may even become more vulnerable when the project ends, because certain nodes may have become dependent on new paths to information, resources, and relationships. Therefore, it is critical that researchers consider these risks before choosing to conduct participatory research design. In this instance, the researcher, whom served as the network weaver, actually lives in the watershed and had committed to four additional years of service in order to more effectively introduce nodes to one another and foster their collaboration, while completing the ambitious five-phase ACM DSS process roadmap (Appendix A. Exhibit 21). This will allow the secondary hub to convert from a bridging role to that of a less important facilitator in time (Section 2.8.6). In this way, the central cluster will gain redundancy, making the loss of the new hub later less important. It will also be crucial to take measures to help the network mature to a more stable core-periphery structure before the BCWA manager must retire after thirty or more years of service.

The Project Management Institute (PMI 2013) uses a formula to calculate the communication channels that could potentially develop from adding more people to a network as:

Communication Channels = N (N-1) / 2 **Equation 1. Communication Channels of Nodes = N**

In this case, the second hub increased accessible nodes from 49 to 99 (Figure 21 compared to Figure 19). Therefore, adding a single network weaver increased potential communication channels from 1,176 to 4,851 – more than four times more! This does not even consider how the network will continue to expand as more BCWA members and participants take on greater leadership in social and knowledge network development. Allowing network expansion to occur naturally is unlikely to be optimal. Instead, as the research hub begins to move from core to facilitator, other strategic network weavers should be developed through formal SNA instruction. Equation 1 and Section 2.6.2 indicate that training others in SNA and giving them focused expansion roles is likely to provide an even larger, more diverse, and less vulnerable network structure over time.

Another important improvement stems from the fact that each new relationship is unique and dynamic. The new hub provided different information and understanding to return to the original hub as secondary information from even its original primary contacts through triangulation. This informed both the manager's choices and the overall direction of the BCWA board. By encouraging BCWA to adopt the ACM DSS process, a formal new project evaluation policy, and study and regulatory changes, this research has improved adaptability. This occurred because of the increased diversity in information and resources available through access to five times more potential ties, each consisting of a unique new pattern of interactions. However, it also allowed BCWA to develop a new level of understanding of their organization from an outsider's perspective. This improved their ability to question underlying assumptions of how they had conducted business for decades. Change was not especially difficult, because it was an *emergent property* of social network evolution (Section 2.4.1).

It is incorrect to assume that change is always positive. In fact, the main use of Equation 1 is to help project managers gauge the complexity of their project team and stakeholders to manage communications risks (PMI 2013). In contrast, as describe in Section 2.7.2, governance of complex social-ecological systems must attempt to attain a similar level of complexity. Systematic focus and enculturation towards cooperative, inclusive structure prevents the disadvantages of complexity from overwhelming the benefits. Social network expansion through the application of *Table 8. Watershed Program Success Factors for ACM* outlined in Sections 4.4.2 is another method to prevent mis-management. These recommendations were developed from comparisons of watershed programs throughout the Upper South Platte Basin and reflect the strengths of each. *Table 7. Core Program Manager Skills* listed in Section 4.4.1 are particularly important for network weaving. An effective watershed program is too complex to be administered by a single watershed manager, or even a single layer of management. Instead, employees, volunteers, and consultants usually must each play a specific, professional role in program success. In each role, the watershed program team must be directed to build their own social networks vertically and horizontally to best access tools and resources to build resiliency in that particular technical, organizational, educational, or legal need. They also must develop cross-disciplinary links and broad system understanding to manage watershed complexity, uncertainty, and ambiguity as discussed in Chapter 5. Conclusion 1.

More formal SNA complimented adhoc coalition building in at least three important ways:

1. Ensuring *systematically* and *verifiably* that every stakeholder and interest in the community had been included *substantively* in the Phase I ACM DSS process, which made sense for this stage of outreach. Often this required reaching out to those who did not make it to public meetings, helping them enter their perspective using the ACM DSS toolset, or amplifying their voice through interviews and one-on-one discussions later, if they did not participate actively.
2. Using network maturity measures to close gaps purposefully, build more cohesive ties, and help specific parties move beyond interests into more collective *sense-making*, problem-solving, and shared resource building action-by-action and issue-by-issue.
3. Building capacity for further cooperation *beyond the facilitated process* - mentoring other leaders and groups to formally play an active "network weaver" role to ensure that ties continue to strengthen and extend over time

4.2.3 Complex Interaction Among Nutrient Issues

A summary of the main issues categories of concern that were reported are listed in Table 4. The complex interaction between these issues is only in the earliest stages of analysis. For example, a leaky public latrine demonstrated a lack of formal regulatory authority to manage compliance for this type of wastewater management system on public lands. Recreational overuse was affected by lack of coordinated public education and multi-jurisdictional controls, which increased erosion of fine sediments, fragmentation, and possibly reduces species diversity, though typically public lands are thought to be pristine. Therefore, it is often impossible to manage one issue without also considering several interacting issues in a control plan. In most cases, vertical coordination among federal, state and local government and horizontal coordination among county departments and nonprofit and private entities may also be required. Table 4 list some of the main concerns reported. Highlighted items were reported most often to be of primary concern as potential contributors to nutrient management issues.

Table 4. Reported Categories of Watershed Issues of Concern
(Bold, underlined items represent the most reported, most analyzed nutrient issues reported)

Agriculture / Ranching	Legislation / Politics
Animal Wastes	Mining / Heavy Metals / Radionuclides
Canal / Ditch Cleanout	Monitoring / **Regulations**
Communication / **Coordination**	Nutrient Deposition / Acid Rain
Construction Erosion Control	Natural Nutrient Cycling
Economic / Community Issues	Program / Project Management
Education / Outreach	**Public Latrines**
Floods / **Droughts**	Recreational Overuse / Social Trails
Fish Stocking / Biological Diversity	**Septic Systems** / Septage Disposal
Funding / Resource Limitations	Small Point Dischargers
Fragmented / Damaged Riparian Areas	Source Water Protection
Groundwater Mining / Contamination	Stormwater (MS4s) / Urban Runoff
Higher Evapotranspiration / Dry Soils	Stream Straightening / Armoring / Encroachment
Higher Temperatures / Early Snowmelt	**Streambank Erosion** / Riparian Health
Illicit Dumping / Spills	**Road Networks** along Stream Networks
Internal (TP) Reservoir Loading	Water Rights / **Diversions** / Low Flows
Invasive Species / Noxious Weeds	**Water Quality Exceedances / Algae Blooms**
Lake Management / **Aeration**	**Wastewater Treatment Facilities**
Lawns and Golf Courses	**Wildfires** / Slash Management

The artifacts developed through the monthly design group meetings to discuss issues jointly in context as they were revealed through the prolonged engagement process led to important expansion in understanding among participants of the complex nature of the problems to be addressed (Appendix A, Appendix D). This led to several breakthrough concepts described in Section 4.2.3, many of which are already being further refined through more incremental engineering analysis, modeling, and planning activities.

4.2.3.1 ***Statistical Analysis Metrics***

With several years of consistent data collection methods at BCR and along streams throughout the Bear Creek Watershed, advanced statistical analysis techniques proved to be a helpful way to gain greater understanding of trends. Comparing results to other South Platte Basin watershed results and those with similar findings in other locations was also an important way to verify validity and possible causes to explore further. Although a monthly dataset has been collected through the long-term monitoring program for over a decade throughout the watershed, discrepancies between spot flow meter and automated gauge measurements demonstrate the importance of extrapolating flow meter data using the closest automated gauge to better quantify total flow at each station. It also demonstrated the utility of localized weather data at BCR to verify USACE evaporation calculations that may indicate underestimation during low flows, since groundwater inflows are not included and automated gauge readings have been observed to be more error prone during low and no-flow conditions. Flow-weighted estimates of incoming and outgoing TP loading show the difficulty of determining accrual because of confounding internal loading contributions. Although Reg, 85 requires wastewater point sources to bracket upstream and downstream of their discharge location under the assumption that WWTFs contributions will be easily recognized downstream compared to upstream of the discharge, except in extremely low flow periods, there was actually little correlation.

One concern arising from statistical analysis results was that monthly sampling required for regulatory compliance does not always provide adequate information for making management decisions. For example, sediment inputs during stormwater runoff periods are never captured during the rising leg of the hydrograph, so maximum nutrient loading cannot be adequately estimated for urban areas and road networks throughout the lower half of the watershed. The four main tributaries do not have permanent or periodic automatic gauging during high flows, so specific flow contributions and nutrient and sediment loading is not well understood. Current efforts to develop state sediment regulations could represent an important opportunity to seek grant funding for equipment and local support to obtain more information on flows and sources during periods of high runoff and floods.

4.2.3.2 ***GIS Metrics***

Over thirty layers were developed in GIS to support spatial analysis of nutrient sources and their relative contributions (Appendix F. Exhibit 1). Some of the results are highlighted:

- Water rights analysis determined over 90 miles of instream flow rights throughout the watershed, dozens of major water rights diversions, storage rights, and high capacity wells,
- Landuse analysis determined over 50 high-density OWTS areas of 30 units or more, and that only about half of the more than 43,000 residents are supplied by central wastewater treatment through a sewer collection system to a WWTF. It also showed ownership of the 43 percent of the watershed in public lands and revealed over 3,500 acres (over 5 square miles) in 34 conservation easements.
- Transportation analysis delineated over 350 miles of private drives, 850 miles of state, county, and city roads, mostly along streams, which often encroach on the floodplain and increases fine sediment loading.
- Aerial photos help delineate over 100 pastures or meadow areas and at least 230 horse properties delineated throughout these areas.

One of the most important benefits of the ACM DSS process involved sophisticated GIS analysis and modeling, resulting in an online, interactive set of maps to develop shared understanding through visualization. Understanding of potential nutrient source issues had been enriched through interviews, engagement, and qualitative / contextual analysis, ensuring a balanced, more-targeted approach to subsequent NPS quantification and delineation using GIS techniques. Specific interactive online mapping results are detailed in Appendix B-6, in the overview of the ACM DSS online toolset, and Appendix D, which reviews results from GIS and other types of analysis of each main nutrient issue.

4.2.3.3 ***Recommended Watershed Management Best Management Practices***

Based on the analysis of the nutrient issues described in Section 4.2.3 and detailed in Appendix D using the mixed methods approach, the following recommendations may be considered in future watershed-planning efforts to accelerate water quality improvement:

- Multi-provider, multi-jurisdictional integration of stormwater, water supply, wastewater, and water quality management.
- Partnerships for more comprehensive road and culvert management to reduce peaks, fines and other water quality concerns at all levels of government road and bridge departments, as well as, along paved and unpaved private drives.
- Further wastewater effluent treatment improvements, such as Enhanced Biological Phosphorus Removal (EBPR) as demonstrated to reduce WWTFs discharges ten-fold in one local instance, as well as, more attention to ongoing, incremental optimization to control TP chemical precipitation removal variability, especially to reduce TP peaks from WWTFs effluent discharges during periods of low flows.
- Ongoing flood, wildfire, drought, and economic downturn recovery assessment and lessons learned documentation for planning further steps to reduce losses and disruptions in the future.
- Effective implementation of new state and county regulations of OWTS with complimentary studies and education.
- Watershed-wide horse, elk, bird, and pet management plans to more consistently track and control concentrated animal waste issues.
- RBER assessment to define areas of exceptional biodiversity for further protection, reconnecting high-quality fragmented reaches, and conducting prioritized revegetation and restoration efforts (Section 2.12.1).

- Pebble counts conducted more frequently at more segments to determine benefits of erosion and fine sediment management for temperature and water quality control.
- What parameters do not improve may degrade, so vigilance will be necessary in periodically expanding project and activity assessments to understand more interacting social and environmental variables.
- Solutions must be constantly reevaluated and BMPs should never be assumed continual best management practices, since evolution means interactions, feedbacks, and variables are in flux.
- Over time, more players should be substantively included in the game to overcome or mitigate obstacles towards aligned, determined, active progress.
- There is no one secret to a healthy watershed. Controlling wastewater discharges provides limited additional benefits below a certain low threshold, so a more holistic approach is usually needed.
- More fine filtering and stream buffering is key – impermeable or source-to-permeable vegetated natural buffers could improve most nutrient source issues. Engineered innovations may substitute as needed.
- Less input – less fertilizer, fewer horses, birds and elks in proportion to a more distributed, diverse ecology, phosphate-free homes and businesses, and more stormwater barriers and attenuation could reduce sources.
- Higher flows – good stream substrate for baseflow with temperature control, less diversions, alternative timing and point of diversion, cleaner return flows and ditch cleaning and ditch waterproofing could help.

4.2.4 Coping with Unexpected Events while Reducing More Vulnerabilities

Before development of the ACM DSS process, efforts to plan for floods, droughts, wildfires, or unexpected events, like non-stationary climate trends, were not well developed. However, through the ACM DSS process, progress was made towards more systematic planning for more future possibilities.

Some recommendations include shifting resources and academic focus from attempting to forecast long-term climate trends to formulating methods to prepare more proactively for inevitable seasonal and annual variability that directly affects economies and societies (Glantz et al. 2013; Shultz 2014). The ACM DSS process supports these efforts by fostering shared learning with mechanisms to record and act upon lessons learned from both extreme events a community experiences itself, as well as, lessons learned that it has gathered from other communities that have experienced similar types of natural disasters and other surprises. In particular, Appendix D. Exhibit 12 demonstrates how the ACM DSS process performed in response to a September 2013 flood in the case study area to document, compare, plan, study, and act to reduce future flooding risks and effects. Before the flood arrived, ACM DSS focus had been similarly directed to analyze drought impacts to improve water security, water quality, and reduce ecosystem losses during a multi-season or extreme drought event. In both cases, new cooperative arrangements and targeted resource acquisition to change circumstances in the present were necessary to reduce risks and uncertainty anticipated under a wide variety of plausible scenarios. Political alignment was more easily achieved by having more usable information available in direct response to an event to attract funding and support for change while negative impacts were still evident and clearly documented.

The ACM DSS process demonstrated how a central repository served to collect lessons learned for improved response to extreme events, including droughts, floods, and source water protection with a focus on wildfire hazard mitigation (Appendix B-2). The Plan tool can be adapted to build information into any standard mitigation plan outline quickly (Appendix B-10). See Appendix D-12-14 for specific analytical details for each unexpected event type.

4.2.4.1 ***Coping with the September 2013 Flood***

In September 2013, a large flood significantly raised BCR normal pool level 50 feet for more than a month, increasing its normal volume from 1,891 to 14,366 AF. Two latrine vaults were submerged and both boat docks were destroyed. Much of the populated lower half of the watershed from Upper Bear Creek through Evergreen, Kittredge, Idledale, and Morrison required significant FEMA funding to repair damages to roads, culverts, streambanks, and structures along Bear Creek and its tributaries. However, this damage was caused by just five days of elevated flows of 900 to 1,200 cfs, a magnitude which may only represent a return period of about 5.5 years (an 18% probability of occurrence in any one year) according to the FEMA flood insurance study updated just this year (Appendix D. Exhibit 12). Even along state and county roads, some culverts and bridges remain undersized. Floodways are not always maintained to safely pass the probable 100-year event of 14,000 cfs at Morrison and of 4,000 to 6,000 cfs at the mouths of the four major tributaries. (See Appendix D-12 for details.)

The ACM DSS process was already implemented when the September 2013 flood arrived, so related flood issues were entered into the Issues tool as a permanent record, as were a number of implemented and proposed projects. Lessons learned continue to be added to the online knowledge base, as well. With a focus on adaptive management to take advantage of crisis, immediate attention was devoted to creating a flood recovery brochure and sharing it with citizens at flood recovery public meetings. As the floodwaters receded, exposed sediments were collected and analyzed to better predict long-term water quality impacts. The brochure was so successful, it led

BCWA members to begin a public Fact Sheet series, which will soon cover more than fifty additional topics. The exposed sediment study was expanded to include a central core sample nine months later to determine how phosphorus and organic matter levels in the flood sediments changed after extended submergence. The subsequent fall, six more sediment samples were collected throughout the reservoir in conjunction with water quality constituents and biological data to begin to develop an integrated reservoir management model to study extreme events and seasonal changes more effectively. Plans and studies to correct deficiencies in bridges and culverts and develop BMPs to share with streamside public and private landowners will continue, supported by new county rules to improve stormwater design requirements. The SNA of flood-related organizational relationships is also being systematically studied to determine how to improve coordination for future events (Appendix D. Exhibit 12. Figure 4). A state-funded, USGS-supported LiDAR project will update and increase the resolution of elevation data in the Bear Creek Watershed in response to the flood, which can also be exploited to improve integrated modeling in subsequent phases of development.

4.2.4.2 ***Planning for Drought Resilience***

In both periods during 2001-2002 and 2011-2012, the Bear Creek Watershed experienced relatively severe, though less than two years of drought in each instance. BCR stagnated and warmed, especially in late summer, as senior water rights diversions during times of drought dewatered the stream above the reservoir for more than thirty consecutive days. There are no instream flow rights on this lower portion of the stream through BCLP. Even where instream flow rights exist upstream, they are junior to all water rights before 1994, so they are rarely, if ever exercised to ensure minimum flows for fish and environmental health. Riparian habitat, including deep-rooted trees, did not die, but data has not yet determine if streambank erosion did increase in subsequent years or if blowing soils and erosion were exacerbated. Luckily, to fulfill the senior rights taken just upstream of BCR, all junior rights further upstream must be curtailed in times of drought, so instream flows are provided by default to supply the senior water rights withdrawal point downstream below Morrison, rather than through instream flow rights.

The ACM DSS process is already being used to conduct drought vulnerability assessments to build a more comprehensive watershed-wide source water protection and conjunctive use plan, rather than only planning water and sanitation district by district, as previously (Appendix D-14). Understanding interacting affects when setting individual district drought stages, trigger points, and response strategies are being considered holistically. Demand management and conservation may also become a greater focus in subsequent phases. Public landowners will begin meeting in Phase II to consider drought and other landscape scale risks, such as wildfire, conjointly, in which the ACM DSS process may be demonstrated and possibly promoted among this expanded group.

4.2.4.3 ***Contending with Growing Wildfire Risks***

Ponderosa pines, in dense, monoculture stands are evident particularly on north-facing slopes throughout the Bear Creek Watershed. In an area of the drier, southeast Turkey Creek subbasin, Jefferson County Open Space (JCOS) Meyers Ranch Park has allowed fires to occur more naturally on its open space, resulting in mature, mixed ponderosa pines and aspen stands. Fires under these circumstances do not burn as hot, removing brush but allowing the well-spaced mature coniferous and deciduous mix to continue to flourish. This provides improved habitat for elk and reduces harm they cause to less mature aspen stands. Jefferson Conservation District (JCD) is promoting similar efforts among other large landowners and through joint efforts by cutting where natural burns are not permitted or risky near the wildlands-urban interface. The ACM DSS process is being applied to promote these efforts, as well as to provide interactive maps from the Phase II Fire Study BCWA helped fund to analyze risks and set more direct, systematic, watershed wide risk reduction goals (Appendix D-13). In Vance Creek and Upper Bear Creek, which drain into Evergreen Lake, in conjunction with source water protection planning, several sites are being investigated as potential pre-permitted sedimentation basin sites (Appendix B-6.3). County officials are also developing slash management initiatives, which BCWA now is focused on promoting through the ACM DSS process, as well. One community that has received a national FireWise designation is also being used as an example to promote more watershed-wide programs for neighborhood-based fire reduction strategies (Appendix D-13).

4.2.5 Reinforcing Joint Academic and Watershed Program Reformulation

Specific problems need to be formulated in a way that would interest the academic community in providing more direct, ongoing support to watershed programs. This would provide needed expertise and insight into nutrient sources and biophysical processes to help foster solution innovations.

Observations made through academic interviews conducted through this research indicated that not only do departments within a single academic institution tend not to collaborate, but also cross-institutional collaboration in Colorado appears limited. For example, even though Colorado School of Mines (CSM), University of CO at Boulder and Denver (UC-Boulder, UC-Denver), and CSU all support watershed-related research in the Upper South Platte Basin, research rarely involves more that one academic institution, even though they may have complimentary focus areas. Federal and state government agencies also often conducted important research that was less likely to be published in scholarly journals, so the academic community was not always aware of their complimentary efforts and rich local datasets. Finally, local high school and undergraduate students and instructors are not often included in research activities, although they could prove to be valuable community education and study partners.

The goal of the ACM DSS process in later phases should not limit communities to a certain toolset or university extension program. Instead, each community should be individually evaluated to provide a buffet of multi-disciplinary, multi-university, multi-education-level, and joint government research services to improve their resource management at their current level of development and focus. Therefore, SNA could help analyze expertise and resources among all institutions in the state that could contribute to watershed program improvement. Results could be developed into a state-level online knowledge base, independent of any one watershed program, which could be accessed seamlessly from each group's own instance of ACM DSS online tools. Later, national-level, and eventually even an international repository could be created.

As an example of how the Phase I ACM DSS process assisted in fostering more targeted engineering research focus, Table 5 lists diverse follow-up studies that are being considered. This research was focused on new ways of distributing academic knowledge for more effective social-ecological analysis, as much as for informing academic transformation by introducing more different ways of knowing to the research community. In other words, a secondary goal was to develop mutual synergies between education and practice. Current plans are to use Phase I exploratory results to formulate an integrative, innovative approach to high school through graduate school learning through participation in watershed studies and improvement actions. There are four area high schools that include students from the watershed: Conifer (south), Evergreen (central), Clear Creek (northwest), and Green Mountain (east). Red Rocks Community College is also situated nearby, and Colorado School of Mines is in Golden, in the adjacent Clear Creek Watershed. Discussion has begun with all three academic levels, and CSU county extension, to develop a tiered program of academic development to provide students, instructors, and researchers meaningful ways to participate in watershed program studies and development. Such efforts would assist in developing an innovative hybrid-learning environment that embeds community practice into an educational framework (Jamison et al. 2014).

Table 5. Proposed Follow-Up Studies based on Phase I Results

Study Title	Study Description	Multi-Disciplines	Institution(s) Involved
Turkey Creek Conjunctive Use and Water Quality Assessment Update	2015-2017 groundwater / surface water quantification and quality assessment follow-up of USGS 1973-75, 1999-2001	Hydrogeology, Enviro.Eng, Hydrology, WRPM	CSU, UC-Denver, CSM USGS federal staff Jefferson County staff
Hyporheic Studies of Nutrient Fate and Transport & Temperature	Follow-up of EPA 2012-13 study of sw / gw effects on temp., chl-a, and shading at sites along Bear Creek to	Hyporheic Studies, Expert in Instrumentation	CSU, CSM EPA federal staff BCWA members
Nutrient Source Identification by coliforms, bacteria, chemical, and other indicators	Analyzing several sites displaying high nutrient levels for separation of sources by a variety of chemical, m-RNA, and micro-organism methods of analysis	Chemistry, Micro-biology, Enviro-Engineering, Bio-technology	CSU, CSM, UC-Denver, UC-Boulder, EPA R-8, USGS federal staff BCWA members
Multiple Lake micro-organism typing through bulk m-RNA analysis	Bulk m-RNA analysis of lake water & sediments of CO lakes for bacterial composition changes under cultural eutrophication to plan in-lake options	Enviro. Engineer, Limnologist, Microbiology, Bio-technology	CSM, EPA R-8 staff BCWA members BCLP and other lake staff CLRMA
LIDAR topographic data enhancements study	Determine how GIS-based models and river model results change with introduction of finer resolution data	GIS/RS, Hydrology, Geomorphology	USGS, Jefferson County, CSU, BCWA members
Leach field nutrient breakthrough analysis for landuse zoning	Obtain monitoring results from existing lysimeters and install several more to study soil treatment area performance	Soil Science, Hydrology, Enviro Engineering	CSU, CSM, RRCC, WQCD Jefferson & Clear Creek Counties
Bench-scale and mesocosms lake treatment studies	Try different phosphorus inactivation methods and biomanipulation practices for cyanobacteria bloom control	Engrs in Chemical, Mechanical and Environmental	UC-Denver, CSU, CLRMA BCWA members, BCLP and other lake staff
2013 Flood lessons learned survey and economic analysis	Survey all on-stream Bear Creek residents, businesses, and public landowners for costs and lessons	Economics, Political Science, Business, Hydrol.	CSU, Jefferson and Clear Creek Counties, BCWA members & participants
Decentralized system economic and technical feasibility study	Determine legislative, developer, industry, economic, and installer antecedent conditions to enhance feasibility of multi-family OWTS	Economics, Business, Political Science, Enviro. Engineer, WRPM	CSU, CSM, Jefferson and Clear Creek Counties, CWCB, WQCD, CWC, CWIC, CPOW
Mt. Evans / Summit Lake Human Impacts on Alpine Ecosystem Study	Analyze soil, water, microbes, vegetation, wildlife, air quality, weather to determine climate change and near and far human impacts on sensitive fen	Microbiology, Engineering, Enviro., Biology, Atmos. Science	CSU, CSM, USGS, DMP, CDOT, USFS, CO Heritage Program

Other areas of the state have already begun to build such programs from which to draw experience. Other national and international case studies may also provide inspiration. This will allow synergies to develop among the academic community at all levels while integrating education meaningfully into the betterment of the community on an ongoing basis. In this way, students will understand how their studies may apply in a diverse team of specialties to generate innovative ways to actively address local complexities. It is hoped that the youngest student or the oldest professional retiree can provide a critical component to the solution set that a less diverse team of academics or community interests could not have discovered. This may lead to both educational and IWRM-based stewardship breakthroughs, and likely both.

4.2.6 Feasibility of Scaling Up

Despite exhibiting very different characteristics, all of the South Platte Basin watersheds could benefit from the ACM DSS process applied specifically to their needs. No other watershed appears to have a system for issues reporting and option and project development and assessment. Those that already have watershed and lake management plans developed could still benefit by including all of the various sections and studies in an ACM DSS plan outline for more ready-access and for continual updating with additional materials. Map-based, real time data access and automated water quality graphing could help watershed community members become more familiar with water quality data trends in their specific location. Although each watershed could choose a different set of maps, the maps developed to date for landuse, ecology, fire hazard, water rights, and agriculture/ranching would probably be of interest to all of them. If one or more other watersheds began to use the ACM DSS process, it could begin to serve larger scale needs at the county, basin, and state-levels, as well as, for useful comparison purposes. At the state level, the ACM DSS process could allow the WQCD to develop a portfolio of increasingly aligned watershed programs to achieve cross-scale benefits and better plan regulatory improvements.

If an Upper South Platte Basin group was interested in using the online ACM DSS system components, the state, or USGS at the larger Missouri Basin scale, then even greater potential benefits may be realized. This would occur if watershed-level ACM DSS users agreed to allow basin-level or high-level access to their ACM DSS instances to develop statistical summaries, a regional dashboard of assessment tools, and generalized mapping and reporting. An example of how this could be accomplished is through the automated division and district summary pages the researcher developed for the Colorado Division of Water Resources (http://water.state.co.us/DivisionsOffices/Pages/default.aspx). The ACM DSS process could then also produce more effective regional-scale options and project development and assessment. In fact, an earlier version of the project development and assessment tools were originally developed for a Colorado statewide watershed restoration assessment program called *Measureable Results* (Herzog et al. 2012).

In time, a single statewide issues reporting system could allow watersheds not even using the ACM DSS process to provide important input locally, regionally, and statewide. As an example, the *Colorado Water Action*

Network was developed to allow citizens to report their involvement in water conservation, watershed and environmental group participation, and other water related activities for recognition and prizes (Herzog & Labadie 2011, Herzog 2012). Results could be provided to each respective watershed and water provider to enhance their community outreach and information gathering activities.

The flexibility of the ACM DSS process to build on nested and overlapping institutional and organizational management levels may enable cooperation without having to implement formal IWRM authorities. In the United States, the Chesapeake Bay, Florida Everglades, and the Delaware River Basin Commission have proven ACM success through regional control, and river-basin scale governance is preferred in many other regions of the world. However, in the United States, it remains more common for multi-jurisdictional and vertical institutional cooperative efforts not to favor this model. *Polycentrism* may be preferable to minimize the perceived distance between citizens and centers of authority (Huitema et al. 2009). The ACM DSS process provides an *organizing framework* and new institutional roles for network weaving, knowledge curation, and systems engineering without necessarily requiring the formation of a related *organizational body* or formal institution. Although in the case study, formation of a watershed-level nonprofit may become the next logical step in legitimizing expanded community efforts, meeting formal legal requirements, and facilitating funding acquisition, in many other cases, the ACM DSS process could merge or connect different institutional levels and existing organizational strengths more effectively without adding additional layers of institutional control. For example, the ACM DSS process could be used by various homeowners' associations in different cities, the county, the watershed, the river basin, and the state with slightly different implementations that could better integrate various needs through selective sharing. Efforts to test such nested systems will be an ongoing ACM DSS process implementation effort.

4.2.7 Feasibility of Adapting the ACM DSS Process to Other Purposes

The flexible, online ACM DSS process framework should allow relatively easy adjustment to other watersheds, scales, or purposes. None of the included tabs is specific to BCWA needs, but could serve other purposes or locations simply by altering underlying database content. The ACM DSS process is particularly applicable to other nutrient management watershed programs, because data access by monitoring station, the topical knowledge base, and planning tools would directly apply. In reviewing the ACM DSS toolset described in detail in Appendix B, it should be evident how each tool could serve a sustainable urban development purpose, or needs that are even more diverse, with relatively simple modifications.

Since the ACM DSS process was developed in an open source framework as an online toolset, it is relatively easy to generalize the underlying database tables for other purposes. For example, issues reporting would not necessarily have to relate to water quality. In fact, issues reporting was originally designed for reporting invasive species sitings, including Russian olive and tamarisk on the Dolores River in southwestern Colorado and noxious weeds in Jefferson County, Colorado. Even the watershed and lake management plan input tools could be substituted with any other formal plan outlines to be developed.

Many of the lessons learned about creating a more adaptive, collaborative program for watershed management could apply to a wide variety of other community programs, such as, urban renewal, early-childhood services for the disadvantaged, modernizing public schools, economic development, or other community-wide needs. Future effort should include testing the ACM DSS process for such diverse community requirements.

4.2.8 Process Emphasis and Future Implementation

It would be a serious oversight to consider the ACM DSS online components to be the main product of this dissertation research. It is deliberate and by design that the system is referred to as the *ACM DSS process* throughout this document; the online ACM DSS toolset is only a component of the design and theory of practice that must envelop and frame these tools to ensure full ACM operationalization. The number one concern expressed in the exit survey was how to keep ACM DSS tools updated and new users fully trained. This was one of the reasons SNA was such a central focus. By understanding SNA principles and tools, ways to further engage users over time could be explicitly determined and systematically pursued.

One way to accomplish this goal in future implementations in other watersheds and for other purposes will be for each ACM DSS process facilitator to be carefully trained and remain a member of a larger ACM DSS management worldwide collaborative in order to have access to the ACM DSS system. Appendix A includes many critical components of the ACM DSS development process that may be developed into a formal training guide for subsequent pilots and more expansive implementations. The process requires prolonged engagement by a sufficiently technical facilitator or team that receives ongoing ACM DSS process support, which is preferably committed to at least a full five-year program of development (Appendix A. Exhibit 21). Preferably, the facilitator would be directly involved in a community group, organization, or institution that has direct influence or control over the watershed or other purpose of ACM DSS process implementation to ensure its success. Without an extended process, full implementation of the sophisticated modeling framework depicted in Appendix B. Exhibit 22 cannot be achieved to ensure adequate integration of the community with the academic support, science and technological understanding, and innovation skills required to create truly transformative options. Phase I initiated community sense-making from a basis of their knowledge and desire for social-ecological system improvement. This case study demonstrated that only through first building sufficient trust and understanding, was a relatively collective viewpoint and direction achieved, which may now permit scientists and engineers to engage participants with greater effectiveness through their tools and trades.

The primary role of the civil engineer is community infrastructure – roads, bridges, water supply, sewers, buildings, etc. The civil engineer has always focused on fulfilling the most basic needs of society to live and work together more effectively during our exponential growth phase. The ACM DSS process helps expand this role to contend with our current resource limitations and uncertain future direction to build a shared future that provides more satisfying, shared benefits for both the continued advancement of our species and for a thriving planet.

4.3 How the ACM DSS Process Promoted Effective ACM

By comparing results of the ACM DSS process to characteristics of effective ACM explained in Section 2.6, it may be possible to evaluate its effectiveness in other respects (Table 6). By strengthening shared understanding and facilitating cooperation, the ACM DSS process seems particularly effective in promoting ACM among BCWA member organizations. As diverse sources of information populate the watershed and lake management plans, topical knowledge base, and group search, trust and understanding was fostered at more levels. The process appears to have led to greater tolerance for a wider diversity of opinion and solution options with a more directed problem-solving focus.

Applying the ACM DSS process to a large September 2013 flood particularly demonstrated its ability to increase reflection, knowledge gathering, community outreach, and targeted studies that may improve future response to more extreme flood events (Section 4.2.2.1, Appendix C. Exhibit 12).

Table 6. ACM DSS Process Performance (Plummer & Armitage 2007, Plummer et. al 2012)

Main Components of Effective ACM	**ACM DSS Process Performance Measurement**
Effective, Local Coalition Leadership	SNA, degree of centrality, number of connections
Coalition building, Social capital increasing, Shared Resource Management	SNA, bridging relationships, project affiliations, DSS selected options expansion of coalitions and linkages
Social Learning, Learning-By-Doing	Options selected with experimental aspects, incremental studies
Measuring Outcomes, Reflection	Action-oriented monitoring and assessment for change
Improved respect and use of local and cultural knowledge and diversity	SNA before and after, showing increased information and resource sharing and more diverse ties
Increasing communication and trust	More joint meetings, public outreach, contacts, trust
Bridging organizations, Brokers	Increase in organizations serving a brokering role linking federal, state, and local agencies and more diverse groups
Institutional arrangements for power-sharing and shared decision making	Regulatory framework, incentives, and enforcement improvements
Ability to solve economic and legal problems	ACM DSS ability to further incremental non-technical options
Actor empowerment, leverage, scope	ACM DSS ability to provide actors greater say in decisions
Shock resistant, Reduced vulnerabilities	ACM DSS nutrient compliance, drought, flood, fire management
Sustainable resource use, eco-health	ACM DSS selected options with secondary beneficial effects
Appropriate incentives / disincentives	ACM DSS selected options that change norms / sanctions

The Florida Everglades ACM Assessment (LoSchiavo et al. 2013) indicated additional components that should be included in successful ACM:

1. Ongoing funding and support from both legislative and regulatory authorities

A Bear / Turkey Creek Alliance (BTCA) nonprofit 501(c)3 corporation is being considered and more BCWA members are being encouraged to become involved in county, state, and federal regulatory and funding coordination activities. Another watershed reported that seeking nonprofit status nearly caused bankruptcy, but that may have been because it did not have an ACM DSS process in place nor underwent a comprehensive watershed program management evaluation to ensure adequate capacity to support such a transformational effort. Most other watersheds interviewed have a successful nonprofit component or park fees or local tax revenues to leverage member funding, but BCWA does not, which has greatly hindered its ability to effectively address nutrient source issues throughout the watershed. In studying successful forest conservation collaboratives, Cheng and Sturtevant (2011) noted that coalitions that developed formal non-governmental for-profit and / or non-profit organizations were more effective at obtaining and using resources, executing projects, developing internet and intranet resources, and working formally with area businesses. These activities will also be critical to implementing ACM effectively, so a nonprofit 501(c)3 corporation model is likely to be an important step to acquiring funds and resources to permit full, phased ACM DSS process implementation. This is also crucial because no similar mechanism already exists and BCWA member dues are already higher than most surrounding watersheds. Another funding alternative being considered is a BCLP decal that would be annually charged to all park visitors. A park decal already provides hundreds of thousands of dollars to Cherry Creek Reservoir, also of the USACE Tri-Lakes flood management unit. Chatfield Reservoir, the other USACE Tri-Lakes facility, is also seeking to develop state legislation to allow all watersheds in the state to more directly pursue a county mil-levy or other diverse funding mechanisms to enhance water quality.

2. Integrating ACM principles into existing institutional frameworks

Throughout the study, BCWA has become increasingly adept at developing policies, fact sheets, map sets, education resources, and other information to promote ACM principles of adaption and collaboration. They are also beginning to work more effectively with other organizations to consciously address shared issues more holistically. However, BCWA continues to experience difficulty communicating with certain federal and state regulators and obtaining county-level political support for BCWA improvement policies. Even though county planning representatives are BCWA members, there are other county departments from which the county representative cannot easily obtain support for water quality initiatives. ACM demonstrates that stronger, more diverse vertical linkages, particularly through cost sharing, will likely become an increasingly important way to continue to address these challenges.

3. Establishing pre-restoration ecosystem reference conditions and systems understanding

The GIS, statistical, and SNA analysis, the ACM DSS design group, and collaborative ACM DSS online component development all served to build greater understanding of the existing system, drivers, and interacting issues complexity. It also revealed knowledge gaps and social network gaps that might be more systematically addressed now through appropriate studies and more focused cooperative efforts. Later phases of the ACM DSS process (Appendix A. Exhibit 21) could implement an integrating modeling framework (Appendix A. Exhibit 22) to move these efforts further as funding and resources are made available to do so.

4. Characterizing uncertainty and developing management options matrices

Both qualitative and quantitative ACM DSS process components created a greater breadth of improvement options (Appendix A. Exhibit 12), while more clearly recognizing continuing areas of disagreement, uncertainty, and ambiguity, as described in nutrient source issue findings described in Appendix D.

5. Establishing independent review and feedback towards ongoing program improvement

By allowing the ACM DSS process facilitator to access all BCWA data and members, BCWA boldly shared all system knowledge, including weaknesses and potential threats to success. BCWA is planning to work more closely with more students and academic institutions and apply more innovative methods in 2014 and beyond, which demonstrates its openness to critical review to reduce deficiencies over time.

4.3.1 How the ACM DSS Expanded Social Learning

In Section 2.2.11, five main attributes of social learning were noted (Plummer and FitzGibbon 2007):

1. **An inclusive, deliberative process;**

   The ACM DSS process through interviews, ongoing facilitation, quarterly reporting, other systematic engagement efforts cited, and action/reflection provided a mechanism to build shared understanding.

2. **A systems approach to connect humans with their environment;**

   Through analysis and interactive mapping for visualization of each nutrient issue in terms of both the nutrient source transport mechanisms and the human causes, both physical and political that led to the situation, the ACM DSS process helped humans better focus on how they impact their environment and how degradation in ecosystem services may reflect back on their livelihoods and well-being.

3. **Integrating diverse perspectives, knowledge sources and disciplines**

   By expanding the social network through collaboration, diversity of opinion and knowledge sharing increased. The introduction of a researcher / facilitator accentuated the importance of a wider variety of disciplines and connecting to academic knowledge through an ongoing study focus (Section 4.2.5).

4. **Reflection on collective actions to learn more about system responses to plan future activity**

   By improving reflection following the September 2013 Flood, the ACM DSS process demonstrated its value for learning from past and current events, as well as, the experience of others in a similar situation to more proactively address future potentials.

5. **Double-loop learning, which questions underlying values and assumptions for transformation**

   Although not always easy or comfortable, BCWA leadership and members welcomed the challenge of an outsider continually questioning how they had conducted business for decades and how their future could be more adaptive and collaborative through the ACM DSS process.

4.3.2 How the ACM DSS Process Increased Social Capital

Section 2.6.2.1 discussed the need to increase social (civic) capital for effective ACM. The ACM DSS process in just this first phase clearly enhanced bonds between BCWA members in strategic ways and helped them begin to value public landowners and county and state regulators more systematically to permit more on-the-ground restoration and more effective nutrient control policy. Improving vertical ties among local, state, and federal levels, as well as horizontal ties among community interests are both gaining more directed focus. Trust between public entities, regulators, consultants representing small dischargers, and environmental groups have improved during Phase I, some of which may be directly related to the ACM DSS process. Interviewing all these entities – and especially by receiving more ongoing feedback from them over time – seemed to begin to change conversations and offer alternatives that tended towards relationship building. Simply increasing awareness of one another in this way and consciously indicating a variety of potentially shared interests appears to have had an impact. As demonstrated in the ACM DSS Quarterly Progress Report (Appendix A. Exhibit 20), the facilitator is tasked to train at least five new leaders of stakeholder groups each quarter to contribute to the ACM DSS online tools to further partnering, knowledge, and resource sharing. This has met with positive response among both BCWA members and external partners for ensuring that ties more consistently strengthen over time. The online ACM DSS toolset, in a sense, provide an enjoyable, relatively exclusive, knowledge-enhancing game to play, which builds creativity and new ways to consider both relationships and ideas. It also serves as a connecting symbol to build shared understanding.

4.3.3 How the ACM DSS Process Built Adaptive Capacity

The ACM DSS process was designed to focus on capacity building. It includes a group search tool for continually adding groups by location and type and a knowledge base in order to keep track of information, resources, and relationship building opportunities. The knowledge base attempts to make acquired information available to all organizational members, rather than only those who first acquired it, or those attending a particular meeting when it was discussed. The projects, options, and planning tools also focus on generating ideas for new studies from past actions to enhance understanding of social-ecological systems and their uncertainties. Quantitative study results provide uncertainty reduction for more effective selection of next steps. The ACM DSS process also encourages more academic review and the inclusion of more professional disciplines in research to improve study design and outcomes.

4.3.4 How the ACM DSS Builds Collaborative Capacity

Lynn Decker of The Nature Conservancy created a *Collaborative Capacity Inventory* from the framework Cheng and Sturtevant (2011) created from 30 federal forest partnerships to evaluate current capacity and ongoing needs (Appendix E. Exhibit 4). Individuals can rate their own individual capacity, that of their organization, and that of the focal coalition of organizations on factors related to organizing, learning, deciding, acting, evaluating, and legitimizing. Strengths of the ACM DSS process in collaborative capacity building appear to include increasing systems thinking, systematic focus on social network expansion, increasing expert knowledge, more diverse participation, improved communications, learning facilitation, strategic planning, increasing technological expertise, and the potential to improve financial support. In later phases of the ACM DSS process development, the *Collaborative Capacity Inventory* may be used as a mechanism for more detailed capacity building initiatives by individual, by organization, and for the coalition overall.

As described in Section 4.2.2, the ACM DSS facilitator, in the capacity of network weaver, systematically evaluated the network, greatly expanding bridging ties, while reinforcing bonds between existing BCWA members, participants, and associates. The participation of the facilitator in all meetings and events served as a constant reminder of the purpose and goals of the ACM DSS process towards greater adaption and collaboration. The process was reinforced through meeting discussions and systematic adoption efforts, as well as, through individual conversations before and after meetings to address concerns. This demonstrated successful fulfilment of the ingredients determined essential for network adaption for innovation and transformation (Moore & Wesley 2011). Section 4.2.4 further demonstrates this ability by indicating how planning and response to extreme events has been impacted by the ACM DSS process.

4.3.5 How the ACM DSS Promotes Specified Resilience

Through the quantitative analysis based on consideration of all the players, issues, and politics encountered through prolonged engagement, interviews, and ongoing feedback, the uncertainty and ambiguity discovered in analysis of each nutrient issue was not such a matter of inaction and hopelessness. The ACM DSS process revealed new -- often previously unconsidered – paths forward towards the next incremental study or action to reduce misunderstandings. By beginning to define drivers like excessive fine sediment effects and areas of inadequate riparian buffering and protection, less pressure will be placed on dischargers to be the sole means of controlling nutrient loading. A more systems-wide, balanced approach based on more upfront analysis and ongoing assessment will better ensure that each new action will be built from what has been learned from previous efforts. Each member will be better equipped to take on personal responsibility for each choice and vote. The project scoring tool (Appendix B-8.1) and BCWA board-adopted project evaluation requirements policy (Appendix A. Exhibit 14) add new ways to think through expenditures to enable good choices to be a source of pride through assessment and poor ones to be more quickly discovered and not repeated or continued.

4.3.6 How the ACM DSS Process Improved General Resilience

Perhaps the most important feature of the ACM DSS process is its ability to systematically build general resilience (Section 2.5.1). Simply by defining potential organizational and institutional players, interviewing each of them, and encouraging each to forge appropriate ties with BCWA and one another to strengthen resource management and institutional controls, each new challenge becomes easier to address. An improvement in one relationship between a public landowner builds capacity to reach out to the next. By working more effectively with one consultant of small dischargers, BCWA was able to work more effectively with their consulting partners, which previously had not participated constructively. The ACM DSS process instigated September 2013 flood follow-up, which further demonstrated how city, county, and park officials could readily support more coordinated response actions (Section 4.2.4.1).

4.3.7 Can the ACM DSS Process Support Better Planning?

Another immediate success of the Phase I ACM DSS process was the way the online Watershed Plan and Lake Management Plan input tools (Appendix B-10) finally encouraged more systematic planning almost immediately. BCWA leadership has taken an active role in creating a variety of inputs to fill in these planning outlines as quickly as possible to formally address the need for a flexible, yet well-documented planning effort that had been absent in the past. BCWA completed all major sections and formally adopting a watershed plan policy derived from these efforts. This is particularly important in the United States, because a watershed gains federal and state legitimacy through successful completion of a watershed plan, which can lead to more public and private funding and support.

4.3.8 Can the ACM DSS Process Promote RBER?

Rapid Biotic and Ecosystem Response (RBER) was described in Section 2.12.1 as a way to improve water management policy. The Phase I ACM DSS process delineation of public lands and issues of concern appears to have helped to define healthy riparian areas in need of protection and those requiring reconnection and rehabilitation. In particular, instead of being areas of the most protected habitat, the study found that public recreational areas were often some of the most denuded and eroded due to social and planned trail systems and overuse of riparian zones. Therefore, as demonstrated in the quarterly report in Appendix A. Exhibit 20, a decision to target public landowners and interest groups as the first expansion effort to Phase II partners for the ACM DSS process was approved by the BCWA board. This effort supports BCWA Policy 10 (http://bearcreekwatershed.org/Policies%20&%20Trading/Policy%2010%20-%20WQ%20Monitoring%20Tiers.pdf), which was also designed during the ACM DSS process to target a buffer zone of 200 feet from major streams and tributaries to focus NPS efforts and enforcement.

4.3.9 Can the ACM DSS Process Avoid Common Pitfalls

Section 2.6.2.6 outlined nine pitfalls Allen and Gunderson (2011) determined through systematic review of ACM in practice, which can be used to begin to evaluate ACM DSS process limitations:

1. **Stakeholders are not substantively included in rule and decision-making.**

   In Phase I of the ACM DSS process, several new stakeholders were included in BCWA activities and projects. Although these new and improved relationships may not be directly attributable to the ACM DSS process itself, the values of collaboration engendered among BCWA members through interviews and ongoing communication appeared to have assisted organizations and institutions to become more aware of one another's needs and potential for contribution, which may have both directly and indirectly led to these results. The spiral model and systematic focus on continual inclusion of new stakeholders at a pace and focus that make sense to BCWA members will reinforce current efforts.

2. **Considering actions as experiments with sufficient evaluation is difficult.**

   The Phase I ACM DSS process was not overly concerned with the adaptive management principle of action as experiment, as much as, creating a paradigm for more targeted adaption and collaboration in future interactions. Therefore, evaluation at this stage should consider if Phase I improved antecedent conditions for better action design and assessment. This appeared to be the case, because reducing ambiguity and uncertainty in understanding of nutrient issues and fostering a more proactive concern for flood, drought, and wildfire planning made members more open to academic studies and alternative actions that would lead to greater experimentation and better, more systematic results assessment. Adoption of Policy 22 for project evaluation created through the ACM DSS process also formally requires multi-criteria analysis of potential project benefits for comparison in funding allocation and annual follow-up assessment of each choice selected (Appendix A. Exhibit 14).

3. **Surprises are not embraced as a learning opportunity, but disregarded.**

   The response to the September 2013 Flood (Section 4.2.4.1 and Appendix D. Exhibit 12), as well as, renewed focus on source water protection with wildfire hazard mitigation control (Appendix D. Exhibit 13) and drought planning (Appendix D. Exhibit 14) demonstrate that the ACM DSS process was particularly effective in increasing follow-on activity from an unexpected event to improve both immediate outcomes and better plan for future events of greater magnitude or duration. However, since complex social-ecological systems are always evolving, it will be important for the ACM DSS process in later phases to assist in further assessment of alterations in the environment. Otherwise, simply adopting lessons learned today as best practices for tomorrow when conditions may have changed may prove to be shortsighted.

4. **Coalitions default to status quo formulas when facing uncertain challenges.**

   The breadth of online tools for interactive visualization of problems and solutions facilitated BCWA members to reconsider their options more systematically to avoid over reliance on heuristics and belief systems that may have helped them in the past, but may be less effective in their new adaptive, collaborative focus. A commitment to strategic, longer range planning in formulation of watershed planning input and improved response and learning from unexpected events further demonstrated how the ACM DSS process has facilitated BCWA to adopt a new way forward.

5. **Groups tend to exchange and deliberate rather than maintain action orientation.**

   BCWA was surprisingly effective at using the ACM DSS process as an impetus for developing an entire series of policies, fact sheets, maps, and input for watershed and lake management planning. For decades, the group had wanted to achieve these results, but only during Phase I of ACM DSS process implementation did these plans finally become more deliberate, documented actions.

6. **Learning is only worthwhile, if it is applied to improve policies and management.**

   BCWA complimented the ACM DSS process by deciding to formalize every learning and discussion with a policy that encapsulated findings. Appendix A. Exhibit 23 demonstrates that just a few policies had been developed over several years prior, but were expanded to dozens since Phase I of the ACM DSS process began, and continues at an accelerated pace as BCWA moves into ACM DSS Phase II development.

7. **Decision makers are risk averse, preferring not to wrestle with ambiguity.**

   Although this remains true to some extent, with decision makers preferring to select a direction rather than consider a wider range of alternatives through discourse with more disciplines and perspectives, ambiguity is being addressed in several important ways. When numbers are presented, they are now more carefully associated with a particular study or actual calculations, so there is more agreement on error propagation, estimation techniques, and resulting precision, and accuracy. NPS planning has been introduced as an important interaction with point source pollution that must be addressed to reduce emphasis on only WWTF regulatory control, which is both expensive and an over-simplification of the complex issues causing BCR cultural eutrophication.

8. **Staid leadership and targeted outcomes are often lacking or one party controls.**

   Although BCWA members remain point wastewater dischargers and stormwater dischargers under EPA federal NPDES regulatory control, the ACM DSS process is reaching out to partners and participants among public landowners, environmental interests, regulators, and researchers to more effectively incorporate knowledge and resources from a wider variety of sources to address nutrient issues. A nonprofit 501(c)3 corporation is also being considered to provide more community resourcing, volunteering, and participation opportunities in Phase II. BCWA leadership has been paramount in ensuring that such a dramatic new direction represented by the ACM DSS process would be so readily adopted. Even with effective facilitation of an engineering researcher or related professional, it would be unlikely that the ACM DSS process would have been so successful unless a strong, talented leader had embraced this new paradigm and encouraged its universal adoption over time. Designating such a coalition leader should be a critical step in determining if a community should consider the ACM DSS process, or if efforts should first focus on establishing leadership as an antecedent condition for success before attempting Phase I ACM DSS process implementation.

9. **Planning processes are too time-consuming or results are not enacted.**

   The lake and watershed plan outlines to drape input upon represent a breakthrough in planning, because it quickly assembled all needed resources and organizations without the burdensome worry of EPA 9-element watershed plan development (Section 2.12). Even though results appear to satisfy EPA compatible watershed plan requirements, this method of incremental development, and visually seeing the different sections becoming populated is more like a game than a chore. Reg. 74 required formal watershed planning within three years of implementation, but it had never been accomplished in more than 10 years, until the ACM DSS process created this alternative formulation route.

4.3.10 ACM DSS Toolset Serves as Organizing Principle and Symbol

Scott (2014) emphasizes that symbols allow institutionalized ideas to move from place to place and across time. The continual development of the online ACM DSS interactive toolset embedded in the ACM DSS facilitate process successfully demonstrated an ability to build a mindset towards incremental, coordinated activity by linking organizations to issues to be addressed through projects and options with supporting scaffolding from maps, data, and knowledge stores. It simplified the process of relating.

4.4 Watershed Manager and Program Assessment Criteria for Program Evaluation

Through studying all watersheds in the Upper South Platte Basin complimented by research of successful watershed programs throughout the United States and the world, it was possible to determine traits of both an individual Watershed Manager and characteristics of Watershed Programs in general that may be particularly helpful in fostering ACM principles (Section 4.4). Using these measures as criteria in evaluating ACM DSS process results will ensure that operationalization promotes effective management. Evaluating both the individual manager or management team and measures of the resulting program provide a more robust evaluation scheme for testing results and better analyzing sources of deficiencies.

4.4.1 Traits of a Successful Watershed Manager

The BCWA watershed manager developed 20 Principles (Code of a Watershed Manager) based on over 30 years of experience in the role of watershed manager for at least four watersheds (Appendix A. Exhibit 25). He also developed state and regional watershed programs that contributed to the factors presented. Relationships and system-wide understanding were stressed, as well as, adaption, visioning, goal setting, and taking a long view. Understanding the watershed through data collection and observation were also noted to be important. It was also mentioned that *knowledge is power*. However, it may be helpful to clarify that while shared understanding may provide cooperative, innovative ways forward, hoarded knowledge may serve more as a political weapon, which tends to increase cohesive cliques and fragmentation. For this reason, the ACM DSS process fostered *transparency* by allowing even *external*, trusted group leaders to participate in the knowledge-building and knowledge-sharing processes.

The PMI Standard for Program Managers (PMI 2013b) also has develop a set of core knowledge areas and skills required of program managers that could apply to watershed program management overall, as a guide for more comprehensive program development (Table 7). The watershed program manager would probably require a program *team* of specific skill sets to meet all formal competency requirements effectively, since no one person is likely to be trained and experienced enough to possess all skills, nor have time to fulfill all needed roles. Although Table 7 is business-oriented, it still applies rather well in most subject areas, so attaining these features could improve ability of a watershed program to employ the ACM DSS process through enhanced management capacity.

Notice how many of the core skills include aspects of communication and coordination. Excellent use of tools and techniques for budgeting, options development, problem solving, decision making, data analysis, organizing, collaborating, motivating, planning, analyzing stakeholders, managing project scope, schedule, and costs, expanding knowledge, and reporting are all crucial core competencies. Watershed programs are extremely complex, as complex as a large airport construction project or a nation-wide drug awareness program might be, and the benefits are equally important to meet critical needs of communities and regions. Program structures that do not reflect sufficient role and task diversity will not adequately address the necessary program complexity required in designing complex social-ecological-technical integrations. Therefore, core competencies should not be ignored and manager and program evaluation criteria and regular evaluations should be incorporated more directly in later phases of ACM DSS process development.

Though no watershed program interviewed had adequately developed all of these core competencies fully, all watershed programs should strive to attain more of them. Watersheds that exhibited a hierarchical (tiered) staffing structure tended to have more diverse expertise and staff time to devote to a wider range of activities to build more competencies. SNA demonstrates that each additional staff member could also build additional relationships with more organizations and institutions to leverage resources. Research indicates that both location and profession play an important role in providing connections to peripheral resource needs (Granovetter 1973); therefore, a tiered management structure with more diverse capabilities can also access resources more effectively. A tiered organizational structure also ensures a stronger core-periphery structure, so that if one staff member leaves, it is less likely to create a leadership crisis or mission shift in the watershed program.

Table 7. Program Manager Core Knowledge and Skill Areas (Adapted from PMI 2013b)

Core Program Manager Knowledge Areas		**Core Skills**
Benefits Measurement & Analysis	Knowledge Management	Active Listening
Budget Processes & Procedures	Leadership Theory & Methods	Employee Engagement
Brainstorming Techniques	Management Techniques	Communicating
Business Environment	Motivational Techniques	Critical Thinking / Problem Solving
Business Ethics / Building Trust	Strategic Planning and Visioning	Customer Centric / Client Focus
Business Models and Organization	Performance Management	Requirements Analysis
Nonprofit Reporting Requirements	Planning Theory & Methods	Capacity Planning
Mentoring Techniques	Presentation Tools & Techniques	Executive-level Presentation
Collaboration Tools & Techniques	Change Management	Facilitation
Contract Negotiation & Administration	Project Management Information Systems / Scope & Scheduling	Interpersonal Interaction / Relationship Management
Conflict Resolution Techniques	Reporting Tools & Techniques	Innovative Thinking
Contingency Planning	Risk Analysis Techniques	Interviewing
Communication Tools & Techniques	Risk Management	Leveraging Opportunities
Contract Types	Data Analysis / Data Mining	Managing Expectations
Stakeholder Analysis Techniques	Safety Standards and Procedures	Managing Diversity / Remotely
Cost Management	Social Responsibility	Prioritizing
Cultural Diversity / Distinctions	Community Engagement	Negotiating / Influencing
Risk Mitigation and Strategies to Take Advantage of Opportunities	Problem Solving Tools & Techniques	Maximizing Resources / Achieving Synergies
Cost / Benefit Techniques	Succession Planning	Time Management
Decision Making Techniques	Sustainability & Environment	Contractor / Vendor Management

4.4.2 Attributes of a Successful Watershed Program

Comparing watershed programs throughout the Upper South Platte Basin led to the contrasting factors for success shown in Table 8. Research was also considered from other successful watershed programs nationwide and worldwide in developing successful watershed program characteristics. Similar to the findings of Plummer et al. (2012) in systematic review of ACM, no single watershed program exhibited all or even the majority of successful attributes, but each one did some things very well.

Table 8. Watershed Program Success Factors for Adopting ACM

<table>
<tr><th colspan="2">1. TIERED ORGANIZATIONAL STRUCTURE</th></tr>
<tr><td>Less Successful Features</td><td>More Successful Features</td></tr>
<tr><td>• One full-time watershed manager hired to meet all diverse program needs
• Program structure does not shrink or grow with workload
• Static policies</td><td>• Layered organizational structure includes management, monitoring, engineering, financial, and outreach team
• Employs Vista Volunteers for additional full-time support
• Pays various part-time staffers for specific expertise
• Pays member organizations to provide watershed services
• Includes financial management, accounting, and auditing
• Large consultants, instead of individuals, may fulfill various roles more effectively through expert skill diversity</td></tr>
<tr><td colspan="2">2. COMPREHENSIVE REPORTING SYSTEMS</td></tr>
<tr><td>Less Successful Features</td><td>More Successful Features</td></tr>
<tr><td>• Minimum average results reported annually to state CDPHE WQCD
• No specific corrective action defined for each water quality exceedance</td><td>• All results are provided near real time from an online system
• Online system includes dashboard of automated graphs and statistics describing variability, system changes, and threshold risks, in addition to progress on ongoing projects, assessment results, and status of prioritized control options
• Results are discussed as a group each month to plan documented corrective actions to exceedances as they occur
• Include videos, fact sheets, project reports, and assessments</td></tr>
<tr><td colspan="2">3. ADAPTIVE MONITORING PROGRAM</td></tr>
<tr><td>Less Successful Features</td><td>More Successful Features</td></tr>
<tr><td>• Small watershed team responsible for all monitoring
• Discourages academics, community groups and others from collecting data or verifying results
• Monitoring is only conducted monthly to meet regulatory requirements</td><td>• Community volunteers, wastewater and stormwater dischargers, environmental groups, and public landowners all collect samples for periodic collective analysis
• Watershed-wide network of automated gauges
• Mobile gauges are placed as-needed in areas of concern
• One or more university programs is actively involved as monitoring partner, auditor, and for specific studies
• Monitoring to meet regulatory requirements is considered secondary to ongoing watershed assessment purposes
• Large flow events are gauged and sampled for quality
• Unexpected exceedances lead to comprehensive survey and assessment, option analysis, and control actions planning</td></tr>
</table>

Table 8. Watershed Program Success Factors (Continued)

4. COMMUNITY PARTICIPATION	
Less Successful Features	**More Successful Features**
• No periodic public meetings • Little direct, ongoing public involvement • Public is considered an adversary, uneducated • Public is not consulted in design of projects • Board meetings are not attended by the public • Less than half of due-paying members attend board meetings	• Diverse and well-attended public meetings • Major community-wide events are held regularly in each population center to expand recreation and awareness • Meetings include phone-in option and after meeting surveys • Meetings describe actual state of watershed and progress • Training is provided to monitor and report issues • Community is regularly solicited for volunteers, resources, donations, and community expertise, and included in plans • Board includes select members of the public and experts • Many additional community groups attend to report on monitoring and project progress and new proposal ideas • Public landowners and business community attend, too • Community involvement expands evenly over time
5. PROACTIVE MANAGEMENT	
Less Successful Features	**More Successful Features**
• Unexpected events addressed as occur • Planning documents have not been developed for droughts and floods	• Floods, droughts, economic downturns, wildfires, spills, and other potential risks have been pre-assessed • Plans have been developed on actions to take at each threshold trigger and online systems monitor real time risks • MOUs have been developed to ensure coordination for ongoing risk reduction and mitigation activities for readiness
6. FORMAL PROJECT EVALUATION PROCESS	
Less Successful Features	**More Successful Features**
• No evaluation system • Project selection is based on prestige of project proponent	• Proponent/team proposes previously well-evaluated project • Technical committee further evaluates and discusses merits • Only if merits justify it, regular membership vote for approval • Project portfolio is planned and assessed at least annually
7. LINKS WATER QUANTITY AND QUALITY	
Less Successful Features	**More Successful Features**
• Water quality and quantity have not been linked • Water rights holders have not been included in water quality plans	• Watershed wide conservation, fire flow MOUs, surface and groundwater water rights optimization management, instream flows, and cooperative drought MOUs have been developed to minimize ecological and water quality affects of extended drought or other causes of extended low flows • Coordinate for floods, high or low snowmelt periods, also

Table 8. Watershed Program Success Factors (Continued)

8. BOTH POINT AND NON-POINT SOURCE NUTRIENT CONTROL FOCUS	
Less Successful Features	**More Successful Features**
• Control focuses on reducing only obvious point discharges • Focus on meeting arbitrary nutrient reduction levels for all dischargers equally, rather than being based on technical capabilities of each facility and operator, other unique issues, and creative incentives programs	• All wastewater dischargers work together to maximize nutrient reductions through technical transfer & incentives • Small dischargers are involved in innovative studies with academic institutions to cost effectively reduce nutrients • Control includes lake sediment and bloom management • Innovative water rights coordination expands water sharing • Land conservation trusts improve riparian protection • Defragmentation and buffering of riparian areas highlighted • Manure management plans with conservation funding • Onsite wastewater permits and effective enforcement • Stormwater collection and treatment where needed • Low-impact development and stormwater detention • Redevelopment for water quality improvement purposes
9. VERTICAL ALIGNMENT	
Less Successful Features	**More Successful Features**
• Limited success satisfying federal and state regulatory requirements • Limited interaction with state and federal landowners in the watershed • Does not apply and coordinate regularly for government grants, resources, and direct support • Watershed stakeholders contact state and federal regulators about dissatisfaction with management decisions	• Meets or exceeds federal and state standards or makes faster progress in doing so than surrounding watersheds • Is selected as pilot for innovative government programs • Helps fund and provide resources to allow federal landowners to participate in watershed-wide programs • Receives funding and resources from state and federal programs on a regular basis and more so over time • Well-planned studies lead to changes in state and federal regulations or reinterpretation for site-specific standards • Federal and state staff interviewed warmly describe the watershed's accomplishments and coordination activities • Watershed documents and processes are showcased in federal and state websites and guidance documents • Watershed stakeholders are fully consulted and committed to decisions the watershed management team makes that would effect its state and federal regulatory compliance • Federal and state regulators and landowners are considered integral to policy development, participate in joint projects & activities, and attend meetings regularly
10. DIVERSE FUNDING SOURCES	
Less Successful Features	**More Successful Features**
• Funding is provided only by organizational member contributions • Only wastewater and stormwater dischargers contribute to program • Not all pay their dues • Funding only covers basic monitoring costs	• Base funding is provided only in part by point dischargers • Public grants, businesses, foundations, community funding • In-kind donations include vehicles, equipment, and services • Watershed program funds member activities and projects • 501(c)3 corporation for other funding and asset protection • Online and credit card donations accepted, not just cash • Well-attended fundraising events provide program info, too • Recreational fees include water quality component • District or county-wide taxes help fund watershed programs

5.0 CONCLUSIONS

Based on Chapter 4 Results and Discussion, ten key findings were demonstrated through collaborative development and testing of the ACM DSS process and online toolset.

1. A watershed would likely benefit from ongoing, substantive involvement of a "resident engineer"

This research represented a departure from more common water resources and environmental engineering studies in its focus on developing a prolonged engagement process spanning more than two years. Study of sociology and implementation of sociological research methods and tools and advanced communication and facilitation methods through ongoing consultation with multi-disciplinary experts were critical components of this otherwise technical endeavor. Throughout the Phase I ACM DSS process, the engineering researcher was enabled to introduce engineering analysis results of the complex problem of cultural eutrophication in a way that demonstrated understanding of the additional uncertainty and ambiguity inherent in multiple perspectives. This helped reduce functional, societal, and institutional fragmentation, while encouraging a collective problem-solving mindset. Trust and other forms of social capital were built continually among an ever-expanding coalition of organizations, emphasizing the benefits of improved connectivity and an incremental, action oriented focus as part of an engineer's expanded integrating role towards IWRM.

Table 9 lists expertise contributed by incorporation of a resident systems engineer in watershed program development and transformation, and some of the other expertise needed for effective ACM through this research. Evaluation of watershed program success factors (section 4.4) and results of the network weaving process (Section 4.2.2) also demonstrated the need for watershed program management structures to reflect more diverse professional expertise to meet today's complex challenges. Each expertise would benefit from formal training and active management of their progress in network weaving to maximize overall IWRM success through expanded cooperation in later phases of the ACM DSS process for watershed program development. In limited funding situations, professional volunteers, often retirees, have provided critical support. They often provide the additional benefit of local knowledge of issues in their community.

Table 9. Need for Transdisciplinary Collaboration to Support the ACM DSS Process

Engineering Strengths	**Other Needed Expertise**
Hydrology / Hydraulics, GIS / Statistics	Group Facilitation / Network Weaver
Integrated Modeling / Model Calibration	Curation / Knowledge Management
Water Quality / Unit Processes / Environmental Monitoring	Project & Financial Management
MCDA / Optimization	Program Administration
DSS / Expert Systems / Computer Programming	Legal / Dispute Resolution
Error Propagation / Accuracy / Precision	Systems Analyst / Software Developer
Engineering Design / Field Data Collection Design	Limnology / Aquatic Biology
Project Estimation / Assessment	Field Experience / Analytical Lab Tech
Problem Definition with Assumptions & Constraints	Marketing / Public Relations
Problem Solving Techniques	Education & Outreach
Project Management / Inspection	Political / Legislative

2. **Systematic, expanding connectivity may be supported by SNA and Trained Network Weavers**

SNA was demonstrated to be a critical tool to force more systematic analysis of ongoing relationships and transactions to foster IWRM. By creating SNA of each nutrient issue, complex relationships not only among organizations, but also among other aspects of the social-ecological environment, such as multi-level, multi-jurisdictional regulatory frameworks and human / environmental interactions could be more consciously considered. After initial SNA model development for each issue, analysis may be continually expanded over time to demonstrate improvements in different forms of connectivity and converse reductions in fragmentation. SNA provides important new metrics for program evaluation towards a more resilient core-periphery network structure and measures of trust and exchange. Formally training practitioners in network weaving through development of a SNA workshop for this purpose was demonstrated to be a potential improvement in both engineering research and practice. Incorporation of the SNA workshop in this research demonstrated how the academic community could design a more intuitive, *evolving social role* for the 21st century university (Bonnen 1998) . Systematic outreach and extension combined with integrative education initiatives may directly orchestrate activities and coordination in each local community towards improved future resilience to begin to build a framework to support more rapid, effective adoption of innovation across sectors.

3. **Technical connectivity may be supported by the ACM DSS Toolset and Knowledge Curators**

In his exhaustive summary and analysis of the progression of the field of institutional theory, Scott (2014) notes that two factors of effective institutional development include symbols and techniques to reinforce a collective mindset towards fulfilling institutional mission. The online, interactive ACM DSS toolset was demonstrated to fulfill both requirements in important ways. The ACM DSS process serves as a potent symbol of a departure from previous ways of conducting business as isolated organizations by allowing all organizational participants to continually contribute issues, group and topical knowledge, options, projects, and plan input to evolve a more collective vision over time. It built a mindset of inclusiveness and interdependence that was previously absent in some members and not consciously pursued among others. Discourse among BCWA organizational members and participants at monthly meetings has become more action-oriented and a wider range of potential options are now being considered. Regulators are understood to be important partners to interpret rules more flexibly and adjust emphasis to address systemic issues more effectively. ACM was also promoted by technical improvements in formal project evaluation processes to score and select best options and to build mechanisms to assess individual and collective project progress at least annually. Sharing knowledge generated through studies, analysis, comparisons, and contributions allows for more rapid, intelligent, directed progress. Each organization gains a sense of system ownership and responsibility beyond its own objectives and roles to support more collective action, because the substantial benefits of cooperation with others is technically easier to recognize and promote among its managers and constituents by demonstrating progress through the growing knowledge shown in each ACM DSS tool.

However, knowledge building in the ACM DSS toolset will not occur without careful attention to achieving this goal at every stage of ACM DSS process development. Designating one or more ACM DSS knowledge curators for each new ACM DSS process instance will be crucial. The “knowledge curator” will remain as essential to ACM DSS toolset and accessible knowledge expansion as the “network weaver” will remain to direct SNA expansion to effective core-periphery network structure. Curators are tasked with continually entering information into the online system discovered in documents, meetings, and one-on-one communications with all participating groups, surrounding watersheds, and from different scales, international studies, and especially from the results of each individual and collective action. Without continual knowledge expansion, the ACM DSS process will stall or even unravel. Although organizational participants can and do enter information into the ACM DSS toolset directly, the support of the curator ensures more complete information from more diverse sources. Effective curation can help prevent poor actions from being repeated for lack of sufficient evaluation and help ensure that effective practices will be more universally adopted. Curation also helps prioritize funding and other resources to align with the most advanced state of the collective knowledge, rather than being based as much on previous power structures and engrained habits.

4. **Adaptive co-management was effectively demonstrated to further IWRM principles**

Traditional consulting project-by-project and research isolated study-by-study engineering has not allowed IWRM to be effectively implemented at the pace necessary to alter unsustainable trajectories. However, recently there has been an explosion in many unrelated fields, which now all seem to recognize the necessity of direct attention to both incremental, system-wide action-and-assessment methods to address complex uncertainties and ambiguities in social-ecological interactions and the need for multi-scaled, shared solutions. This case study demonstrated that ACM is not just an alluring framework, but that systematic implementation is both practical and possible through careful attention to research-based process and tools development to ensure continual social network expansion, diversification, and inclusion and incremental action-by-action improvement.

5. **An effective resilience practice will continually improve both specified and general resilience**

Reducing the risks of crossing irreversible thresholds and the possibility of shocking social-ecological systems into states that are more desirable can both be more consciously pursued through monitoring and modeling to manage specified resilience. However, this cannot be accomplished without significant effort to understand complexity, uncertainty, and ambiguity inherent in complex social-ecological interactions. This research demonstrated how more formal complex system thinking and analysis contributed to forwarding resilience practice to better manage nutrient issues and related watershed program challenges. By consciously reducing fragmentation and coordinating alignment in advance, it also permitted the community to better contend with unexpected events, thereby improving general resilience, as well.

6. **Further community-wide integration is required to achieve transformative change towards IWRM**

Throughout Phase I, prolonged engagement focused on understanding, before encouraging progressive, paced, change, in organizational alignments throughout the community. However, in later phases, greater attention will also be required to further community participation and reintegration in three other important ways:

i. developing a community-wide nonprofit organization to promote direct community participation,
ii. creating a multi-institutional, multi-disciplinary, multi-level effort (local high school through graduate school watershed study integration) to actively involve academic faculty and students in studying local

social-ecological systems complexities and potential improvement and assessment options (Section 4.2.5), and

iii. establishing innovation clusters for specific, local challenges to involve more industrial and business sectors substantively to generate context sensitive solution innovations.

7. **Cultural eutrophication is a global crisis requiring complex analysis and greater action-orientation**

Engineering analysis of nutrient issues contributing to cultural eutrophication demonstrated how to begin to analyze complex interrelationships. In particular, it demonstrated how water rights diversions, water residence time, groundwater, fine sediments, nutrient deposition, and seasonal effects might each contribute to cultural eutrophication. Phosphorus desorption from reservoir bottom sediments usually doubles loading in mid-summer to exacerbate blooms in August and September. Incoming dissolved phosphates from wastewater point sources may only represent a minor fraction of the total, despite its regulatory focus. NPS, including OWTS, denuded horse properties, urban areas, road networks, deposition, and streambank erosion may contribute more than double the nutrients in most years. Since only a fraction of the NPS dissolved and particulate TP sources might ever be significantly reduced, it is possible that BCR – with fast flushing in spring, stagnation in summer, and a relatively small, permanent-pool-to-drainage-area ratio – may prove to be an irreversible reservoir (Carpenter et al. 1999, Hejzlar et al. 2006). This does not signify that it will not be important to seek reductions in all sources of TP delivery mechanisms continually based on economic, political, and technical feasibility. Rather the purpose of the ACM DSS process and toolset will focus on continually becoming more adept phase-by-phase in addressing this goal. However, it does signify that regulatory frameworks, which tend to target only a few water quality parameters, may need to focus instead on how well BCR is meeting its desired uses. Emphasis on threshold monitoring to ensure incremental improvements in a wider variety of ecological measures may also be necessary to prevent BCR from shifting to an even more undesirable hypereutrophic state (Duarte et al. 2008).

8. **Regulations and management practices need to transition to better address water quality, quantity, groundwater, and surface water, economics, and ecosystems in a unified framework**

IWRM is not only concerned with addressing sectorial, societal, and institutional fragmentation, as much as, in managing all aspects of the hydrological cycle in conjunction with contaminant fate and transport to achieve successful measures of economic and ecosystems health. Integrated water resources and environmental modeling has still not reached a level of maturity to provide a single, integrated framework to consider the full complexity of water as it moves from the airshed to the watershed and through surface, subsurface, and aquifer interactions that could be manipulated conjunctively in space and time to improve water quality and avoid water scarcity. It will require an international effort to develop the needed scientific research, parameter estimations, sensitivity analysis, model comparisons, and integration frameworks necessary to achieve this important goal more rapidly. Although no model is a complete reflection of reality, modeling is an effective means to evaluate and optimize next steps as each new piece of information is added and each theoretical and conceptual improvement is integrated. By focusing on continual modeling, data gathering, and data analysis improvements, enhanced forecasting abilities may reduce risks of unanticipated catastrophes from occurring, undesirable thresholds from being crossed, and more social-ecological benefits to be achieved. The risks and benefits of innovation can also be more objectively addressed through modeling to encourage an expanded choice set to permit breakthroughs that could further reduce the relative costs of mitigation and restoration projects and ACM implementation.

9. **Through concerted, conscious effort, communities can design new ways forward to reduce risks**

This research demonstrated a number of novel, yet potentially effective ways in which communities may more consciously design their future, particularly through mechanisms that support more diverse discourse and cooperative actions. This has been a recurring theme in the study of social evolution of the human species, yet research that has specifically sought to demonstrate this active evolutionary potential has been limited. The research-based ACM DSS process and online toolset represents a flexible, generic process that could be applied at one or more scales of a problem simultaneously, and used to address diverse community problems, not just those represented by the case study in context. This research should encourage other researchers and practitioners to consider developing their own methods to implement ACM and other potential IWRM frameworks that specifically meet cultural and local preferences to focus on more directly controlling their collective destiny and protecting the health of the planet.

10. **Not project-centric problem-solving, but rather incremental, ongoing vigilance and action**

Perhaps the most critical departure represented by this research demonstration of how to implement ACM effectively was its de-emphasis on selecting potential over-arching solutions to complex problems. This resulted because complex social-ecological systems are constantly evolving, so related issues are dynamically changing, as well. Thus, challenges must be continually reevaluated to reflect the current knowledge of impending effects and the state of shared understanding to achieve desired objectives of current collective priority. This attitude is not yet common. Typically, a water service provider develops a range of potential project options, but with little direct community or other sectors influence and support. Therefore, even though the final choice is thought to be well deliberated, it often does not consider scale factors, water quality effects, or more effective global options only revealed through ongoing cooperative efforts.

Unfortunately, history does not demonstrate that humans have met all resource challenges effectively or in a way that maximized benefits in an equitable manner, neither among sectors and statuses, nor between the needs of humans and other species. Specifically concentrating on mid-course corrections and applying more kinds of diverse knowledge as a situation unfolds should permit more adaptable, stepwise, collective decision making at multiple-scales. In this way, the systematic ACM DSS process consciously focused on continual, incremental, targeted knowledge and network expansion may implement IWRM to a degree not previously achieved by other means.

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APPENDICES

APPENDIX A. ACM DSS PROCESS EXHIBITS

EXHIBIT 1. GROUPS CONSULTED

Items in parenthesis indicate specific department(s) to consider contacting. Organizations may be added or removed from this starting list at any time. The goal was to interview 75% of Bear Creek members listed on this page. BCWA participants and other related organizations in the watershed or institutions regulating its activities may also be consulted.

Table A-1. Bear Creek Watershed Association Members (Due Paying) and Participants (Attend Only)

Bear Creek Watershed Association Members and Associates	**Wastewater Discharger**	**2013 Program Participation**	**2013 Meeting Attendance**
Counties			
Jefferson County (Planning, Health/Septic Permits, IT, Transportation/Stormwater)	MS4s Stormwater, landuse permits, construction permits	Active	67%
Clear Creek County	Same as above	Active	100%
Park County (very small land area)	Same as above	No Dues, Not Active	0%
City and Towns			
City of Lakewood (Bear Creek Lake Park, City Stormwater, City Planning)	MS4s Stormwater Permit, BCR manager	Active	100%
Town of Morrison (City Planning, Utilities)	Yes	Active	83%
Water & Sanitation Districts			
Aspen Park Metropolitan District	Yes	Dues Paid	50%
Bear Creek Cabins	Yes	Active (In-kind Service)	25%
Brook Forest Inn	Yes	Active (In-kind Service)	25%
Conifer Sanitation Association	Yes	Dues Paid	8%
Conifer Metropolitan District	Yes	Dues Paid	0%
Evergreen Metropolitan District	Yes	Active	100%
Forest Hills Metro District	Yes	Dues Paid	0%
Genesee Water & San District	Yes	Active	75%
Geneva Glen	Yes	Dues Paid, Not Active	0%
Jefferson County School District (Operations, Outdoor Lab)	Yes	Active	92%
Kittredge Water & San District	Yes	Active	100%
Singing River Ranch	Yes	Dues Paid, Not Active	0%
The Fort Restaurant	Yes	Dues Paid, Not Active	0%
Tiny Town Foundation, Inc.	Yes	Dues Paid, Not Active	25%
West Jeff. Co. Metro District	Yes	Active	100%

Table A-1. Bear Creek Watershed Association Members and Associates (Continued)

BCWA Past, Potential, or Current Participants (Not due-paying members, may attend meetings)	**2013 Program Participation**	**2013 Meeting Attendance**
Evergreen Trout Unlimited	Active	58%
Jefferson County Open Space	Not Active	0%
Denver Mountain Parks	Active	25%
Denver Environmental Health	Active	25%
Aspen Park Homeowners Association (+ other HOAs?)	Not Active	0%
Colorado Department of Transportation (Kitteridge Facility, Illicit discharge detection program, Stormwater)	Not Active	8%
Denver Reg. Council of Govts (DrCog)	Not Active	0%
Denver Water Department (Planning, Operations)	Active	17%
CDPHE (Water Quality Control Division, Nonpoint Source Program, Permitting, Data Program)	Not Active	17%
Nat. Res. Conservation Service (Jefferson Conservation District, Longmont/FedCtr Office staff, Greeley Biologist-Noe Marymor)	Not Active	17%
CO Division of Water Res. (District 9 Water Commissioner)	Not Active	0%
U.S. Army Corps of Engineers (Bear Creek Reservoir/Tri-Lakes Manager)	Active	50%
U.S. Forest Service (public landowner)	Not Active	8%
EPA Region 8 (Person responsible for water quality standards)	Not member, but federal water quality enforcer	0%

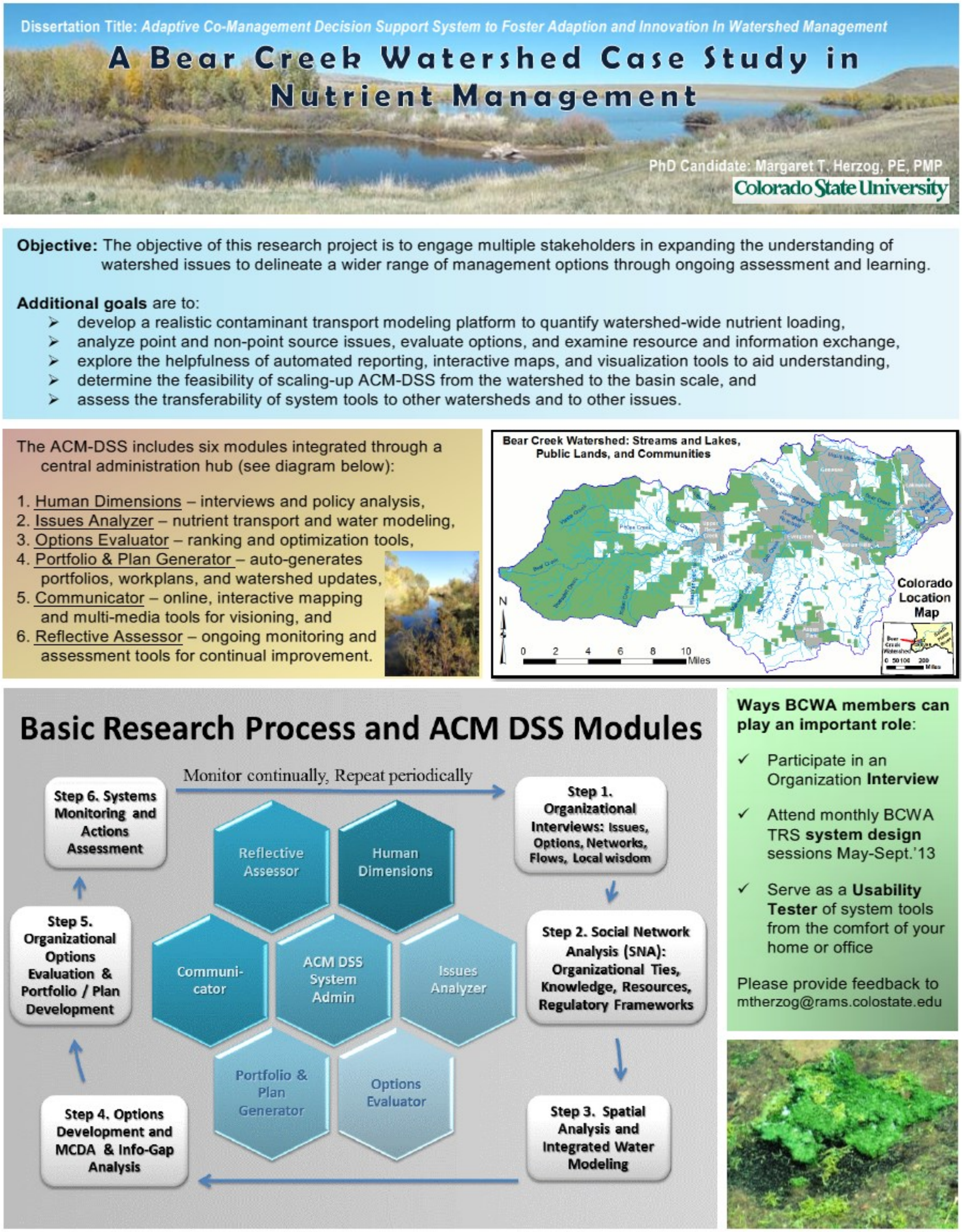
Table A-2. Other Bear Creek Watershed Area Groups and Reasons Included

Bear Creek Watershed Organization	**Reasons for Potential Inclusion**	**Notes**
Evergreen Audubon	Bird atlas of area with understanding of related needs	Sponsored BCWA Watershed 101 and lent watershed artwork
Mountain Area Land and Trust (Evergreen)	Conservation easements	Help with needed riparian buffers
Evergreen Equestrian Services	Consulting expertise on large animal issues and BMPs	
Evergreen Park & Recreation District	Lake and area restoration, preservation opportunities	Dedisee Park Management, Volunteers
Evergreen Alliance for Sustainability - EAS+Y	Expanding community group for conservation, community garden, sustainable actions	Could support certain potential residential action alternatives for nutrient loading reduction as pilot
Evergreen Rotary	Flood relief fundraiser	Partner in medical takeback program
Evergreen Chamber of Commerce	Evergreen downtown issues	Non-profit quarterly to find partners, help
Downtown Evergreen Economic District (DEED)	Evergreen downtown issues	Parking lot project concept
Indian Hills (Water District and Fire District)	Parmalee Gulch septic systems	Landuse restrictions, FireWise
Brook Forest Water District	Well water supply	Informational Resource south of Evergreen
South Evergreen Water District	Well water supply along NTC R	Augmentation program for individual wells
Conifer Chamber of Commerce	Conifer area business network	Many on OWTS
Idledale Water and Sanitation District	Water only, Genesee water req.	Decentralized system to replace OWTS?
Friends of Mount Evans & LC Wildernesses	Trail repair, volunteer work	Assistance and local knowledge, inspection
Ski Soda	Ski School of West Soda Lake	Recreational issues
CSU Extension Offices of CC and Jeffco	Revegetation expertise	Invasive Species and Plant Identification

Table A-3. Regional Partners and Pathfinders Consulted

Organization	Reasons for Potential Inclusion	Notes
Groundwork Denver	Lower Bear Creek Watershed Project	E-coli NPS
Upper Clear Creek Watershed Association / Clear Creek Watershed Foundation	Monitoring efficiently, working with downstream WWTF, Stanley Lake	BCWA sister organizations
Chatfield Watershed Authority	Expanding community group for conservation, community garden, sustainable actions, Tri-Lakes	BCWA sister organization
Cherry Creek Basin Water Quality Authority (and Consultant: Hydrosphere)	Award-winning contractor on JCD clear cut project to reduce fire hazards, enhance ecology, Tri-Lakes	BCWA sister organization
Barr-Milton Watershed Association	Excellent survey of organizations and models, Barr Lake, Milton lake	BCWA sister organization
Coalition for the Upper South Platte (CUSP)	Hayman fire led to expertise	Exemplary program!
SPCURE and Greenway Foundation	SPCure to develop regional data sharing and community projects	Regional south platte river projects
Green Mountain Water and Sanitation District	Serves drainages east of Morrison	Sewer connections
Willowbrook Water and Sanitation District	Serves drainages south of T. Creek	Sewer connections
Metro Wastewater	Serves two districts above and more	Expertise, sewers
Urban Drainage and Flood Control District	Streamflow gauge sponsor, stormwater, BMPs, grants	Funding, data, and expertise
Northern CO Water Conservation District	Shadow Mt., Lake Granby, Grand Lk	3-lake model, studies
Summit County	Dillon reservoir NPS management	OWTS studies
Georgetown Water and Wastewater	WWTF innovations	Accepts septage how
Colorado Water Conservation Board (Flood and Drought management, Watershed protection programs, ISF, Grants)	Potential project funding source, drought and conservation planning tools, Instream Flow Program	90+ ISF water rights in watershed, grants needed, expertise
IBCC/BRTS – South Platte Basin Round Table	Regional and state level coalition	WRSA grants
Colorado Lake and Reservoir Association	Limnologist throughout state	Expertise
Colorado Riparian Association	Restoration and preservation	Expertise
Colorado Professionals in Onsite Wastewater	Septic and decentralized systems	Expertise
Colorado Environmental Health Association	County EHS member association	Expertise
Special District Association of Colorado	Assists members with regulations	Expertise
Colorado Nutrient Coalition	BCWA member in statewide group to lobby on WQCD regs	Regulatory Support
Colorado Rural Water	Source Water Protection	Resources
Great Outdoors Colorado (GOCO)	Lottery funds for preservation	Project Funding
Colorado State University Soil, Water, and Plant Lab	Reasonable sampling analysis	Flood sediments
Colorado Division of Parks and Wildlife	Fish counts, habitat and on ecological data and projects	Expertise
U.S. Fish and Wildlife Service	Threatened species and habitat	Expertise
U.S. Forest Service	Slash management, watershed framework, project support	Expertise and land in watershed
U.S. Geological Survey / CO Geological Survey	GIS data, gw/sw data, geology	2003 Turkey Creek

EXHIBIT 2. ACM DSS FACT SHEET
(provided along with study summary for initial contact)



Dissertation Title: *Adaptive Co-Management Decision Support System to Foster Adaption and Innovation In Watershed Management*

A Bear Creek Watershed Case Study in Nutrient Management

PhD Candidate: Margaret T. Herzog, PE, PMP
Colorado State University

Objective: The objective of this research project is to engage multiple stakeholders in expanding the understanding of watershed issues to delineate a wider range of management options through ongoing assessment and learning.

Additional goals are to:

- develop a realistic contaminant transport modeling platform to quantify watershed-wide nutrient loading,
- analyze point and non-point source issues, evaluate options, and examine resource and information exchange,
- explore the helpfulness of automated reporting, interactive maps, and visualization tools to aid understanding,
- determine the feasibility of scaling-up ACM-DSS from the watershed to the basin scale, and
- assess the transferability of system tools to other watersheds and to other issues.

The ACM-DSS includes six modules integrated through a central administration hub (see diagram below):

1. Human Dimensions – interviews and policy analysis,
2. Issues Analyzer – nutrient transport and water modeling,
3. Options Evaluator – ranking and optimization tools,
4. Portfolio & Plan Generator – auto-generates portfolios, workplans, and watershed updates,
5. Communicator – online, interactive mapping and multi-media tools for visioning, and
6. Reflective Assessor – ongoing monitoring and assessment tools for continual improvement.

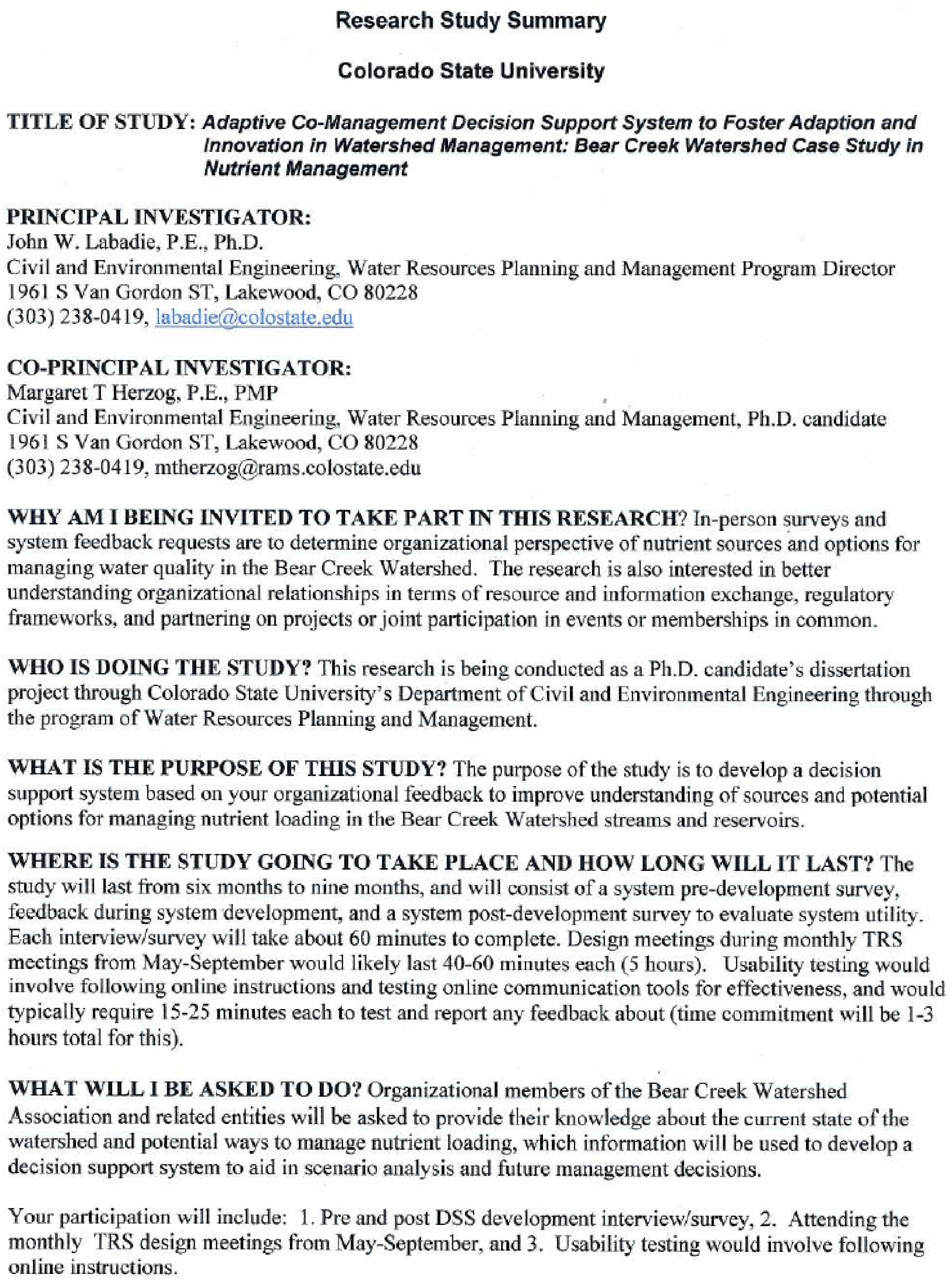
Basic Research Process and ACM DSS Modules

Ways BCWA members can play an important role:

- ✓ Participate in an Organization **Interview**
- ✓ Attend monthly BCWA TRS **system design** sessions May-Sept.'13
- ✓ Serve as a **Usability Tester** of system tools from the comfort of your home or office

Please provide feedback to mtherzog@rams.colostate.edu

EXHIBIT 3. RESEARCH STUDY SUMMARY
(provided along with Fact Sheet to each initial contact)



Research Study Summary

Colorado State University

TITLE OF STUDY: ***Adaptive Co-Management Decision Support System to Foster Adaption and Innovation in Watershed Management: Bear Creek Watershed Case Study in Nutrient Management***

PRINCIPAL INVESTIGATOR:
John W. Labadie, P.E., Ph.D.
Civil and Environmental Engineering, Water Resources Planning and Management Program Director
1961 S Van Gordon ST, Lakewood, CO 80228
(303) 238-0419, labadie@colostate.edu

CO-PRINCIPAL INVESTIGATOR:
Margaret T Herzog, P.E., PMP
Civil and Environmental Engineering, Water Resources Planning and Management, Ph.D. candidate
1961 S Van Gordon ST, Lakewood, CO 80228
(303) 238-0419, mtherzog@rams.colostate.edu

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? In-person surveys and system feedback requests are to determine organizational perspective of nutrient sources and options for managing water quality in the Bear Creek Watershed. The research is also interested in better understanding organizational relationships in terms of resource and information exchange, regulatory frameworks, and partnering on projects or joint participation in events or memberships in common.

WHO IS DOING THE STUDY? This research is being conducted as a Ph.D. candidate's dissertation project through Colorado State University's Department of Civil and Environmental Engineering through the program of Water Resources Planning and Management.

WHAT IS THE PURPOSE OF THIS STUDY? The purpose of the study is to develop a decision support system based on your organizational feedback to improve understanding of sources and potential options for managing nutrient loading in the Bear Creek Watershed streams and reservoirs.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? The study will last from six months to nine months, and will consist of a system pre-development survey, feedback during system development, and a system post-development survey to evaluate system utility. Each interview/survey will take about 60 minutes to complete. Design meetings during monthly TRS meetings from May-September would likely last 40-60 minutes each (5 hours). Usability testing would involve following online instructions and testing online communication tools for effectiveness, and would typically require 15-25 minutes each to test and report any feedback about (time commitment will be 1-3 hours total for this).

WHAT WILL I BE ASKED TO DO? Organizational members of the Bear Creek Watershed Association and related entities will be asked to provide their knowledge about the current state of the watershed and potential ways to manage nutrient loading, which information will be used to develop a decision support system to aid in scenario analysis and future management decisions.

Your participation will include: 1. Pre and post DSS development interview/survey, 2. Attending the monthly TRS design meetings from May-September, and 3. Usability testing would involve following online instructions.

ARE THERE REASONS WHY I SHOULD NOT TAKE PART IN THIS STUDY? There are no known negative effects of participating, and your input will help provide a diverse, more complete set of information and tools to permit the system to better support nutrient management in the Bear Creek watershed over time.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? Although there are no direct benefits to participating in this Bear Creek Watershed Case Study, indirect benefits to your organization may include greater sharing of important knowledge about nutrient sources and potential management options that may help in developing a more useful, comprehensive tool to aid in future nutrient management decisions over time.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may simply stop participating at any time.

WHO WILL SEE THE INFORMATION THAT I GIVE?

This study is anonymous. For this study, we are not obtaining your name or other identifiable data from you, so nobody (not even the research team) will be able to identify you or your data. We may be asked to share the research files for audit purposes with the CSU Institutional Review Board ethics committee, if necessary, but for this study, your name or other identifying information will not appear anywhere in our collected data.

WHAT IF I HAVE QUESTIONS?

If you have questions about the study at any time, you can contact the co-principal investigator, Margaret T Herzog at mtherzog@rams.colostate.edu or (303) 238-0419. If you have any questions about your rights as a volunteer in this research, contact Janell Barker, Human Research Administrator at 970-491-1655.

This study was approved by the CSU Institutional Review Board for the protection of human subjects in research on June 12, 2013.

Signature John Labadie **Date** 6/14/13

Principle Investigator, Dr. John W. Labadie (student's advisor)

Signature Margaret Herzog **Date** 6/14/13

Co-Principal Investigator, Margaret T. Herzog (student researcher)

EXHIBIT 4. CERTIFICATE OF TRAINING IN ETHICAL CONDUCT

Colorado State University

CERTIFICATE OF COMPLETION OF RESPONSIBLE CONDUCT OF RESEARCH TRAINING

THIS CERTIFICATE IS AWARDED TO

Margaret Herzog

IN FULFILLMENT OF THE ONLINE RCR TRAINING REQUIREMENT

Colorado State University

Kathryn M. Partin

KATHRYN M. PARTIN, PHD
DIRECTOR, RESEARCH INTEGRITY & COMPLIANCE REVIEW OFFICE

November, 18 2012
DATE

EXHIBIT 5. FREQUENTLY ASKED QUESTIONS ABOUT THE BEAR CREEK STUDY

Why is a CSU engineering student studying BCWA and the Bear Creek Watershed for her CSU dissertation?

The Bear Creek Watershed Association (BCWA) is one of the oldest and most respected nutrient monitoring and management organizations in Colorado. Many *best practices* have been developed over its more than 30 years, and members are natural innovators and adapters that will assist in system development and implementation. Although all wastewater treatment plants are considered minor facilities, all residential providers still achieve nutrient treatment levels well below current state standards. The Bear Creek Watershed itself is also unique in being one of Denver's better preserved *exurban* watersheds due to a large portion of public land ownership by federal, state, county, and local entities, including several CO Natural Heritage Program preservation areas. Finally, the researcher lives in the Bear Creek Watershed, simplifying study and enhancing personal commitment.

What is a Decision Support System?

A decision support system (DSS) is an interactive software system for compiling useful information, analyzing and modeling systems, and providing results in ways that makes comprehensive decision making easier and more fun. The purpose of the Adaptive Co-management Decision Support System (ACM-DSS) process being developed through this Bear Creek Watershed case study will focus on understanding sources and contributing factors of nitrogen and phosphorus pollution throughout the watershed, and how it migrates through our stream systems into Bear Creek Lake and other receiving waters. Planning options for reducing nutrients will be analyzed and selected by BCWA members for prioritizing implementation to achieve better water quality indicated by healthier fish and the types of water insects they eat, less algae blooms, better chemistry, and clearer waters.

What is Adaptive Co-Management?

Adaptive co-management focuses on incremental improvement and changing policy, as much as, technical solutions. It helps foster collaboration throughout the watershed by analyzing how rules, information, and resources are exchanged among organizations, and how these relationships might be improved. It considers both the issues that lead to nutrient pollution, as well as, the underlying assumptions about monitoring, mechanisms, and regulations that may reduce understanding and the range of possible solutions. Adaptive co-management takes a systems-wide approach to solving environmental problems, with the realization that human needs and economic interests play a critical role in ecosystem management.

How can I participate?

BCWA members would play a critical role in the success of the ACM-DSS process by becoming involved!

Pre and Post System Interviews – Share your understanding of the issues, options, relationships and resource flows. At the end of the project, you can also test out the final system and provide additional ideas for next steps.

System Designer – the System Design Group will meet during BCWA TRS meetings at the BCLP Visitor's Center each month to review system development progress and guide next steps, so that the result meets ongoing needs. If you want to be involved, but cannot attend in person, you can still be part of this group through one-on-one Skype review of the materials covered that month to still provide your personal input to guide the process successfully.

Usability Tester – usability testers will be provided monthly with online links or CD-based tools to test with simple instructions. Testers will be asked to provide online survey feedback on what they liked and difficulties they had with the tools and suggestions for improvement.

What are the benefits of participation?

BCWA and the watershed by capturing much of the information now in spreadsheets, various studies, different Geographical Information System (GIS) spatial data sets, and in experts' minds into a single, automated system. Modeling tools will better characterize nonpoint sources of nutrients, such as septic systems, animal wastes, erosion, stormwater, and other potential contributing factors. Analysis of the options BCWA members provided during their spring surveys will help inform the group's choices of which projects and policies to pursue next and in what order. The system will also produce reports, maps, and other useful ways to review ongoing progress and better plan future activities.

EXHIBIT 6. PRE-DESIGN INTERVIEW – SAMPLE QUESTIONS

Code
Date

1. What is your role in your organization?

2. What is the organizational mission? Current objectives? Future challenges / priorities?

3. Which other organizations in the watershed does your organization work with?

4. From which sources do you obtain the most information to do your job or for your organization?

5. Has you organization receive funding in the past from any sources or have you contributed jointly for a project with other organizations?

6. What do you perceive to be the greatest upcoming challenges to nutrient management in the entire Upper Bear Creek Watershed?

7. What are your organizations greatest upcoming challenges to nutrient management and how will you tackle them?

8. How much will you have to expend to meet phosphorus and new nitrogen standards to be imposed in 2017? What technology, equipment, or other measures will you use to address these requirements?

9. Are there any nonpoint sources that affect your jurisdiction particularly?

10. What are your three greatest risks to meeting regulatory standards?

11. How could households in your jurisdiction better support your efforts? Landowners? other major contributors?

12. What is one goal you have as an organization to improve the Bear Creek Watershed? Your operations?

13. Will you be willing to review Bear Creek Watershed Nutrient Management system tools and evaluate options? Provide feedback? During design and development or only at end? Time and frequency?

14. Are there any lessons learned that you want other BCWA members to know that could be written down or captured in a video?

15. What additional information or insight related to nutrient management would you like the ACM DSS to provide BCWA?

EXHIBIT 7. POST-DESIGN INTERVIEW – SAMPLE QUESTIONS

Code
Date

1. After reviewing the Bear Creek Watershed ACM DSS, are there any particular project or processes identified, which particularly appeal to you and / or your organization? Why?

2. Do you feel the selected first-round options portfolio will provide more, less, or about the same nutrient load reduction as calculated – what might be factors that could affect results and projected nutrient savings?

3. How might your organization support options materially, provide funding, or increase community support?

4. Which other organizations could you collaborate with on options in the portfolio?

5. What organizations or other obstacles might you encounter if you were to attempt to implement the full options portfolio?

6. Which federal, state, or other sources might provide project financing?

7. How does the Bear Creek Watershed ACM DSS assist in developing options and better understanding issues?

8. How important are the real time monitoring and assessment components to you personally?

9. What surprised you most about the ACM DSS process?

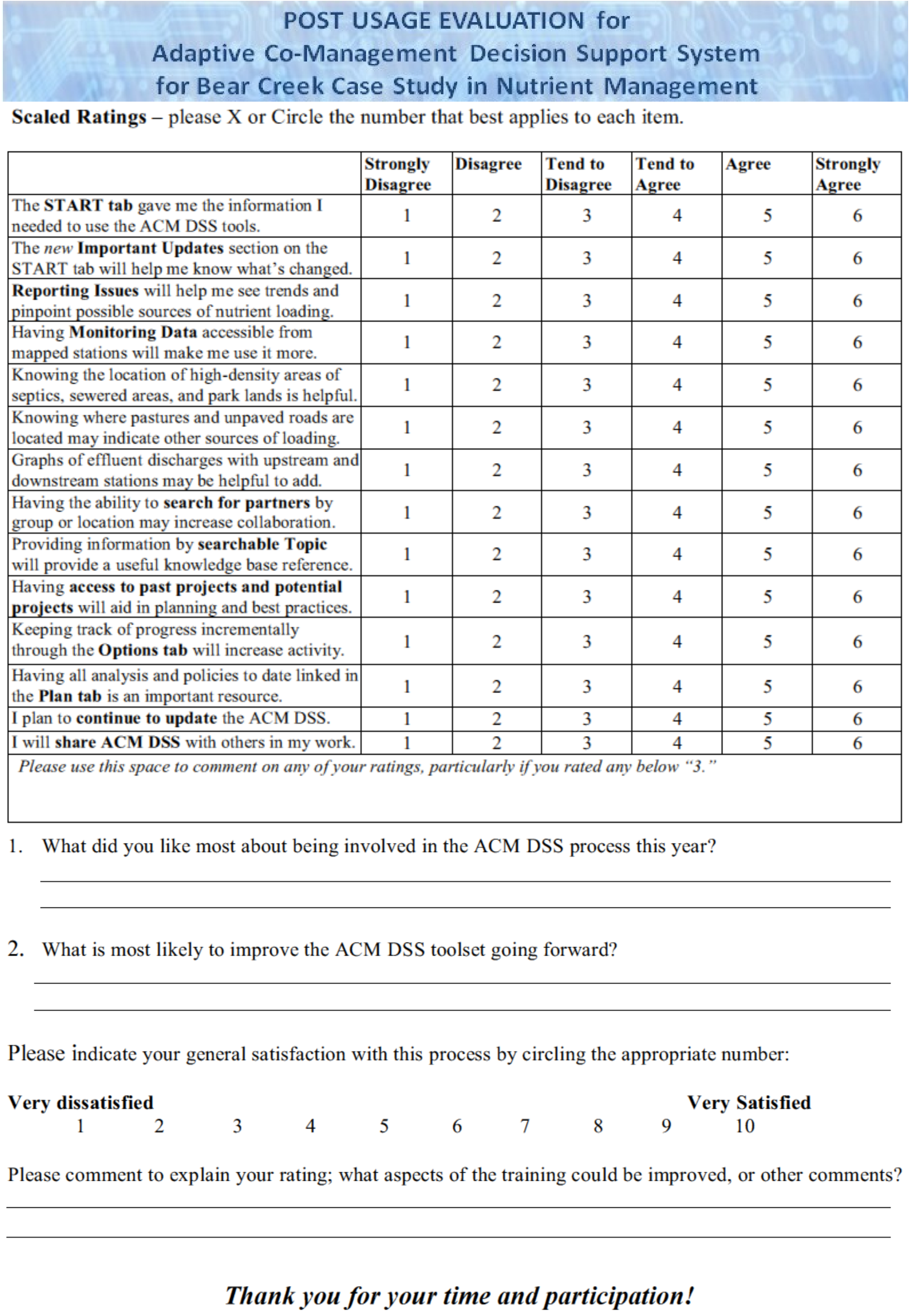
10. How could we make the ACM DSS more useful?

11. What are next steps?

12. What do you consider as up and down sides of taking any particular actions? What advantages do you see to having all options enumerated in the system that you've discussed, even if you have chosen not to pursue some of them now?

13. Would you like the BCWA to continue to use and expand the ACM DSS? Why or why not?

EXHIBIT 8. POST-PROJECT SURVEY FORM AND RESULTS



POST USAGE EVALUATION for
Adaptive Co-Management Decision Support System
for Bear Creek Case Study in Nutrient Management

Scaled Ratings – please X or Circle the number that best applies to each item.

	Strongly Disagree	**Disagree**	**Tend to Disagree**	**Tend to Agree**	**Agree**	**Strongly Agree**
The **START tab** gave me the information I needed to use the ACM DSS tools.	1	2	3	4	5	6
The *new* **Important Updates** section on the START tab will help me know what's changed.	1	2	3	4	5	6
Reporting Issues will help me see trends and pinpoint possible sources of nutrient loading.	1	2	3	4	5	6
Having **Monitoring Data** accessible from mapped stations will make me use it more.	1	2	3	4	5	6
Knowing the location of high-density areas of septics, sewered areas, and park lands is helpful.	1	2	3	4	5	6
Knowing where pastures and unpaved roads are located may indicate other sources of loading.	1	2	3	4	5	6
Graphs of effluent discharges with upstream and downstream stations may be helpful to add.	1	2	3	4	5	6
Having the ability to **search for partners** by group or location may increase collaboration.	1	2	3	4	5	6
Providing information by **searchable Topic** will provide a useful knowledge base reference.	1	2	3	4	5	6
Having **access to past projects and potential projects** will aid in planning and best practices.	1	2	3	4	5	6
Keeping track of progress incrementally through the **Options tab** will increase activity.	1	2	3	4	5	6
Having all analysis and policies to date linked in the **Plan tab** is an important resource.	1	2	3	4	5	6
I plan to **continue to update** the ACM DSS.	1	2	3	4	5	6
I will **share ACM DSS** with others in my work.	1	2	3	4	5	6

Please use this space to comment on any of your ratings, particularly if you rated any below "3."

1. What did you like most about being involved in the ACM DSS process this year?

2. What is most likely to improve the ACM DSS toolset going forward?

Please indicate your general satisfaction with this process by circling the appropriate number:

Very dissatisfied **Very Satisfied**
1 2 3 4 5 6 7 8 9 10

Please comment to explain your rating; what aspects of the training could be improved, or other comments?

Thank you for your time and participation!

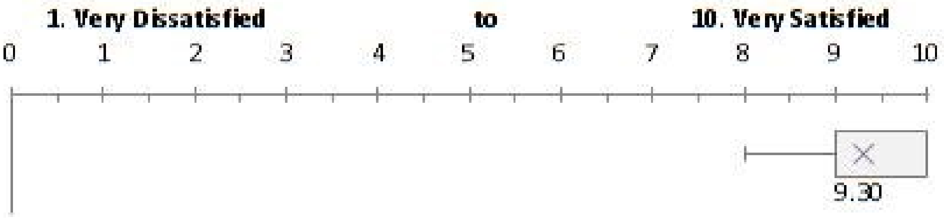


Figure A-1. General ACM DSS Process Satisfaction

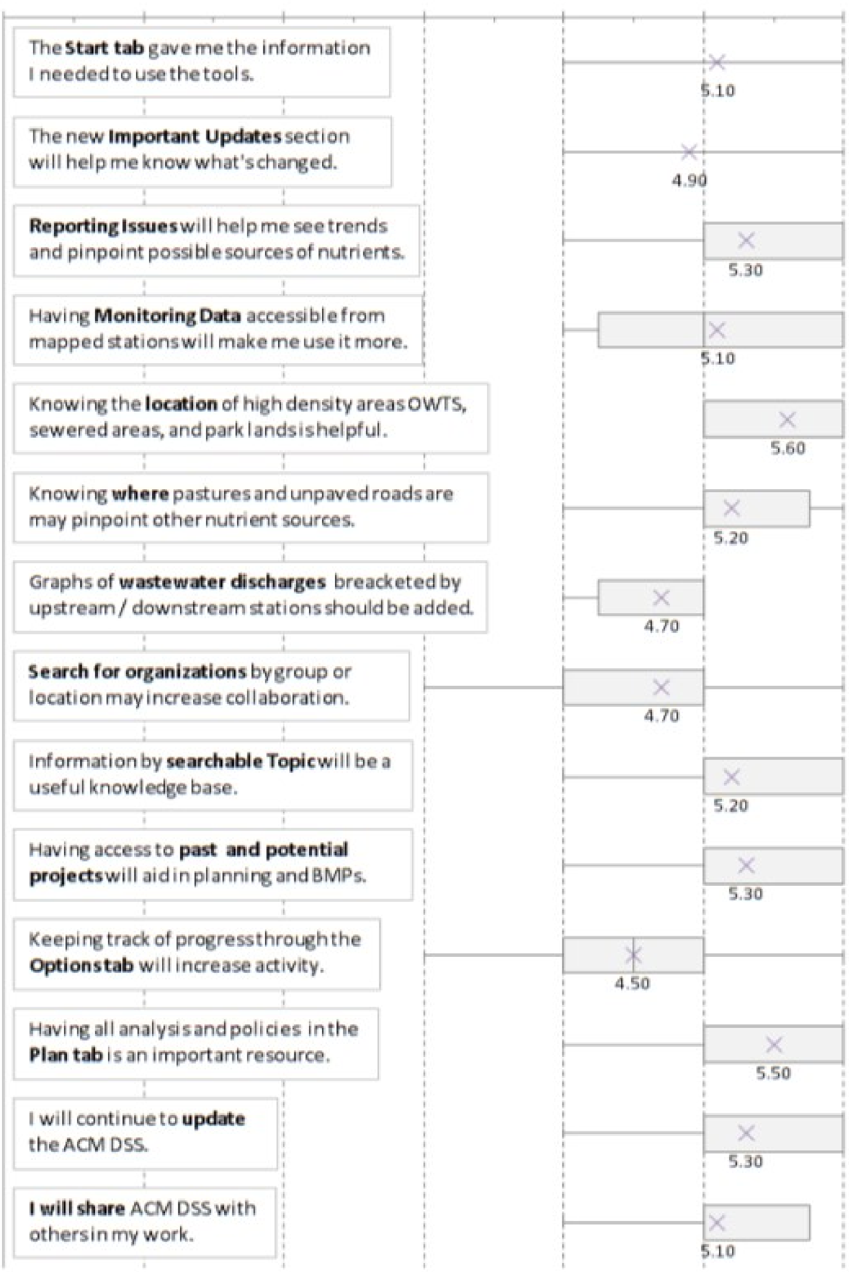


Figure A-2. ACM DSS Statistical Results by Exit Survey Question

EXHIBIT 9. PLANNING AND PRIORITIZING NUTRIENT ISSUES

BCWA TRS Design Group #2 (6/5/13): Mass Balance Analysis Planning Worksheet

Nu Source	Priority	Nutrient Contribution		Controllability?	Analysis Needs	Your Comments
Wastewater Treatment Plants	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Small Treatment Systems	High Medium Low	>40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Stormwater / Erosion Control	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Internal Reservoir Loading	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Septic Systems (OWTS)	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Vaults / Pits / Park Latrines	High Medium Low	>40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Large Animal Wastes	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Streambank Erosion / Bedload	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Fire Hzd / Source Wtr Protection	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Lawns & Golf Courses	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Low Flow / Water Rights	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Illicit Dump / Canal Cleanout	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Mining and Agriculture	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Deposition and Natural Processes	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		
Other Significant Sources	High Medium Low	> 40% 30-40% 20-30%	10-20% < 10% neglible	Not controllable Somewhat controllable Highly controllable		List source here:

EXHIBIT 10. BCWA TRS DESIGN GROUP EXPLORATORY QUESTIONS

DS2: W June 5, 2013

Understanding Values to Improve Design Focus and Decision Making Capability

Area	Questions
WWTP	Why was BCWA considering 1.0 mg/L P small dischargers and 0.2 mg/L P large dischargers?
	Why does regulation focus on point discharge reduction and wastewater dischargers in particular? Is it in dischargers interest to continually seek ways to decrease Phosphorus discharges?
	Are their ways large and small dischargers might work together to decrease P?
	Reasons why dischargers my want to collaborate or not?
	Has Morrison reconsidered utility of being included in BCWA Reg 85 monitoring and reporting?
Small Systems	Why aren't small dischargers or their consultants present at BCWA meetings? Is this ideal? If not, what are ways that this might be changed?
	Should small dischargers / Treatment Tech be asked to reconsider BCWA Reg 85 inclusions?
Stormwater	Is BCWA stormwater manager MS4 involvement adequate?
Erosion Control	BCWA county members not necessarily focused on this, Lakewood outfalls mostly downstream
	How might CDOT and county roads depts. become more involved in BCWA?
	Does BCWA have adequate oversight / manpower to review construction erosion control plans? Are USACE on-stream permits also under BCWA review or only county and city ones?
County Involvement	Are counties adequately involved in BCWA?
	Is it sufficient to have a single department represented?
	Should different departments input be sought on different topics of discussion?
	How improve dialog and adoption of nonpoint source policies (vaults, manure, buffers, etc.)? Timing policies for county commissioner review? Direct dialog? Dept. focused dialog first?

BTCA Roles What should be the main roles of the Foundation, a nonprofit corporation that supports BCWA?

Grant seeking for in-stream restoration project funding and erosion control?

Innovative monitoring tool acquisition?

Increasing partnering for better nonpoint source control (DMP, JCOS, USFS)?

Increasing stakeholder involvement from community groups (ETU, EA, JCD, Mountain Trust)?
Funding plant upgrades and operations improvement?

Increasing direct community participation in monitoring and reporting?

Increasing community participation in project and selection?

Increasing volunteer participation in restoration projects (bank stabilization, etc.)?

Increasing community education and awareness of issues and their role in solutions?

What may be drawbacks to increase participation or partnering that may be mitigated by BCWA/BTCA separation?

EPA Has BCWA responded directly to EPA letter not accepting 32 mg/L or is updated response needed before state /EPA discussion?

State Contact How can BCWA deal with different WCCC/WQCD staff requesting contradictory reporting?

Defining what to include / focus on in Mass Balance analysis?

Source Related Questions

WWTFs DMRs not included in BCWA reports, but would they improve loading calculations?

WWTF may be only nutrient source with adequate information to well define loading

How greatly may lab methods affect accuracy/precision of nutrient concentration calculations.

Do some WWTP have a more variable nutrient concentration than others – variance of each?

Are their seasonal variations in loading?

Small Dischargers Can the total volume discharged be calculated accurately enough?

Is their relative important so insignificant not to conduct further analysis?

Stormwater MS4s Have nutrients been measured at end-of-pipe anywhere in watershed?

Are stream bedload and streambank erosion a more significant source?

Have construction erosion control practices improved enough to ignore in analysis?

Ditch Cleanouts How should illicit dumping and canal cleanout temporary load be considered or don't matter?

Septic Systems Are BCLP near BCR and Dedisee Park near Evergreen Lake public latrines of concern/risk?

What does bracketed Idledale data tell us about the potential impact of septic systems close to mainstem?

Are alternative systems feasible and have they been used anywhere?

> Are single-pipe leach fields from public composting toilets more concentrated, but of less volume than conventional?

What does the Indian Hills experience teach since 1970s Environmental Resource Inventory?

Are their really 27,000 septic systems or closer to the 8,000 to 12,000 estimated by Denver Water in 2011 and the 6000 to projected 9000 estimated by the original 1990 Clean Lakes Study?

Vaults Is Summit Lake really the worst pollution in North America if Site 38 has only shown periodic exceedances?

Is Al, DEH right to argue that pocket pool values from hillslope?

Are 80 years of pit privies that significant, if not noticed before 2011, when vaults installed?

Does streamflow through natural areas in upper reaches of watershed serve as a better attenuator?

Should vaults at BCLP near Soda Lakes and BCR and at Dedisee Park near Evergreen Lake be considered risk to analyze failure loading?

Should vaults outside buffer areas receive less concern or no effort in analysis?

Internal P In addition to PhosLock, what other management practices should be analyzed for controlling internal reservoir loading?

Loading How well has the portion of P loading related to internal P loading been documented or analyzed? More needed?

EXHIBIT 11. BCWA TRS DESIGN GROUP CRITERIA / BASELINING WORKSHEET

COSTS	Calculate all costs to Present Value					
		Use Options to include upfront costs by task				
		Ongoing O&M including monitoring and assessment				
BENEFITS (report in more results oriented annual report)						
TP reduction	0.1	0.2	0.5	1	ug/L	
TN reduction	10	20	50	100	ug/L	
Chl-a reduction	1	2	3	4	>5	ug/L
Temp reduction	0-1	1-2	2-3	4 or more	degrees F	
	MWAT compliance			percent improvement		
	DM Compliance			percent improvement		
	Air Temperature comparisons					
	Vegetation indices above non-compliant reaches					
Fish Health	Increase desirable sports fish					
	Fish by species - brown, rainbow, other sport, other					
	Fish size (pounds or # / acre, # or lb > 12 cm)					
	Stocking					
				streambank stabilization, etc.		
Riparian Habitat	10	50	100	1000	river feet treated	
	1	5	10	50	acres planted	
Lake Health	pre-lake channel sediment removal					
	increase lacustrine wetland / littoral zone vegetation area					
MMI score	5	10	15	20	point improvement	
	other macroinvertebrate measures (Shannon, HBI, O/E, Total Taxa)					
Other Eco	Daphnia or other indicator species levels					
	Zooplanktivorous fish levels					
	Macrophyte levels (good habitat or nuisance boating levels?)					
Secchi Depth	2	3	4	5m	or depth increase	
pH	> 6	7	< 8	or pH improvement		
DO	6	7	8	9 or more		
e. coli	reduce runoff peaks, chronic levels, low flow levels				cells / 100mL	

Dischargers

WWTP TP	<0.1	0.1	0.2	0.3	0.4	0.5ug/L
WWTP TN	10	20	50	100	200	ug/L
Sewer Tap conversions	1	5		10 or more		
BNR	additions or conversions, or other advanced or tertiary treatment additions					

Education

Attend Workshop/Ed	10	20	50	100	500	people
View geocache sign	10	20	50	100	500	geocached signs

Large Animals

Pasture Mgmt	1	2	5	10	50	acres
Manure Mgmt	1	5	10	20	50	head

Conduct allowable goose control measures
Work with JCD to increase # small ranch management plans / cost share for conservation

Roads / Erodes land

Road revegetation	100'	500'	1000'		(exact length)
Culvert pre-sed basin to also catch first flush				Volume, drainage area, etc.	
Detention Ponds					
County reduction in sand use				Tons	
County sweeping (add as part of property tax)				Frequency, locations	
Direct runoff diverted to sheetflow (LID)				method, area, peak attenuation	
Reduce number and length of roads				#1 impermeable surface in mountains	
Boulder (access / runoff) barriers				Length or area	
Rock check structures in ditches, along ridge breaks				Bank length stabilized / slowed	
Indirect culvert outflow (spreader, wetland, etc)				Number, Capacity	
Berms and Swales					
Wetland / Raingarden					
Parking lot runoff and snow removal diverted / infiltrated					
Road accident spill risk mitigation					

Illicit Discharges

Reduce Number
Increase reporting / enforcement actions

Water Rights

Min Flow Right Enforce	1	2	3	4	5

Harriman POD moved DS of BCL-might happen if can improve WQ to make worth it,
    Bear Creek BCR inflow wetland analysis (based on Denver Water 2010)
    Seek CWCB Bear Creek Min Flow Right Morrison to Bear Creek Lake
    Seek storage right on BCL permanent pool elevation at 5558
        currently 1800 or 2000AF below permanent pool level water rights owned but not exercised!

Fire Risk Mitigation

Pre-sed basins					
Defensible barrier	1	5	10	50	properties
Clear cut meadow patches	50	100	200	500	acres
Fire Risk Mitigation Plans					number / area covered

Collaboration

County adopts portion of BCW policy for manure, OWTS, roads, etc.

Project Partners	Number
	New Partners

Citizen Science (weather station, etc.)
Business / Commercial Property Cooperator
Joint assessment efforts

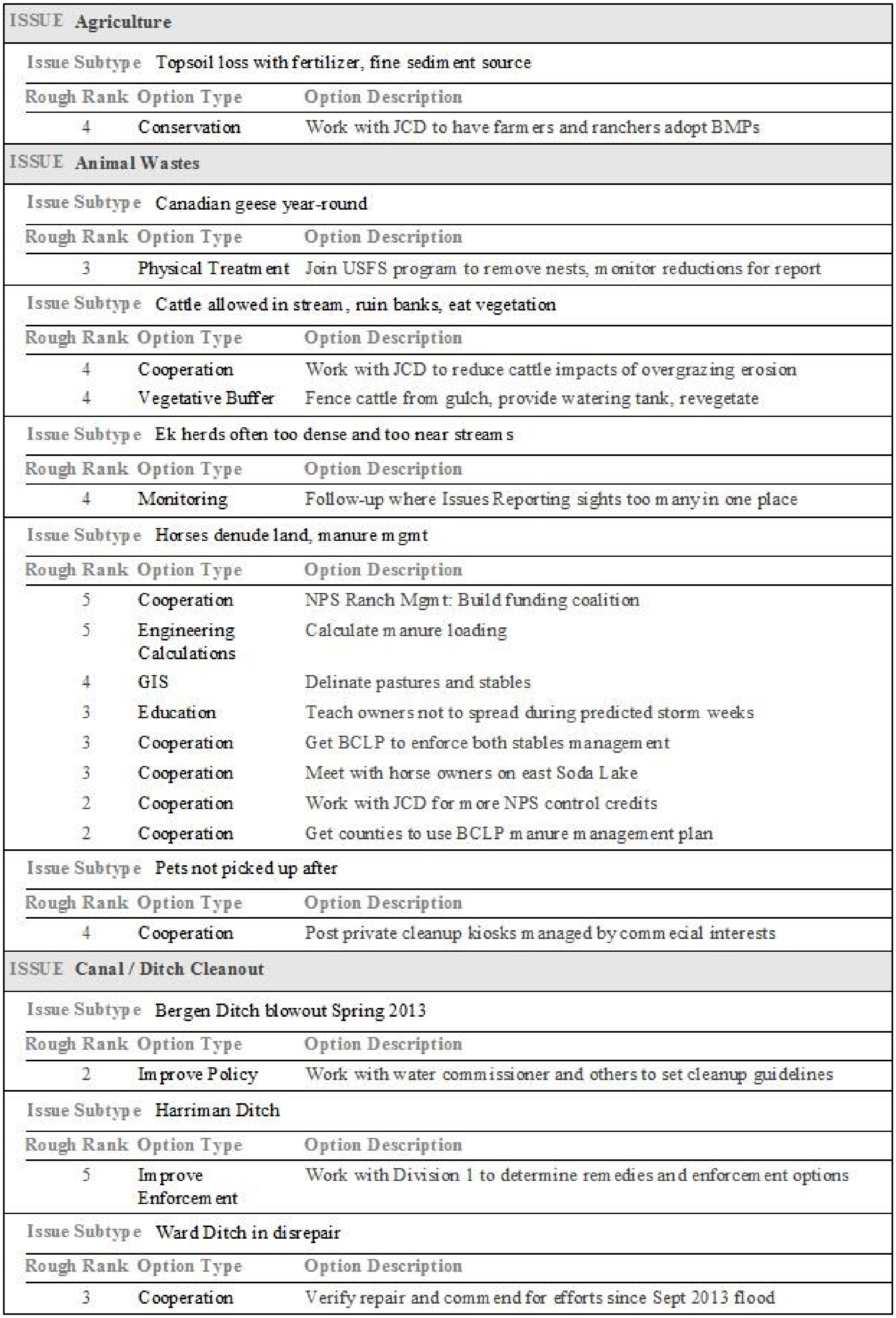
OWTS / Park Latrines

Number emptied (from cleaners)
Number replaced (from counties)
OWTS Surveys conducted
Vault leak tests conducted
Advanced treatment added
Clustered, advanced system
Maintenance Plans implemented

Funding

Private Donations
Business Donations
Grants
Cost Share
In-Kind Services / Resources
Volunteers

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE



ISSUE Agriculture

Issue Subtype Topsoil loss with fertilizer, fine sediment source

Rough Rank	Option Type	Option Description
4	Conservation	Work with JCD to have farmers and ranchers adopt BMPs

ISSUE Animal Wastes

Issue Subtype Canadian geese year-round

Rough Rank	Option Type	Option Description
3	Physical Treatment	Join USFS program to remove nests, monitor reductions for report

Issue Subtype Cattle allowed in stream, ruin banks, eat vegetation

Rough Rank	Option Type	Option Description
4	Cooperation	Work with JCD to reduce cattle impacts of overgrazing erosion
4	Vegetative Buffer	Fence cattle from gulch, provide watering tank, revegetate

Issue Subtype Ek herds often too dense and too near streams

Rough Rank	Option Type	Option Description
4	Monitoring	Follow-up where Issues Reporting sights too many in one place

Issue Subtype Horses denude land, manure mgmt

Rough Rank	Option Type	Option Description
5	Cooperation	NPS Ranch Mgmt: Build funding coalition
5	Engineering Calculations	Calculate manure loading
4	GIS	Delinate pastures and stables
3	Education	Teach owners not to spread during predicted storm weeks
3	Cooperation	Get BCLP to enforce both stables management
3	Cooperation	Meet with horse owners on east Soda Lake
2	Cooperation	Work with JCD for more NPS control credits
2	Cooperation	Get counties to use BCLP manure management plan

Issue Subtype Pets not picked up after

Rough Rank	Option Type	Option Description
4	Cooperation	Post private cleanup kiosks managed by commecial interests

ISSUE Canal / Ditch Cleanout

Issue Subtype Bergen Ditch blowout Spring 2013

Rough Rank	Option Type	Option Description
2	Improve Policy	Work with water commissioner and others to set cleanup guidelines

Issue Subtype Harriman Ditch

Rough Rank	Option Type	Option Description
5	Improve Enforcement	Work with Division 1 to determine remedies and enforcement options

Issue Subtype Ward Ditch in disrepair

Rough Rank	Option Type	Option Description
3	Cooperation	Verify repair and commend for efforts since Sept 2013 flood

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Climate Change**

Issue Subtype Invasive species

Rough Rank	Option Type	Option Description
4	Monitoring	Obtain Audubon and county data on extent of infestations
3	Cooperation	Determine effectiveness of grants for BCLP and others to control
2	Cooperation	Invite CSU Jeffco Ext to describe program as CCC Ext did

Issue Subtype Lower flows, higher temp, lower soil moisture

Rough Rank	Option Type	Option Description
5	Vegetative Buffer	Assess the effectiveness of shading and EPA 2 year study

Issue Subtype Species move up mountain

Rough Rank	Option Type	Option Description
3	Monitoring	Determine migration of plants and animals and implications

ISSUE **Communication**

Issue Subtype Disagreements are not resolved within BCWA

Rough Rank	Option Type	Option Description
2	Cooperation	fairly allocate responsibility throughout watershed to locate and fund projects

Issue Subtype Gaps both within BCWA and with landowners and regulators

Rough Rank	Option Type	Option Description
2	Education	SNA workshop for BCWA

Issue Subtype Miscommunication

Rough Rank	Option Type	Option Description
4	Communication	BCWA Board meetings call-in so all members get same details

Issue Subtype Not listening / Taking care of concern Expressed

Rough Rank	Option Type	Option Description
5	Communication	BCWA should call concerned to make sure issue addressed

ISSUE **Community Needs**

Issue Subtype Don't know where Water / WW comes from

Rough Rank	Option Type	Option Description
5	Education	Watershed 102 - water and wastewater treatment with plant visits

Issue Subtype Little BCWA interaction

Rough Rank	Option Type	Option Description
5	Education	BTCA Orientation / SNA workshop
4	Volunteers	Have Evergreen EASY members promote & pilot Property 350 program
4	Volunteers	Evergreen Audubon volunteer network
2	Cooperation	Get people in watershed actively involved with issues

Issue Subtype More septic and land management capacity

Rough Rank	Option Type	Option Description
4	Education	Provide stickers on BMPs for OWTS and property to put on heater

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE	**Community Needs**	
Issue Subtype	No watershed concept	
Rough Rank	**Option Type**	**Option Description**
5	Education	Evergreen Audubon visitors center at Evergreen Lake
4	Education	Property 360 inspection and OWTS inspections with incentives
4	Education	Evergreen Audubon panel discussions and Watershed 101 hosting
4	Education	Education programs
4	Education	ETU meetings very educational
2	Education	Joint problem solving after survey or cleanup stream to plan next steps
1	Education	Adopt BMW H20 Only / Keep It Clean Campaign
Issue Subtype	Slash options and training	
Rough Rank	**Option Type**	**Option Description**
5	Education	Develop FireWise program watershed wide, not just by community
Issue Subtype	Water and sewer, not just sewer for decent price	
Rough Rank	**Option Type**	**Option Description**
5	Cooperation	Work with districts to offer both w/ww services by sector
ISSUE	**Construction Erosion Control**	
Issue Subtype	construction site erosion control plan not followed	
Rough Rank	**Option Type**	**Option Description**
4	Improve Policy	Employ volunteers to get two or more reviews on major projects
Issue Subtype	no construction site erosion control plan	
Rough Rank	**Option Type**	**Option Description**
4	Improve Enforcement	Record all plans reviewed as go to ensure none missed and any modifications requests
4	Cooperation	Get trained volunteers to visit each site
4	Improve Enforcement	Visit every construction site
ISSUE	**Coordination**	
Issue Subtype	academic community	
Rough Rank	**Option Type**	**Option Description**
4	Communication	Share what learn more with other disciplines and institutions
Issue Subtype	agriculture	
Rough Rank	**Option Type**	**Option Description**
3	Cooperation	Attend Jeffco 4-H, equestrian and other events to reach horse owners
Issue Subtype	BCLP	
Rough Rank	**Option Type**	**Option Description**
2	Cooperation	Use nonprofit to generate funds for BCLP and BCR purposes
Issue Subtype	business community	
Rough Rank	**Option Type**	**Option Description**
2	Cooperation	Get Evergreen, Conifer, Morrison, Genesee businesses involved

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Coordination**

Issue Subtype Conifer Area

Rough Rank	Option Type	Option Description
2	Cooperation	Meet in Conifer area at least annually to generate more activity

Issue Subtype Conifer Chamber of Commerce

Rough Rank	Option Type	Option Description
2	Partnering	Develop projects for LID and other projects with area businesses

Issue Subtype County Roads

Rough Rank	Option Type	Option Description
5	Cooperation	Reduce chemical and sand effects Dedisee bridge and others

Issue Subtype DEED / Evergreen Chamber of Comm

Rough Rank	Option Type	Option Description
4	Cooperation	Promote parking lot project, repair, and sediment control
3	Cooperation	Have different BCWA member attend Nonprofit quarterly

Issue Subtype DMP

Rough Rank	Option Type	Option Description
5	Cooperation	Use earmarked funds for design of joint stream restoration project

Issue Subtype EPRD

Rough Rank	Option Type	Option Description
4	Cooperation	Control deer, pets and birds causing high manure levels in park

Issue Subtype ETU

Rough Rank	Option Type	Option Description
5	Cooperation	Stream surveys and grant opportunities for revegetation

Issue Subtype Evergreen Audubon

Rough Rank	Option Type	Option Description
5	Cooperation	Expanded education on responsible recreation and watershed info

Issue Subtype federal

Rough Rank	Option Type	Option Description
3	Cooperation	Obtain grants and support from NPS and others like GWD does

Issue Subtype Genesee

Rough Rank	Option Type	Option Description
4	Cooperation	Encourage ACM DSS usage and better resolution on TP reduction goals

Issue Subtype Groundwork Denver

Rough Rank	Option Type	Option Description
3	Cooperation	Get sign project extended downstream and obtain assistance

Issue Subtype international

Rough Rank	Option Type	Option Description
2	Studies	Determine how advances in Europe, Australia, and China may apply

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE Coordination

Issue Subtype JCOS

Rough Rank	Option Type	Option Description
4	Cooperation	Begin planning public open space projects together

Issue Subtype manufacturers

Rough Rank	Option Type	Option Description
5	Partnering	Aerator tests and alternatives to provide greater benefits
4	Partnering	Mesocosm study of internal loading and its control at BCR

Issue Subtype Morrison

Rough Rank	Option Type	Option Description
4	Partnering	Get more adjacent OWTS and small systems on Morrison's system

Issue Subtype multidisciplinary

Rough Rank	Option Type	Option Description
5	Studies	Work to get CSU, CSM, UCD all working together on decentralized or lake systems

Issue Subtype park county

Rough Rank	Option Type	Option Description
3	Cooperation	Once park county mapping updated, meet with GIS team and assessor

Issue Subtype services / consultants

Rough Rank	Option Type	Option Description
4	Studies	Develop OWTS innovation cluster and seek more BMPs from field

Issue Subtype State Parks and Wildlife

Rough Rank	Option Type	Option Description
4	Cooperation	Control fire hazard, elk, invasives and other problems on state land
2	Cooperation	Obtain more support for ecological monitoring, diversity, change

Issue Subtype UBC

Rough Rank	Option Type	Option Description
3	Cooperation	Study illegal irrigation, w/ww supply needs, sediment issues together

Issue Subtype USFS

Rough Rank	Option Type	Option Description
4	Cooperation	Request Management Plan more focused on fire hazard mitigation

Issue Subtype WQCD Reg 74 managers

Rough Rank	Option Type	Option Description
4	Communication	Engage on plans and progress early

Issue Subtype WQCD Reg 85 managers

Rough Rank	Option Type	Option Description
4	Communication	Ask them if satisfied with first year monitoring report, 2014 requests for improvements

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE	Issue Subtype	Rough Rank	Option Type	Option Description
Deposition	Acid Rain	3	Studies	Determine if Echo Lake rain gauge can be sampled for WQ, others
	Ammonia N from injected fertilizers	2	Studies	Use LVW LTM and other studies to proportion deposition sources
	N Deposition at high altitudes	1	Studies	Mass balance only on lightning and acid rain
	P deposition at high altitudes	1	Cooperation	Find out NRCS/USDA recommendations, work w/ JCD to reduce
	TP from fertilizer / soils blowing	1	Studies	Determine if Echo Lake rain gauge can be sampled for TP, too
Development	New development does not stress LID in mountain communities to degree does in city	3	Cooperation	Expand MS4 education by including Property 360 inspection option
Ditch Cleanout	No resolution since reported in 2009 and since	3	Communication	Work with ditch cos after determine DWR, WQCD regulation and create related policy
Drought Related	blowing deposition	3	Studies	Collect blowing soil samples during drought periods to gauge effect
	increasing concentrations	4	Conservation	Drought conservation - make sure all communities set thresholds
	invasive species	3	Physical Treatment	Irrigate native vegetation if appears stressed, remove invasives
	low flows, high temp kill fish	5	Vegetative Buffer	Shade stream now and measure before and after effects

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Drought Related**

Issue Subtype Riparian vegetation dies

Rough Rank	Option Type	Option Description
3	Vegetative Buffer	Replant and irrigate if must to ensure rigourous reestablishment

ISSUE **Ecology / Habitat**

Issue Subtype Fragmented, lacks diversity

Rough Rank	Option Type	Option Description
3	Cooperation	Determine how boulder creek uses buffer policy to create riparian zone
3	Studies	Develop fractal and bubble analysis of ecosystem continuity

ISSUE **Economics**

Issue Subtype BCLP does not collect for water quality

Rough Rank	Option Type	Option Description
4	Cooperation	BCLP should collect $0.50 / visitor by city ordinance or by sales tax mil levy

Issue Subtype BCLP walk-in, bike-in users not paying

Rough Rank	Option Type	Option Description
4	Cooperation	BCWA could help collect from walk/bike in visitors w ed program

ISSUE **Education**

Issue Subtype Few community members adequately informed

Rough Rank	Option Type	Option Description
4	Education	Topical webinars sponsored through BCLP and Eaudubon and Conifer

ISSUE **Fertilizer**

Issue Subtype Agriculture and pasture application

Rough Rank	Option Type	Option Description
4	Cooperation	Work with JCD to improve farm and ranch plans

Issue Subtype golf courses

Rough Rank	Option Type	Option Description
4	Cooperation	Learn how Summit CO developed golf course green mgr program

Issue Subtype lawns along creek

Rough Rank	Option Type	Option Description
5	Funding	Pay stream side properties to tear out lawns and buffer riparian

ISSUE **Fire Hazard**

Issue Subtype FireWise

Rough Rank	Option Type	Option Description
5	Cooperation	Work with communities and county to set up at watershed-wide level

Issue Subtype Preplan post mitigation support and activities

Rough Rank	Option Type	Option Description
5	Cooperation	Post Fire Restoration Options, obtain resources, connections to support
2	Trap Sediment	Below-ground, after-fire Sediment basin recommended by CUSP

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Fire Hazard**

Issue Subtype Prescribed burns for weed controlled disallowed

Rough Rank	Option Type	Option Description
4	Cooperation	Demonstrate effective controls to prevent spread and winter burns

Issue Subtype Presed basin

Rough Rank	Option Type	Option Description
1	Trap Sediment	Fire Hzd Mitigation: Prepermit sed basins

Issue Subtype Slash mgmt

Rough Rank	Option Type	Option Description
4	Cooperation	JCPS / JCD assistance w camp fire threat mgmt
4	Cooperation	Regional slash management plan with more transfer stations, pickup, chipping rentals
4	Cooperation	JCD partnerships and funding
1	Cooperation	Bird Atlas survey sites to limit fire thinning

ISSUE **Fish**

Issue Subtype Stocking

Rough Rank	Option Type	Option Description
3	Biomanipulation	Manage catch
3	Biomanipulation	Do not stock trout July and August to see if reduces blooms

ISSUE **Flood Related**

Issue Subtype driveway culverts washed out

Rough Rank	Option Type	Option Description
5	Education	Flood Tips for Watershed Health / Water Quality

Issue Subtype Lair of the Bear Park upstream bank cuts after flood

Rough Rank	Option Type	Option Description
1	Physical Treatment	Move path, restabilize partially with vegetation

Issue Subtype Latrines submerged

Rough Rank	Option Type	Option Description
3	Operation & Maintenance	Complete more inspections before put back into service in spring

Issue Subtype potential phosphorus flushing

Rough Rank	Option Type	Option Description
3	Monitoring	Determine rate and magnitude of effects from deposition, decomp

Issue Subtype sediment, debris, OM in water body

Rough Rank	Option Type	Option Description
5	Studies	Flood sediment analysis in both streams and reservoirs, cores
4	Monitoring	Dedissee Pre-project monitoring - refocus to new problems
3	Monitoring	BCR: Televise Aerators and estimate debris load washed in

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE Flood Related

Issue Subtype Structure flooding

Rough Rank	Option Type	Option Description
5	Education	Flood and Recovery documentation
3	Studies	Find out how many structures flood in addition to bar in Evergreen

ISSUE Funding

Issue Subtype Single source - BCWA dues, extremely inadequate

Rough Rank	Option Type	Option Description
5	Funding	Develop 501(c)3 nonprofit corporation and rapidly build funding
2	Funding	Work with JCOS, DMP, and BCLP to allow trailhead donation collection

ISSUE Groundwater Contamination

Issue Subtype Higher TDS

Rough Rank	Option Type	Option Description
2	Water Rights	Districts with adequate water rights should promote w/ww connections

Issue Subtype Septics nitrates

Rough Rank	Option Type	Option Description
5	Modeling	USGS followup study from 1970 and 1990
3	Modeling	Septic System zones by geology and soils

ISSUE Groundwater Pumping

Issue Subtype Effect on streamflow

Rough Rank	Option Type	Option Description
3	Studies	Need to better determine effect gw pumping during low flows, baseflow

ISSUE High Evapotranspiration / Dry Soils

Issue Subtype Affecting riparian vegetation, unless stomata adjust

Rough Rank	Option Type	Option Description
2	Cooperation	Develop drought plan to support critical habitat, not just human needs

ISSUE High Temperature

Issue Subtype drying out soils and streams, increasing water temp

Rough Rank	Option Type	Option Description
4	Vegetative Buffer	Increase shading and ensure adequate hyporheic connection

ISSUE High Water Use

Issue Subtype how promote conservation when use it or lose it

Rough Rank	Option Type	Option Description
2	Legislation	Create incentives for water sharing in low flow times, not just prior

ISSUE Illicit Dumping

Issue Subtype Chemical and fuel spills

Rough Rank	Option Type	Option Description
2	Improve Enforcement	Make public aware of emergency contacts, Verify plan in place to reduce sediment, too

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE Illicit Dumping

Issue Subtype Dead tress and slash in streams

Rough Rank	Option Type	Option Description
5	Partnering	Regional Slash management plan with education program

Issue Subtype Trash and debris along stream and in parks

Rough Rank	Option Type	Option Description
5	Improve Enforcement	Volunteer reporting through ACM DSS issues reporting system
3	Volunteers	Trash pickup, bird/weed counts while stream survey

Issue Subtype Trucks and cars falling in lakes and streams

Rough Rank	Option Type	Option Description
2	Cooperation	Work with CDOT and counties to study each case to reduce risk

ISSUE Information

Issue Subtype overload

Rough Rank	Option Type	Option Description
1	Education	Find more mechanisms to allow citizens easier knowledge building

ISSUE Internal Reservoir Loading

Issue Subtype 1000mg/L TP in sediment

Rough Rank	Option Type	Option Description
5	Studies	Reservoir Model - dynamic programming, calibrate to actual data
5	Chemical Treatment	Aeration optimization - work with manufacture to modify, optimize
4	Biological Treatment	Top-down ecological controls - seed daphnia and other algae eating species
4	Physical Treatment	Discharge anoxic, hypolimnetic water from existing lower elevation pipe
3	Studies	BCR: Keep trying for DO while improving temperature and TP compliance
3	Chemical Treatment	N/P ratio TMDL, so nitrogen does not become limiting
3	Eliminate Discharge	Determine way to capture fines and reduce TP levels before reaches BCR
3	Studies	Lake mesocosms next to lake to study more treatment options
2	Physical Treatment	Opt. aeration to better circulate phytoplankton below euphotic zone
2	Trap Sediment	reservoir dredging planned for Evergreen Lake, not feasible BCR yet
1	Biomanipulation	remove carp, shad or other lake species linked to eutrophication
1	Chemical Treatment	Flocculation (alum) may cause harmful effects, but could test
1	Studies	Limnocorral studies at Barr Milton - learn from them, replicate best
1	Physical Treatment	Bypass high, nu-rich flows
1	Trap Sediment	Obtain approval for small lake pilot in BCW

Issue Subtype 400 pounds, increase with aeration throughout summer

Rough Rank	Option Type	Option Description
3	Studies	Use bench scale analysis to determin how and how much internal

ISSUE Invasive Species

Issue Subtype Aquatic snail or mussel

Rough Rank	Option Type	Option Description
2	Monitoring	In addition to boat inspections, find out if other ways to prevent

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE	**Invasive Species**	
Issue Subtype	Asian clam (streams)	
Rough Rank	**Option Type**	**Option Description**
1	Communication	DEHS reports this an issue in streams, so learn more to prevent
Issue Subtype	Noxious Weed	
Rough Rank	**Option Type**	**Option Description**
3	Cooperation	Join more collaborations to reduce throughout watershed
Issue Subtype	Pelican moving cyanobacteria / toxic algae around to all lakes	
Rough Rank	**Option Type**	**Option Description**
1	Physical Treatment	Determine if way to prevent pelicans from visiting BCR with algae
Issue Subtype	Russian Olive or Tamarisk	
Rough Rank	**Option Type**	**Option Description**
1	Monitoring	Use Issues reporting to include weeds and invasives from community
Issue Subtype	Rusty Crayfish	
Rough Rank	**Option Type**	**Option Description**
5	Monitoring	BCWA noted 1, need to survey area where found for more
ISSUE	**Lake Management**	
Issue Subtype	Aerators	
Rough Rank	**Option Type**	**Option Description**
5	Operation & Maintenance	EL: Optimize operation
4	Operation & Maintenance	Determine if TP higher in bottom of reservoir when not aerating
3	Operation & Maintenance	legs on aerator
3	Operation & Maintenance	BCR: Prevent aerator from moving
2	Trap Sediment	Aerator Stands to reduce resuspension of sediments
Issue Subtype	Macrophytes	
Rough Rank	**Option Type**	**Option Description**
3	Biomanipulation	Grass carp evergreen
2	Biomanipulation	Harvesting macrophytes
Issue Subtype	Sediments	
Rough Rank	**Option Type**	**Option Description**
4	Vegetative Buffer	Control lakeshore erosion
3	Operation & Maintenance	Phase 1 Dredge Operations
ISSUE	**Lake Residence Time**	
Issue Subtype	how manage with diversions and drought	
Rough Rank	**Option Type**	**Option Description**
5	Cooperation	Fund water rights purchases and leases and pod moves to reduce

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Latrines**

Issue Subtype BCLP vault, septic, compost maintenance

Rough Rank	Option Type	Option Description
5	Cooperation	Seek funding for BCLP decentralized system or w/ww connections
5	Operation & Maintenance	Verify O&M on all Vaults and Privies in Parks

Issue Subtype O&M

Rough Rank	Option Type	Option Description
5	Improve Policy	Recommend and verify all parks complete yearly leak testing
5	Improve Policy	Develop BMPs as a group with all public landowners for all issues
5	Cooperation	Ongoing public landowners group to work directly on issues with watershed

Issue Subtype Pit latrine drainage, leach fields

Rough Rank	Option Type	Option Description
4	Improve Enforcement	SL: Repair Verification and Monitoring

Issue Subtype Vault latrine cracks / leaks

Rough Rank	Option Type	Option Description
2	Improve Policy	Remove with 200 feet of waterway

ISSUE **Legislation**

Issue Subtype Decentralized systems <10000 - less reporting, expedited

Rough Rank	Option Type	Option Description
5	Legislation	Create innovation policy to expedite focus on decentralized systems

ISSUE **Macrophytes**

Issue Subtype Too few with carp in EP

Rough Rank	Option Type	Option Description
2	Biomanipulation	Compare game fish health before and after carp intro to adjust use

Issue Subtype why limited in BCR - clarity, enough for habitat?

Rough Rank	Option Type	Option Description
3	Studies	Map macrophytes using boat with radar throughout BCR to study

ISSUE **Management**

Issue Subtype Capacity building

Rough Rank	Option Type	Option Description
5	Management	Four management team - multidisciplinary
2	Management	BCWA SWOT Analysis, CPR criteria too

Issue Subtype Project selection - not enough choices, eval proc

Rough Rank	Option Type	Option Description
3	Policy	Find way to reduce comprehensive list into options to pursue quarterly for each member

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Mining**

Issue Subtype Aggregate mind south of Morrison effects?

Rough Rank	Option Type	Option Description
2	Studies	Assess state NPDES and other info and direct monitoring of effects

Issue Subtype any drainage from any old mine anywhere

Rough Rank	Option Type	Option Description
1	GIS	use rural water swap and BLM, state data to locate all AML

Issue Subtype Historic Idledale mines- effects?

Rough Rank	Option Type	Option Description
1	Communication	Find out if county or others know of any radioactive wells or effects

ISSUE **Monitoring**

Issue Subtype Algae blooms - types and extent

Rough Rank	Option Type	Option Description
4	Statistics	Determine exceedance frequency, magnitude, antecedents
2	Biomanipulation	Target nuisance types and emergent bloom properties
2	Modeling	Dynamic programming to model reservoir

Issue Subtype Costs increasing, more stations required w/ 303(d) listings

Rough Rank	Option Type	Option Description
5	Studies	Conduct monitoring retrospective to prioritize sites, reschedule

Issue Subtype E-coli

Rough Rank	Option Type	Option Description
2	Studies	Analyze source to control, develop management options

Issue Subtype Emerging Contaminants

Rough Rank	Option Type	Option Description
1	Studies	Study / research actual aquatic effects from WWTF & OWTS

Issue Subtype frequency

Rough Rank	Option Type	Option Description
4	Studies	Automatic gauging for storm water, flood sampling

Issue Subtype Heavy Metals

Rough Rank	Option Type	Option Description
2	Studies	Test BCR water and sediments and fish for all heavy metals

Issue Subtype High Iron

Rough Rank	Option Type	Option Description
4	Studies	Determine if iron addition reduces internal in low flow periods

Issue Subtype High nutrients at Site 63, 30% Bear Creek dainage

Rough Rank	Option Type	Option Description
2	Studies	Determine source - test for toilet paper chemicals and sheep dung

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Monitoring**

Issue Subtype High Temperature

Rough Rank	Option Type	Option Description
4	Studies	Follow-up on EPA study of creek water temperature and shading

Issue Subtype Inconsistent Results

Rough Rank	Option Type	Option Description
5	Monitoring	Need to move gauge or flowmeter for longer periods
5	Monitoring	Summit Lake Plume Monitoring / Assessment
5	Monitoring	Automatic gauges at Mount Vernon, Troublesome, Cub and Turkey
3	Monitoring	Split and test against GEI annually two different options

Issue Subtype Low or decreasing MMI scores

Rough Rank	Option Type	Option Description
2	Stream Restoration	Dedisee Park restoration project

Issue Subtype no funds to expand for each 303d listed item

Rough Rank	Option Type	Option Description
1	Cooperation	Allow JEHS, DEHS, RiverWatch, CLRMA volunteers to do MORE!

Issue Subtype No real time nutrient stations to determine flux, storm events

Rough Rank	Option Type	Option Description
5	Studies	Need to set up some choice stormwater monitoring stations
4	Statistics	types of events and duration
4	Monitoring	Automated collection sites catch high flows and rainfall upstream

Issue Subtype Reg 85 plant monitoring not accurate enough for comparison with Reg 74 GEI monitoring

Rough Rank	Option Type	Option Description
5	Pollution Trading	Require those seeking P trading to join BCWA analytical lab to compare

Issue Subtype Soda Lake no monitoring

Rough Rank	Option Type	Option Description
2	Cooperation	Get all Denver Water and BCLP data and use CLRMA volunteers

Issue Subtype storm / runoff events

Rough Rank	Option Type	Option Description
1	Modeling	Artificial Neural Network or genetic algorithm methods to fill in missing stream data on events

Issue Subtype TP peaks ruin averages

Rough Rank	Option Type	Option Description
4	Chemical Treatment	In-channel , in canal treatment

Issue Subtype Uncoordinated WWTP and stream sampling

Rough Rank	Option Type	Option Description
5	Cooperation	Call all non-participants and incentivize to join Reg. 85 monitoring program

Issue Subtype ungaged streams

Rough Rank	Option Type	Option Description
5	Studies	Stream Surveys / ACM DSS input

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE Natural nutrient cycling (forests, etc.)

Issue Subtype Flood vegetation decomposition

Rough Rank	Option Type	Option Description
5	GIS	Mass balance only on storm water and snowmelt controlled movement
5	GIS	Mass balance only on forest debris

Issue Subtype Forest debris, pine needles

Rough Rank	Option Type	Option Description
3	Studies	Determine allocatho

ISSUE NPS

Issue Subtype General problems of unknown source

Rough Rank	Option Type	Option Description
2	Stream Restoration	PRFs: Restoration projects

ISSUE Other

Issue Subtype beaver over-limited, convince parks to allow more

Rough Rank	Option Type	Option Description
1	Studies	Determine actual costs and benefits beaver compared to literature

ISSUE Policy

Issue Subtype implementing, not just writing

Rough Rank	Option Type	Option Description
1	Cooperation	Implement BCWA policies rather than complete at board approval

ISSUE Recreation

Issue Subtype Limited parking, places to go

Rough Rank	Option Type	Option Description
3	Cooperation	Work with public landowners to determine solutions to overuse

Issue Subtype Overuse

Rough Rank	Option Type	Option Description
3	Education	Respectful Recreation Program

Issue Subtype Social trails

Rough Rank	Option Type	Option Description
4	Education	Put signs at all social trails after repair explaing detrimental features

Issue Subtype Trampling riparian vegetation

Rough Rank	Option Type	Option Description
4	Education	Respectful Recreation Program and signs at trampled sites before repair
4	Physical Treatment	Rope off sensitive or degraded areas

ISSUE Regulation

Issue Subtype 303d listing does not consider wetlands differently than streams, but chem may differ

Rough Rank	Option Type	Option Description
3	Improve Process	Revised Annual Report Format to be more P-specific

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Regulation**

Issue Subtype Reporting

Rough Rank	Option Type	Option Description
3	Regulation	Adjust control reg for site specific WWTF, not one-size-fits-all

Issue Subtype Too focused on WWTF

Rough Rank	Option Type	Option Description
2	Chemical Treatment	include water treatment plant limit of 200 ug/L so water itself not already loaded

Issue Subtype Too stringent > 2000 gpd, high regulatory burden

Rough Rank	Option Type	Option Description
5	Legislation	Change rules so 2000-10000 expedited permitting process or devolved to county level

Issue Subtype TP and chlorophyll not correlated

Rough Rank	Option Type	Option Description
3	Regulation	wasteload not as good as concentrations

Issue Subtype TP Trading

Rough Rank	Option Type	Option Description
5	Improve Policy	Use P trading credits

Issue Subtype Uncertainty

Rough Rank	Option Type	Option Description
5	Cooperation	Meet and communicate with all WQCD sections at least quarterly

ISSUE **Relationship**

Issue Subtype DEH on sampling discrepancy, what to report

Rough Rank	Option Type	Option Description
3	Cooperation	Find way to support each others monitoring programs, not refute them

Issue Subtype ETU on temperature metering and 4th of July fishing

Rough Rank	Option Type	Option Description
4	Cooperation	Use BCWA member who is ETU member and ETU participant to smooth away issues

Issue Subtype Small dischargers

Rough Rank	Option Type	Option Description
5	Communication	Call directly and send by mail and allow phone-in to meetings

ISSUE **Resources**

Issue Subtype limited equipment - street sweeping in evergreen

Rough Rank	Option Type	Option Description
3	Funding	Buy street sweeper to focus on stream side roads throughout watershed continually

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Roads**

Issue Subtype embankment erosion

Rough Rank	Option Type	Option Description
4	Cooperation	Mark all eroding embankments and road type and work with owners

Issue Subtype encroached on floodplain

Rough Rank	Option Type	Option Description
3	Funding	Move roads, raise, increase culvert and bridges to flood less

Issue Subtype snow and ice management - chemicals, sand, fines, snow dumping into stream

Rough Rank	Option Type	Option Description
5	Cooperation	Find ways to mitigate negative effects of chemicals, salt, and sand

ISSUE **Sediment**

Issue Subtype major issue, too large proportion of soil movement

Rough Rank	Option Type	Option Description
5	Cooperation	Work with all public and private MS4 and others to reduce fines

ISSUE **Septic Systems (OWTS / ISDS)**

Issue Subtype charge volume exceeds 75 gallons / day

Rough Rank	Option Type	Option Description
3	Conservation	conservation to limit overcharging of SAT and ponding
3	Social Enterprise	Service Agreements to maintain annually for county permit discount

Issue Subtype near creek

Rough Rank	Option Type	Option Description
5	Cooperation	Learn from licensed cleaners and designers
4	Improve Policy	Renewable 5-year permits, no grandfathered
4	Studies	Shingle Creek trib to mt vernon hd owts
4	Improve Policy	Require gauge to determine if full
4	Studies	Analyze existing data for hot spots, esp. if seep out laterally
4	Improve Policy	Restrict placement near waterways and waterbodies
4	Policy	Develop management plan options together
4	Studies	Determine if 10K or 27K and threats
4	Sewer Extension with Water Supply	BCLP Sewer/Water Connection
4	Improve Enforcement	Fine failed systems, require improved replacement
3	Conservation	Add graywater treatment for flushing to reduce groundwater pumping in high density areas to also reduce leachate contramination
3	Sewer Extension	Convert to sewer
3	Education	Short course for HOAs and groups
3	Conservation	Separate graywater from blackwater for further treatment
2	Biological Treatment	Aerobic tank between anaerobic tanks
2	Chemical Treatment	Add nitrate fixing chemical
2	Communication	Funny, informative campaign to maintain OWTS
2	Improve Policy	Require floodplain to be sewered to take offsite

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE	**Septic Systems (OWTS / ISDS)**	
Issue Subtype	near creek	
Rough Rank	Option Type	Option Description
2	Improve Policy	Reduce permit cost for annual maintenance plan
Issue Subtype	near fractured bedrock / tributary groundwater	
Rough Rank	Option Type	Option Description
3	Studies	Study soils and geology by area to zone and prevent preferential flow
Issue Subtype	nitrates leaching to groundwater	
Rough Rank	Option Type	Option Description
3	Studies	Repeat USGS study 2015-17 from 1970, 1990 that evaluated risk
Issue Subtype	not permited / older	
Rough Rank	Option Type	Option Description
5	Operation & Maintenance	Get BCWA Inspection License / Event Signup
4	Improve Enforcement	Find all unpermitted OWTS, get inspected and permitted
Issue Subtype	O&M	
Rough Rank	Option Type	Option Description
4	Social Enterprise	Regional Sepatage Plan - stand-alone local treatment farm
4	Cooperation	Contact CSM
3	Social Enterprise	Regional plants, esp Conifer should accept septage from surrounding OWTS
Issue Subtype	phosphorus migration	
Rough Rank	Option Type	Option Description
2	Studies	Conduct near stream gw and limited monitoring to pinpoint
Issue Subtype	residents won't connect to nearby WWTF	
Rough Rank	Option Type	Option Description
4	Sewer Extension with Water Supply	UBC Water & Sewer to replace failing wells and OWTS, integrate UBC
3	Cooperation	Seek grant funding to connect Evergreen Lake / Dedisee Park to EMD
Issue Subtype	saturated soils reduce TP removal	
Rough Rank	Option Type	Option Description
5	Studies	Nutrients and GW / SW interaction
ISSUE	**Small Dischargers**	
Issue Subtype	Innovation for cost effective TP reduction	
Rough Rank	Option Type	Option Description
5	Cooperation	Find grants and incentives to connect to get out of WWTF biz
4	Pollution Trading	Set up reusable trading program, through legal contract
3	Studies	Decentralized system design and data
3	Social Enterprise	OWTS Innovation Cluster
2	Studies	Design advanced OWTS to provide longer life, better treatment

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Small Dischargers**

Issue Subtype Innovation for cost effective TP reduction

Rough Rank	Option Type	Option Description
1	Regulation	Find out why state regulation tried to put The Fort at 0.5 mg/L and why BCWA agreed

Issue Subtype monitoring

Rough Rank	Option Type	Option Description
5	Monitoring	Encourage to test TP with more precise lab

Issue Subtype O&M

Rough Rank	Option Type	Option Description
3	Operation & Maintenance	Determine how can better maintain to effluent limits

ISSUE **Source Water Protection**

Issue Subtype CUSP Denver Water 2013-14 Basin Wide Study

Rough Rank	Option Type	Option Description
4	Cooperation	Work with CUSP and Denver Water to follow watershed-wide process

Issue Subtype Rural Water EMD 2013-2014 Grant and Study

Rough Rank	Option Type	Option Description
4	Cooperation	Collaboration Toolkit with NRCS and others to reduce risks

ISSUE **Spill**

Issue Subtype Many roads that allow trucks that could spill in, fuel tanks, other

Rough Rank	Option Type	Option Description
2	Cooperation	Survey roads for potential risks and work with owners to reduce them

ISSUE **Stormwater (MS4s) / urban runoff**

Issue Subtype Deicing and sanding

Rough Rank	Option Type	Option Description
5	Partnering	Coordinate cost share for road projects with CDOT
5	Monitoring	Stream surveys
4	Operation & Maintenance	Work with CDOT and County Road and Bridge in prevention
3	Cooperation	Evgr Pk Lot Build coalition
2	Funding	Evgr Pk Lot Design and Fund

Issue Subtype erosion

Rough Rank	Option Type	Option Description
5	Volunteers	Volunteer work always available
4	Restoration Project	Stream buffers

Issue Subtype polluted runoff

Rough Rank	Option Type	Option Description
5	Policy	Model ordinance
4	Cooperation	Contact CSU
4	Modeling	Integrated Urban Water Model (IUWM)

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Stormwater (MS4s) / urban runoff**

Issue Subtype polluted runoff

Rough Rank	Option Type	Option Description
4	Biological Treatment	Artificial wetlands or retention before BCR
3	Regulation	3-tier stormwater system for development

Issue Subtype Roads named after every creek alongside

Rough Rank	Option Type	Option Description
5	GIS	Demonstrate where floodplain would have been without them, erosion

Issue Subtype sediments

Rough Rank	Option Type	Option Description
5	Restoration Project	Evergreen parking lot erosion / plowing control - Deed, Ross Trust
4	Modeling	Complex modeling entire watershed and reservoir
4	Trap Sediment	Downtown Evergreen
4	GIS	Where was storm centered
3	Conservation	Rainwater and Graywater

ISSUE **Stream Sediments / Bedload**

Issue Subtype fine sediments hurt temperature and benthic

Rough Rank	Option Type	Option Description
5	Stream Restoration	Stabilize banks
5	Vegetative Buffer	buffers as water quality mitigation
5	Pollution Trading	Trading incentives program
5	Studies	Streambank survey
5	Physical Treatment	BUFFERS
5	Policy	buffer zone wide determin by features
5	Vegetative Buffer	Vegetative Buffers
3	Vegetative Buffer	Native seeding - Chatfield seedbank, RM native plant nursery
2	Stream Restoration	Use template on one p reduction for others
2	Stream Restoration	O'Fallon ETU stream project
2	Stream Restoration	Grade control structures
1	Stream Restoration	Cherry Creek Eco Park

ISSUE **Streambank Erosion**

Issue Subtype Streambank erosion, esp after event

Rough Rank	Option Type	Option Description
3	Studies	Verify streambanks eroding low in P and fines or remediate

ISSUE **Wastewater Treatment Plant (WWTP)**

Issue Subtype byproducts

Rough Rank	Option Type	Option Description
5	Cooperation	Explore WLA credits for Morrison to connect Idledale, Fort, BCLP
3	Studies	Determine how sediments affected by seasonal waste loading
2	Management	Determine if FHMD changes will ensure 2014 compliance now

EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE **Wastewater Treatment Plant (WWTP)**

Issue Subtype emerging contaminants

Rough Rank	Option Type	Option Description
1	Studies	Determine how far downstream can detect them below WWTF

Issue Subtype high nitrogen

Rough Rank	Option Type	Option Description
4	Water Rights	Determine how to minimize concentrations during low flows

Issue Subtype high phosphorus

Rough Rank	Option Type	Option Description
5	Chemical Treatment	Have university students design improved processes
5	Cooperation	Review AWWA and other BMPs for TP and temperature reductions
5	Cooperation	Direct DMR upload as provide to state monthly
4	Chemical Treatment	Test and rank chemical TP precipitates for cost and effectiveness
4	Cooperation	Have all WWTP work together to mimimize releases
4	Cooperation	Rather than allow EPA/state to dictate standards and WLA, provide models and risk analysis
3	Studies	Harriman ditch withdrawals to determine amount reaching BCR
3	Improve Process	Optimize timing and dosage of existing chemical P removal
2	Improve Policy	Seek below 1.0 mg/L TP for smaller dischargers
2	Biological Treatment	Test modified BNR to improve both N and P removal
2	Improve Policy	Continue toward 0.2 mg/L TP target for WWTFs effluent discharges

Issue Subtype high temperature

Rough Rank	Option Type	Option Description
2	Cooperation	Determine how could reduce in stream reach downstream

Issue Subtype malfunction

Rough Rank	Option Type	Option Description
1	Improve Policy	How should best deal with exceedances due to a process failure?

Issue Subtype O&M

Rough Rank	Option Type	Option Description
4	Improve Process	Continually optimize to squeeze out additional nutrient reductions

ISSUE **Water Rights / Low Flows**

Issue Subtype Bear Creek diversions

Rough Rank	Option Type	Option Description
5	Water Rights	Move point of diversion below BCR, so Bear Creek not dewatered
4	Cooperation	Alert CWCB when upstream lawn waterers divert ISF rights
4	Cooperation	Lease or purchase instream flow rights from senior owner
3	Water Rights	Strategies to minimize adverse impacts of the exercise of water rights

Issue Subtype Diversion / Canal cleanout

Rough Rank	Option Type	Option Description
4	Improve Policy	Canal cleanout, require sediment removal and disposal

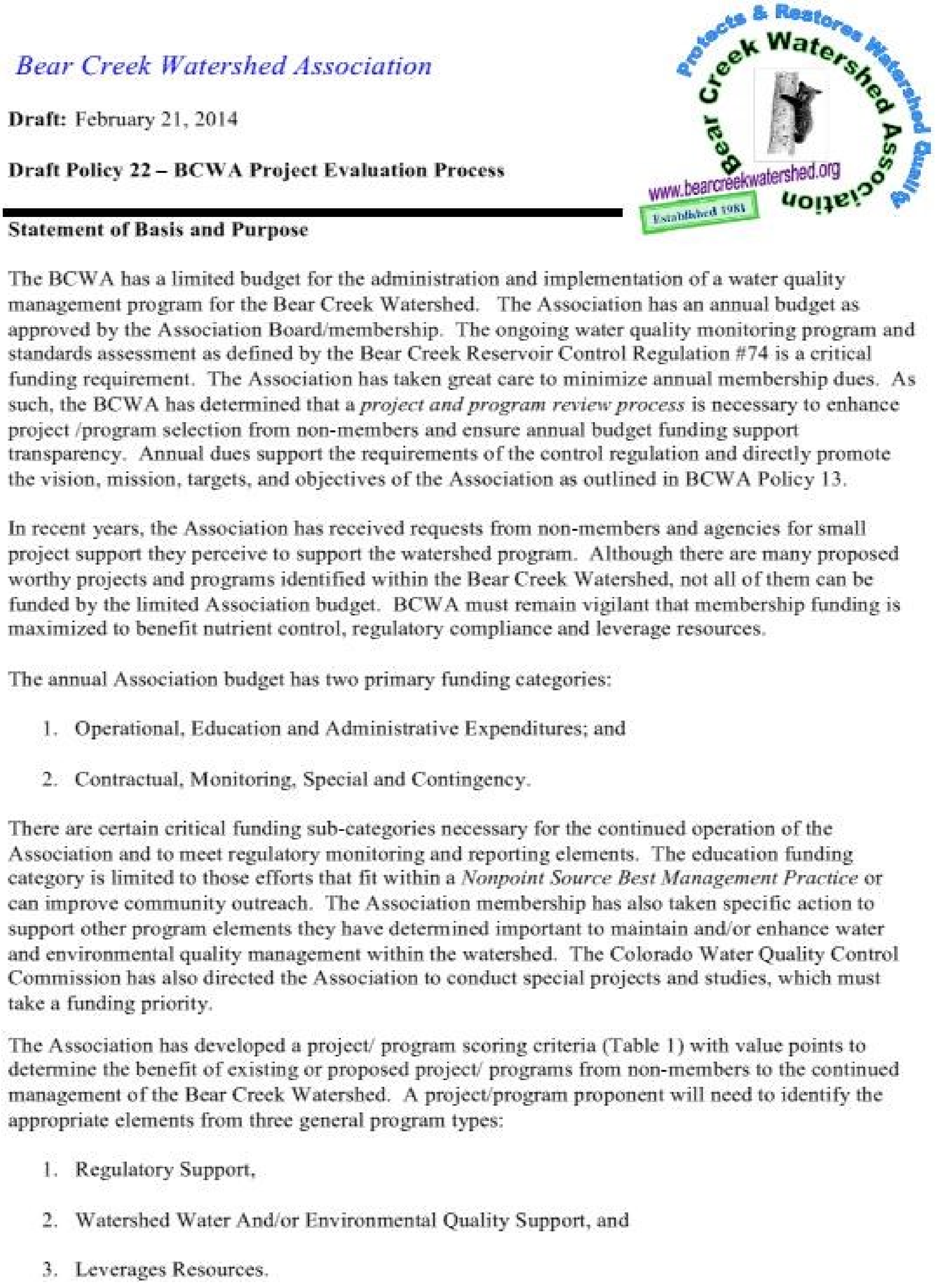
EXHIBIT 12. POTENTIAL OPTIONS BY NUTRIENT ISSUE (Continued)

ISSUE	**Water Rights / Low Flows**	
Issue Subtype	Drawdown in Soda Lakes	
Rough Rank	**Option Type**	**Option Description**
4	Cooperation	Develop relationship between recreational managers and diverters
Issue Subtype	increases pollutant concentations	
Rough Rank	**Option Type**	**Option Description**
5	Cooperation	Buy or lease water or change point of diversion to reduce issue
Issue Subtype	Irrigating lawns illegally along streams	
Rough Rank	**Option Type**	**Option Description**
4	Communication	Let CWCB know and use BCWA flowmeter to determine loss
Issue Subtype	OWTS to sewer conversion effects	
Rough Rank	**Option Type**	**Option Description**
1	Studies	Determine water rights affects of converting OWTS to sewer if well user
Issue Subtype	Turkey Creek diversions	
Rough Rank	**Option Type**	**Option Description**
1	Studies	Determine proportional losses of nutrients and water diverted
Issue Subtype	Well pumping effects on aquifer	
Rough Rank	**Option Type**	**Option Description**
2	Cooperation	Use county data and supplement with state and usgs to calculate
Issue Subtype	well pumping effects on streamflow	
Rough Rank	**Option Type**	**Option Description**
3	Studies	Use methods to determine seasonal losing and gaining reaches
ISSUE	**Water Supply**	
Issue Subtype	no conjunctive use	
Rough Rank	**Option Type**	**Option Description**
3	Cooperation	MOUs between well and surface users to support each other in drought
Issue Subtype	not incentizing waste hookup, reliability	
Rough Rank	**Option Type**	**Option Description**
4	Cooperation	Begin sector level connection studies for w/ww, not individual, one type only

EXHIBIT 13. OPTION SELECTION WORKSHEET

Pursue? Yes or No	Issues Addressed	Option Title	Option Description	TP (kg/yr) Reduction	TN (kg/yr) Reduction	Other Improvements
	FIRE	Pre-permit sedimentation basin	Select Sites			
			Obtain cooperation			
			Seek Permit Approvals			
		Clear Cut	Delineate JCD existing location/benefits, Promote new cooperators?			
			Promote NRCS EQIP thinning, improve awareness / understanding			
			USFS - promote ponderosa thinning, prescribed fire			
			Focus on overly dense lower elevation ponderosa pine stands threat			
		Aspen Regeneration	Encourage landowners to create openings over weak stands			
		Post fire rehabilitation	Who worked on bluebell, squaw pass, and conifer area fires - get info			
			Seeding, raking, log erosion barriers, wattles, home drains, rock and bale			
			check dams, post and wire check dam, sed basin, see JCD list and others			
			Invasive species control after fire			
			Felling hazardous trees			
		Make each community FireWise	By fire district - genesee already, elk, evergreen, indian hills,			
		Advertise each districts slash collection dates, incentivize participation, help foster new options				
		Review CWPP	Any areas missing, any need to be expanded, recommendations followed			
	AERATORS	BCL Aeration System	Fence off susceptible to movement areas			
			Try different on / off diurnal cycles for better temperature control			
		Evergreen Aeration System	Evaluate first year operation for improvement opportunities			
	INTERNAL	Calculate sediment load	Determine potential additional Internal BCL P load from Flood			
	LOADING	Algae harvesting options	Compost algae when bloom, best to harvest before too advanced			
		Commercial pond sealing options	Talk to Lakewood pond divers about options statewide, BMPs			
	SMALL	Create Benefit Packet	Create brochure about benefits/responsibilities of BCWA membership			
	DISCHARGERS	Host meeting / social at their location	Most small dischargers are businesses, restaurants, so meet up there			
		Bring into compliance	Pair small dischargers with large one or otherwise help meet standards			
	EDUCATION	Watershed 102	Hold Watershed 102 and re-offer Watershed 101 at different venues			
		Sign Project	After signs up, find creative ways to maximize marketing and exposure			
		BCWF setup	Complete paperwork, bank, accounting system, and other prerequisites			
		BCWF website	Target website for donations and other support to community and biz			
	SEPTIC SYSTEMS	Complete analysis, share with countie	Encourage adoption of recurring permits, cleanout record, full warning			
		Create Latrine BMP Working Group	Have public landowners work to develop BMPs for latrine management			
		Summit Lake Plume followup	Ensure vault repair leading to reduced nutrients or check legacy pits			
		Support Graywater Reuse Study	Determine feasibility of supporting graywater reuse to reduce effluent			
		Determine feasibility of M Plans	Determine if cleaners could develop program for annual maintenance			
		Septic System Studies	Need further evidence of P and N transport to surface water			
	STORMWATER	Evaluate Morrison Rd for BMPs	Determine where in particular could benefit creekside BMPs			
		Complete design and funding Dedisee	Approve SOW, complete design, and obtain funding to begin Dedisee			
		Further evaluate Parking lot project	Work with owner and area businesses to build support for project			
		Guardrails at eroding pulloffs	Work with CDOT and counties to place guardrails where parking eroding			
		Review flood damages for clues	Review Sept. 2013 flood damage areas to clues for where BMPs needed			
		Mark all streambank erosion	Determine where streambanks wider or eroded from floods			
	LARGE ANIMALS	Learn if JCD projects successful	Determine if JCD pasture management, fencing ranch projects working			
		Delineate all pastures and stables	Locate all areas where riparian areas might be restored through pastures			
		Calculate manure loading	Determine potential load per pasture, animal count more specificall			
	WWTFs	Work for 0.2 ug/L P standard by 2016	Work to optimize treatment systems to achieve consistent, low P discharge			
		Share BMPs	Share BMPs to reduce operating and maintenance costs overall			
		Obtain trading credit approval	Obtain approval for WWTF discharge reduction and Coyote Gulch credits			

EXHIBIT 14. BCWA POLICY 23. PROJECT EVALUATION SYSTEM



Bear Creek Watershed Association

Draft: February 21, 2014

Draft Policy 22 – BCWA Project Evaluation Process

Statement of Basis and Purpose

The BCWA has a limited budget for the administration and implementation of a water quality management program for the Bear Creek Watershed. The Association has an annual budget as approved by the Association Board/membership. The ongoing water quality monitoring program and standards assessment as defined by the Bear Creek Reservoir Control Regulation #74 is a critical funding requirement. The Association has taken great care to minimize annual membership dues. As such, the BCWA has determined that a *project and program review process* is necessary to enhance project /program selection from non-members and ensure annual budget funding support transparency. Annual dues support the requirements of the control regulation and directly promote the vision, mission, targets, and objectives of the Association as outlined in BCWA Policy 13.

In recent years, the Association has received requests from non-members and agencies for small project support they perceive to support the watershed program. Although there are many proposed worthy projects and programs identified within the Bear Creek Watershed, not all of them can be funded by the limited Association budget. BCWA must remain vigilant that membership funding is maximized to benefit nutrient control, regulatory compliance and leverage resources.

The annual Association budget has two primary funding categories:

1. Operational, Education and Administrative Expenditures; and

2. Contractual, Monitoring, Special and Contingency.

There are certain critical funding sub-categories necessary for the continued operation of the Association and to meet regulatory monitoring and reporting elements. The education funding category is limited to those efforts that fit within a *Nonpoint Source Best Management Practice* or can improve community outreach. The Association membership has also taken specific action to support other program elements they have determined important to maintain and/or enhance water and environmental quality management within the watershed. The Colorado Water Quality Control Commission has also directed the Association to conduct special projects and studies, which must take a funding priority.

The Association has developed a project/ program scoring criteria (Table 1) with value points to determine the benefit of existing or proposed project/ programs from non-members to the continued management of the Bear Creek Watershed. A project/program proponent will need to identify the appropriate elements from three general program types:

1. Regulatory Support,

2. Watershed Water And/or Environmental Quality Support, and

3. Leverages Resources.

A project/program for consideration should receive value votes from all three program types and can score several elements in each program type.

Table 1 BCWA Project Scoring Criteria and Value

Regulatory Support	
Supports watershed standards and regulations	5
Supports Association annual reporting and data management	5
Supports watershed permitted wastewater management	5
Supports Association to meet requirements of Control Regulation	5
Watershed Water and/or Environment Quality Support	
Potentially reduces watershed nutrient loading/ improves management	4
Supports trading program/ generates phosphorus trade credits	4
Targets nonpoint/ stormwater pollutants in watershed	4
Targets adopted BCWA Policies	4
Improves watershed water or environmental quality	4
Leverages Resources	
Leverages members and affiliated volunteers resources/ funding	3
Targets educational or informational water or environmental quality	3
Supports watershed community outreach/ improves community outreach	3
Increases members ability to partner with other groups	3
Can generate outside funding/ resources for watershed projects	3
Total available value points	55.0

Review and Scoring Process

1. To propose a new project or program disbursement, a BCWA member or participant should enter the concept as a *Potential Project* in the Project tab of the ACM DSS, and then the proponent should enter cost, partners, benefits or other available information.

2. The proponent should choose *Project Score* on the Costs tab of the new project and provide a preliminary score for the *project*.

3. If the initial score passes the threshold level of 20 value points, the proponent may copy the link to the score sheet in an email to the BCWA manager and request further project or program consideration.

4. The manager will review the proponent *project* scoring and do a budget analysis on available funds and present findings in a technical memorandum at the next TRS meeting to further discussion of technical merits, funding levels, and potential benefits to the watershed management program.

5. If the TRS supports the proposal, the proponent and the BCWA manager will bring the *project* up for discussion and action at an appropriate BCWA Board meeting.

Policy Positions

1. Potential *project/ program* funding requests from non-member groups or agencies will be subject to an Association review and scoring process using the Project tab of the ACM DSS online system and a screening at an Association Technical Review Session.

2. Any potential *project/ program* funding request will only be considered by the Association if there is no other better or more appropriate alternative.

3. Potential *project/ program* funding requests must demonstrate the potential to benefit water and environment quality within Bear Creek Watershed or support watershed specific regulatory programs.

4. Potential *project/program* funding must score a minimum of 20 value points as verified at an Association Technical Review Session for consideration by the Association membership for funding.

5. All new approved funding requests must be incorporated into a revised annual budget, subject to a majority vote of the Association membership.

6. Special *project/ program* funding requests are subject to annual review and approval of the Association. Multiple-year funding requests for non-critical program elements are discouraged, but maybe considered by the Association membership.

7. Any potential *project/ program* that receives Association funding is expected to complete a project/ program performance review at the completion of the first year of funding; and any multiple year funding projects/ programs must do a 5-year performance review.

EXHIBIT 15. ACM DSS EXAMPLE USABILITY TESTING LETTER

YOUR USER NAME:________________________ YOUR PASSWORD: ________________________

Dear BCWA Usability Testers,

Thank you very much for agreeing to help test the tools developed for my CSU research project. Earlier this morning, you should have received your Bear Creek Watershed Online login information to begin testing. If you did not receive your login information by email earlier today, please REPLY (mtherzog@rams.colostate.edu) and I'll get you set up.

The survey you need to complete is attached.
You can print out the PDF version attached for manual survey response entry. However, if you prefer, the MS Word version attached will allow automatic check box and short answer completion, which you can fill out and email back electronically. I will shuffle all responses and delete the original reply emails to keep results as anonymous as possible. I will need to know if you completed a survey though, so you can get prize credit, since CSU allows small tokens of appreciation for your precious time and expert review. Also, it is *especially helpful* to catch design problems to actually WATCH users in action and hear their fuller responses directly, so if any of you wouldn't mind, please email me to set up an in-person usability test, rather than filling out the survey yourself.

INSTRUCTIONS
1. Using the login information you received in a prior email today, please login to the system on the right side of the homepage with your user name and password.

2. Briefly review the HOME tab and open the linked study documents for review, then answer the related survey questions attached.

3. Carefully review the Tools tab for tools access and use instructions, then answer related survey questions attached.

4. In the Issues tab, zoom into a known area of concern, click the *Aerial* or *Bird's eye* option in the upper left to see the aerial imagery backdrop for closer point placement, then RIGHT CLICK to add a new issue point. Enter the type of issue from the dropdown and brief clarifying comments, then choose save at the bottom of the popup form (you will have to allow popups for this site for this to work). Finally, please answer the related survey questions on page 2 of the survey attached.

5. Lastly, in the Data tab, click on your favorite site circle and select one of the *Yearly Reports* from those that appear in the site information box. Next, choose just one site from the *Filter by Site* dropdown on the left to show only one dot to ease selection, and again click the dot to review this site's *Yearly Reports*. Finally, choose one of the *All Site Reports* at the bottom, left of the Legend to review all sites at once for a given year. Please complete the survey and either return the hard copy printed out PDF version to me at a meeting or email back your fillable MS Word form responses.

Again, thank you for your honest criticism and recommendations to make these very rough tools more useful and user-friendly!

Best regards,
Margaret

Margaret T. Herzog, PE, PMP
CSU CIVE WRPM PhD in progress
Topic: Adaptive Co-Management Decision Support System
to Foster Adaption and Innovation in Watershed Management

Email: mtherzog@rams.colostate.edu
Phone: (303) 238-0419
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Lakewood, CO 80228

EXHIBIT 16. USABILITY TESTING SURVEY #1

CSU Research Study: ACM DSS

Usability Testing #1 for BCWA Members and Participants

Please complete this form to help improve the Watershed Issues and Data Viewer tabs.
You can print out or fill in electronically and return to me at a BCWA meeting or by email:
mtherzog@rams.colostate.edu. Please contact me if you have any problems (303) 238-0419.

System Info	
Which operating system do you run?	☐Windows ☐Apple ☐Android ☐Other
Which web browser do you use?	☐IE ☐Safari ☐Chrome ☐ Firefox ☐Other
What type of device did you test the app on?	☐Desktop ☐Laptop ☐Tablet ☐Mobile
What is your level of internet comfort?	☐Power User ☐Average ☐Don't Use Much
Homepage – please briefly review the homepage at http://bc.wateractionnetwork.org	
Does this page provide enough info about the study? If not, what more info is needed?	☐ Yes ☐ No Please list other info would like here? Click here to enter text.
Were you able to view / download study docs?	☐Yes ☐ No
Is it clear where to go next? Please comment.	☐Yes ☐ No Explain:Click here to enter text.
Is there anything that bothers you here?	Click here to enter text.
Is there anything that grabs your attention?	Click here to enter text.
Login	
How did you obtain your login information?	☐Paper handout ☐Email ☐Both ☐Other
Could you find and login easily?	☐Easily ☐Yes, but difficult ☐Not found
After login, did Issues and Data tabs appear?	☐Yes ☐Not found
What would improve the login experience?	Click here to enter text.
Tools **Overview / Instructions** (Tools tab)	
Did the tools overview meet your needs?	☐Too detailed ☐Adequate ☐Too brief
Did the Tools info help you understand the Issues and Data tabs better before use?	☐Not really ☐A little ☐Quite a bit
What would make this info more helpful?	Click here to enter text.

Watershed Issues (Issues tab, login required to view) Please add at least THREE REAL issues you know of, then answer the questions.	
If you were able to click a location, enter an issue type, and provide comments, please describe your experience.	☐Added ☐Could not add any new issues Explain:Click here to enter text.
Please list types of issues missing from the dropdown list that are important?	Click here to enter text.
Should users be able to upload a photo or document describing the issue they found.	☐Yes ☐ No Explain:Click here to enter text.
What would improve the issue reporting experience?	Click here to enter text.
In addition to collecting a wider variety and number of issues for this research, how else might the issues tool aid BCWA management?	Click here to enter text.
Monitoring Data (Data Tab, login required to view) Please visit 2 sites and review at least 1 report for each, as well as, one of the All Sites Reports below the Legend before answering the questions below.	
Please describe any missing or misplaced sites	Click here to enter text.
Please describe any graphing errors or graph or data improvement ideas.	Click here to enter text.
In the All Sites Reports, could you understand the site arrangement with tributaries entering from top site to bottom site where they drain in? What might be a better depiction?	Click here to enter text.
Does having map-based data online increase your personal likelihood of using the data?	☐Yes ☐Maybe ☐No Explain:Click here to enter text.
Can you think of any uses for this Data tool?	Click here to enter text.
What other ways might the data be presented to improve its access and use? Animation, etc	Click here to enter text.
Other Concerns or Recommendations	
Please provide comments on other issues you encountered or other recommendations for improvement of any aspect of the tools or website.	Click here to enter text.
How much time did you spend on this test?	Click here to enter text.

THANK YOU FOR YOUR ASSISTANCE!

EXHIBIT 17. USABILITY TESTING SURVEY #2

CSU Research Study: ACM DSS

Usability Testing #2 for BCWA Members and Participants
Please complete this form to help improve the Maps, Search, Projects, Options, and Plan tabs.
You can print out or fill in electronically and return to me at a BCWA meeting or by email:
mtherzog@rams.colostate.edu. Please contact me if you have any problems (303) 238-0419.

Maps (Maps tab, login required to view) Please select each type of land and see if the information is useful.	
Does knowing where parks, providers, and high-density septics are located help you	☐Yes ☐No Explain:Click here to enter text.
Please list other landuse you'd like to see that wouldn't overlap or other maps.	Click here to enter text.
Search Data (Search Tab, login required to view) Please visit each search data tab. In the first, click BCWA participant and pick one. In the second choose a zip code and then a city to view groups shown. Finally, in the third tab, pick a Topic to see if the information is useful.	
Does it help to have info on BCWA members and other groups available.	☐Yes ☐ No Explain:Click here to enter text.
What other information about groups would be helpful?	Click here to enter text.
How might Topical Knowledge be useful to you or the BCWA?	Click here to enter text.
Projects (Projects Tab, login required to view) Pick a project and click through its tabs, clicking on any item of interest for more information.	
Does it help to be able to add projects at the start and link all related info to them.	☐Yes ☐Maybe ☐No Explain:Click here to enter text.
Would you visit this information?	Click here to enter text.
Might it serve as BMP DB over time?	Click here to enter text.
Options (Options Tab, login required to view) Select a Year = 2014 and add an option you brainstorm, then add it to portfolio and follow tabs.	
Can you see how enumerating options and then picking specific ones to pursue each year in advance could aid in funding and watershed development?	☐Yes ☐Maybe ☐ No Explain:Click here to enter text.
Would you consider using it – why or why not.	Click here to enter text.
Plan (Plan Tab, login required to view) Review what has been added to keep track of what portions of formal watershed plan done.	
By building the watershed plan with every GIS and analysis effort and listing them all in one place assist BCWA for grants and management?	☐Yes ☐Maybe ☐No Explain:Click here to enter text.
Would you visit this information if you needed something specific to satisfy a grant?	Click here to enter text.
What other purposes might it serve?	Click here to enter text.
Other Concerns or Recommendations	
Please provide comments on other issues you encountered or other recommendations for improvement of any aspect of the tools or website.	Click here to enter text.
How much time did you spend on this test?	Click here to enter text.

THANK YOU FOR YOUR ASSISTANCE!

EXHIBIT 18. ACM DSS AWARD WITH BCWA PERMANENT ADOPTION

In recognition of the ongoing utility and collaborative development effort involved in creating the ACM DSS throughout the case study period, a coveted *BCWA Golden Trout Award* was awarded. The award really belongs to the entire BCWA membership for their participation in interviews, design meetings, system usage, usability testing, data development, and responses.

January 8, 2014

Bear Creek Watershed Association

The Bear Creek Watershed Association protects & restores water & environmental quality within the Bear Creek Watershed from the effects of land use.

Presents the Golden Trout Award

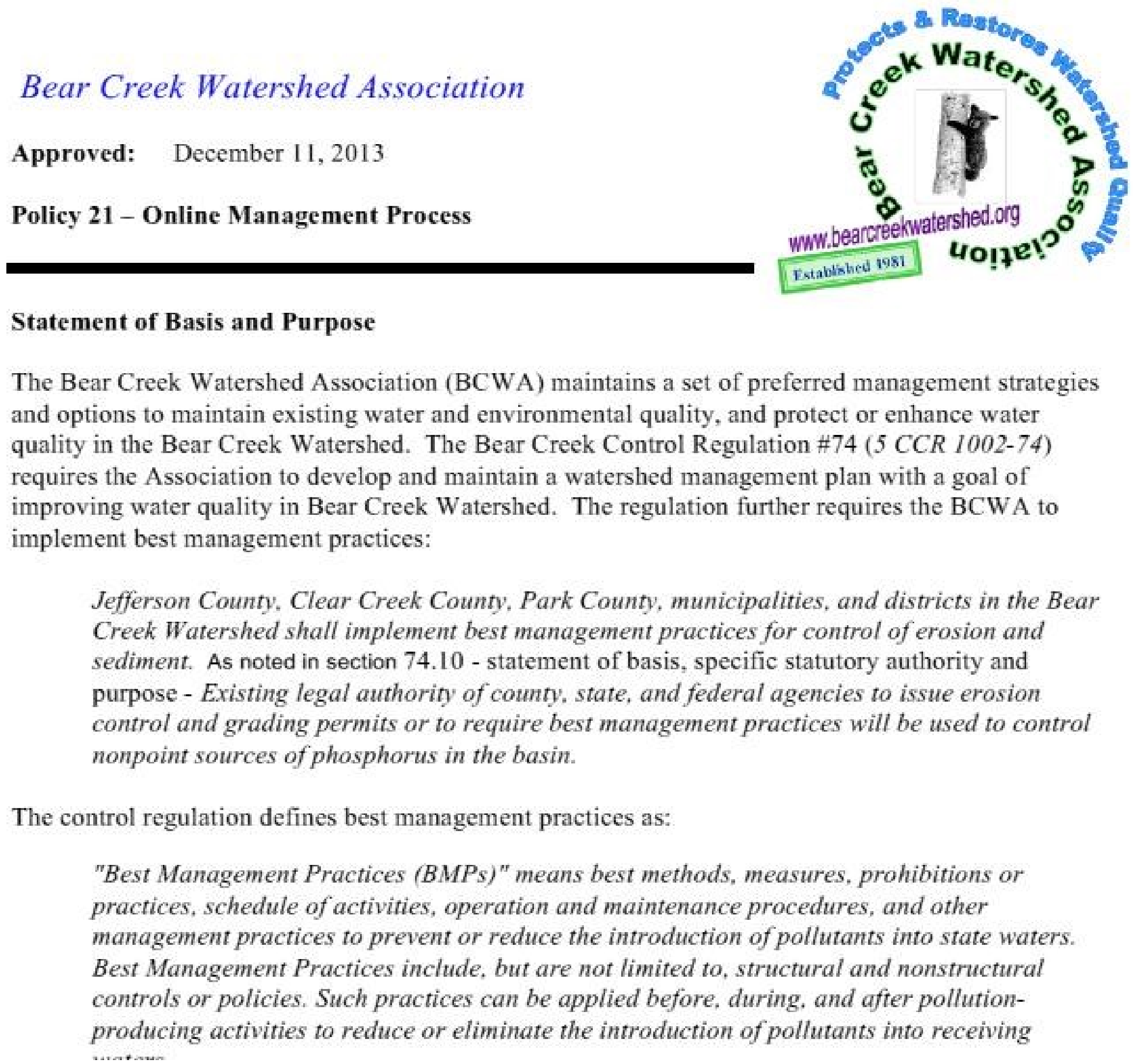
Margaret Herzog

Golden Trout Award

For Development of the Adaptive Co-Management Decision Support System (ACM DSS) as a BCWA best management practice and BCWA Policy 21

Clear Creek County Jefferson County City of Lakewood Town of Morrison Aspen Park Metropolitan District Bear Creek Cabins Brook Forest Inn Conifer Sanitation Association Conifer Metropolitan District Conifer Sanitation Association Denver Water Department Evergreen Metropolitan District Forrest Hills Metropolitan District Genesee Water and Sanitation District Geneva Glen Jefferson County School District (Conifer High School & Mt. Evans Outdoor School) Kittredge Water and Sanitation District Singing River Ranch Tiny Town Foundation. Inc. The Fort Resturant West Jefferson County Metropolitan District Evergreen Trout Unlimited Jefferson County Health U. S. Army Corp of Engineers - Tri-Lake District

EXHIBIT 19. BCWA POLICY 21: ADOPTION OF ACM DSS AS PERMANENT BMP



Bear Creek Watershed Association

Approved: December 11, 2013

Policy 21 – Online Management Process

Statement of Basis and Purpose

The Bear Creek Watershed Association (BCWA) maintains a set of preferred management strategies and options to maintain existing water and environmental quality, and protect or enhance water quality in the Bear Creek Watershed. The Bear Creek Control Regulation #74 (*5 CCR 1002-74*) requires the Association to develop and maintain a watershed management plan with a goal of improving water quality in Bear Creek Watershed. The regulation further requires the BCWA to implement best management practices:

> *Jefferson County, Clear Creek County, Park County, municipalities, and districts in the Bear Creek Watershed shall implement best management practices for control of erosion and sediment.* As noted in section 74.10 - statement of basis, specific statutory authority and purpose - *Existing legal authority of county, state, and federal agencies to issue erosion control and grading permits or to require best management practices will be used to control nonpoint sources of phosphorus in the basin.*

The control regulation defines best management practices as:

> *"Best Management Practices (BMPs)" means best methods, measures, prohibitions or practices, schedule of activities, operation and maintenance procedures, and other management practices to prevent or reduce the introduction of pollutants into state waters. Best Management Practices include, but are not limited to, structural and nonstructural controls or policies. Such practices can be applied before, during, and after pollution-producing activities to reduce or eliminate the introduction of pollutants into receiving waters.*

The Association considers the Adaptive Co-Management Decision Support System (ACM DSS) as a BCWA best management practice. This online management process is an interactive decision support tool to help manage natural resources and protect water and environmental quality in the watershed. The ACM DSS or online management process functions to:

- Evolve and document the BCWA membership and manager understanding of the watershed characteristics and responses, risks and uncertainties,
- Provide a method to learn from past actions and better plan for future actions with an express goal to improve overall watershed resilience, and
- Maintain an online management mechanism to forge partnerships for shared governance and coordinated response to unexpected events.

The BCWA can review ACM DSS analytical results as entered into and maintained in the Plan, Monitoring Data, and Maps sections of the online program, and use the Issues Reporting Tool to report problems as they are identified in the watershed. The BCWA membership and manager can create mitigating Projects, and then identify stepwise Options to pursue these goals, incrementally. Projects and options can be set by BCWA membership as personal watershed improvement goals. BCWA membership can also agree to create Projects with Options that require more coordinated actions and pooled resources.

Through this ACM DSS process, a wider range of solutions can be more actively pursued by the BCWA membership. The BCWA manager can use this information to guide the watershed management program and achieve membership goals through data, analysis, coordination, and funding efforts. This online management process will also provide a wider variety of potential projects that can be targeted for specific grants and select donations from businesses and foundations through an affiliated not-for-profit corporation 501(c) 3. Both public and private donors can also be provided reports that demonstrate systematic management to build their confidence in the BCWA administrative process.

ACM DSS is designed to allow greater participation over time. BCWA members list partners for each Project they enter to build a growing database of potential partners over time. Trusted partners such as Evergreen Trout Unlimited, Evergreen Audubon, Jefferson Conservation District, Denver Mountain Parks or others that regularly attend BCWA board meetings, or partner on projects will be granted full or limited access to the system to directly enter their own issues and recommendations on Projects and Options.

All BCWA members/ participants will be encouraged to update the **Search tools** to expand information about their own Group or others they know in their Local search area and to build the knowledge base by Topic. The BCWA will host at least one annual interactive workshop for orientations. In this way, the online management system will give an improved opportunity for all BCWA membership and participants to access better information and tools, move forward to plan and execute more projects that will have a greater long term impact on the bear Creek Watershed health.

Policy Position

The BCWA supports the ACM DSS or online management process as a long-term, necessary and permanent watershed best management practice. As such, the online management system is deemed a dynamic component of the Bear Creek Watershed Management Plan.

- The BCWA membership and manager will utilize the online management process to help administer Bear Creek Watershed program elements.
- The BCWA manager and a designated ACM DSS coordinator will maintain the established ACM DSS as an online management tool, which includes site-specific orientations for new users.
- The BCWA will allow all designated members and active participants, as approved by the membership, access (user log-on) to the online management system.
- Additional access by potential partners requires approval by the Bear Creek Watershed Association Board when voted on at a regular meeting of the BCWA.

EXHIBIT 20. ACM DSS QUARTERLY PROGRESS REPORT

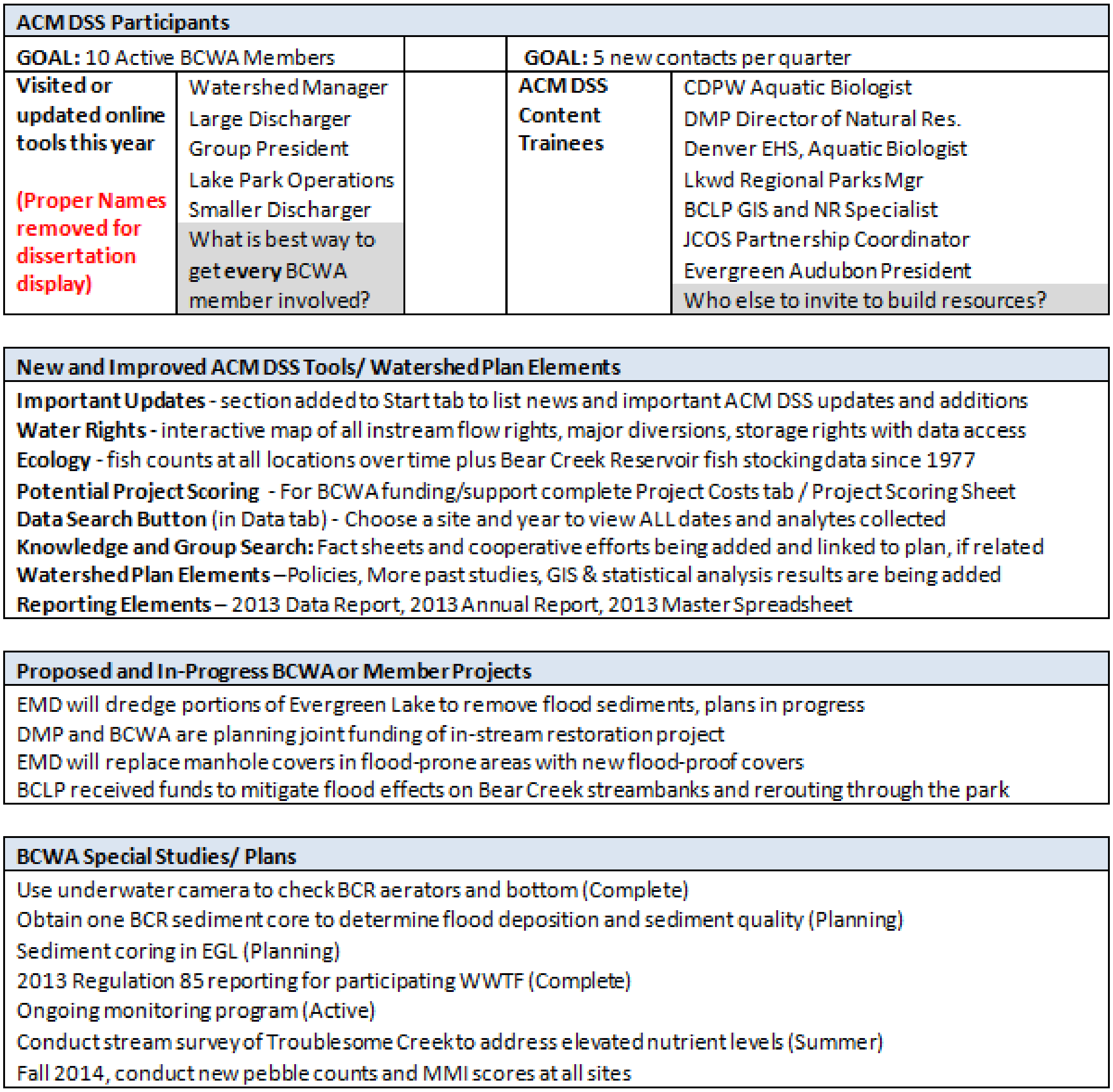
MEMORANDUM

Date: May 8, 2014

To: **Bear Creek Watershed Association**

From: **Margaret Herzog, ACM DSS Coordinator**

Re: **ACM DSS* Quarterly Progress Report 2014 Q1: 1/1/14 – 3/31/14**



ACM DSS Participants				
GOAL: 10 Active BCWA Members			**GOAL:** 5 new contacts per quarter	
Visited or updated online tools this year (Proper Names removed for dissertation display)	Watershed Manager Large Discharger Group President Lake Park Operations Smaller Discharger What is best way to get every BCWA member involved?		**ACM DSS Content Trainees**	CDPW Aquatic Biologist DMP Director of Natural Res. Denver EHS, Aquatic Biologist Lkwd Regional Parks Mgr BCLP GIS and NR Specialist JCOS Partnership Coordinator Evergreen Audubon President Who else to invite to build resources?

New and Improved ACM DSS Tools/ Watershed Plan Elements
Important Updates - section added to Start tab to list news and important ACM DSS updates and additions
Water Rights - interactive map of all instream flow rights, major diversions, storage rights with data access
Ecology - fish counts at all locations over time plus Bear Creek Reservoir fish stocking data since 1977
Potential Project Scoring - For BCWA funding/support complete Project Costs tab / Project Scoring Sheet
Data Search Button (in Data tab) - Choose a site and year to view ALL dates and analytes collected
Knowledge and Group Search: Fact sheets and cooperative efforts being added and linked to plan, if related
Watershed Plan Elements – Policies, More past studies, GIS & statistical analysis results are being added
Reporting Elements – 2013 Data Report, 2013 Annual Report, 2013 Master Spreadsheet

Proposed and In-Progress BCWA or Member Projects
EMD will dredge portions of Evergreen Lake to remove flood sediments, plans in progress
DMP and BCWA are planning joint funding of in-stream restoration project
EMD will replace manhole covers in flood-prone areas with new flood-proof covers
BCLP received funds to mitigate flood effects on Bear Creek streambanks and rerouting through the park

BCWA Special Studies/ Plans
Use underwater camera to check BCR aerators and bottom (Complete)
Obtain one BCR sediment core to determine flood deposition and sediment quality (Planning)
Sediment coring in EGL (Planning)
2013 Regulation 85 reporting for participating WWTF (Complete)
Ongoing monitoring program (Active)
Conduct stream survey of Troublesome Creek to address elevated nutrient levels (Summer)
Fall 2014, conduct new pebble counts and MMI scores at all sites

Educational Initiatives
BCWA at 25th Earth Day Fair, Saturday, April 19th, Evergreen Lakehouse (Complete)
April BCWA Newsletter sent out on Earth Day and to 35 new Earth Day Fair registrants (Complete)
Watershed 102 in planning with TRS
Manager & OMS Coordinator developing a series of BCWA maps
Manager developing a series of BCWA Fact Sheets for distribution, ACM DSS KB, and other purposes
BCWA/BCLP will host **CLRMA Day on the Rez** at Boat Docks during Lake Appreciation Month **July 30, 2014**

New BCWA Policies
Policy 22: Project Evaluation Process - BCWA fund requests must include technical review with value scoring
Policy 23: System of WWTF - clarification of BCWA role in WWTF system plans and TP waste allocation loads
Policy 24: DMR Reporting - BCWA must receive DMR reports monthly to fulfill its regulatory reporting roles
Policy 25: Water Reuse and Conservation (drafting) - supported to allow more water instream, if not problematic
Policy 26: Point to Point Trade Administration (draft) - large to small discharger for concentration exceedances
Policy 27: Source Water Protection Planning (draft) - based on EMD/CO Rural Water Association SWAP findings

Improved Cooperation
BCWA / ETU share stream temperature gauge results in 2014, rather than duplicate/check each other's efforts
Denver EHS Analytical Lab & Sample Collection: Continue monitoring at Summit Lake, Maybe at Red Rocks
BCWA provided $250 to support CCC Transfer Station for hazardous wastes and slash collection
Groundwork Denver will seek BCWA technical review 5/9/14 & discuss possibly sharing student intern
JVA and Treatment Tech are working with BCWA to address small dischargers exceedance issues
CDPW will conduct fish counts on all three lakes: Summit, Evergreen, Bear Creek in Fall 2014

New Funding and Funding Opportunities To Pursue
Now that EMD has completed Source Water Protection Plan, additional funding may be available for mitigation
BCLP received COGO and FEMA funds and donations to recover from flood, as did DMP & JCOS public lands
Funding & collaboration ideas to obtain more nonpoint source credits for 2:1 trading?

New issues? Options? Projects? Watershed and Lake Management Plan Input?

Other recommended pursuits?

Please report *September 2013 Flood Lessons Learned* for full compilation!

- **The ACM DSS focuses on constant, incremental progress towards nutrient reduction and watershed improvement, while expanding shared knowledge, funding, and cooperation.**

For help in updating your input or use, please contact Margaret at: water2share@gmail.com, (303) 238-0419

EXHIBIT 21. ROADMAP TO EXPAND OUT PHASE I ACM DSS DEVELOPMENT PROCESS

The five-phase roadmap describes how the ACM DSS process is designed to expand beyond the Phase I covered in this dissertation research. Phase I included conducting a needs assessment based on existing data using spatial, statistical and social network tools. Research in Phase II would focused on trans-disciplinary studies involving multiple institutions to further assessment for system understanding. Only after Phase II, involving a more concerted effort between the community, industry, and academic experts, might a sufficiently comprehensive and relevant integrated modeling framework begin to evolve. Concomitantly, the online ACM DSS tools developed in Phase I would be expanded for both watershed program management and community participation. To support these efforts, the social network would need to more systematically evolve from the less effective hub-spoke to a diverse core-periphery level of maturity over several phases of development. Efforts would shift from focusing on monitoring for regulatory compliance to data collection and studies to support pilots to develop expanded solution sets. The process could expand beyond the watershed to other watersheds and scales and to other locations to gather more useful feedback.

Focus Area	**Phase I**	**Phase II**	**Phase III**	**Phase IV**	**Phase V**
Research	Data Gathering, QA/QC GIS, Statistics, SNA	More Multi-disciplinary SES Assessment & Planning	Design Phase I Framework for Integrated Monitoring	Populating Model & Testing Calibration & Validation	Online modeling system Expanded expert base
Collaborative Online System Development	Issues, KB, Groups Projects, Options, Plan Usability Testing, Usage	Project Partnering Program & Nonprofit Support Team Recruiting	Phase I Community Tools Volunteer KB & Validators Networked Support Team	Phase II Internal Program Management Tools Role-based Dashboards	Phase II Expanded Community Tools & Multi-scale reporting
Social Network	BCWA - Isolated Hub	BCWA and Prime Partners	Cluster & Community	Weak Core / Periphery	Strong Core / Periphery
Project Focus	Regulatory Monitoring	Focused study to reduce gaps	Data to model & manage	Pilot projects	More focused decisions
Process Expansion	BCWA Case Study Watershed/Basin Review	Watershed and Basin level introduction to other pilots	Integration of at least two instances to higher scale	Consideration for other unrelated needs	Usage in other places for varied purposes

EXHIBIT 22. INTEGRATED MODELING FRAMEWORK

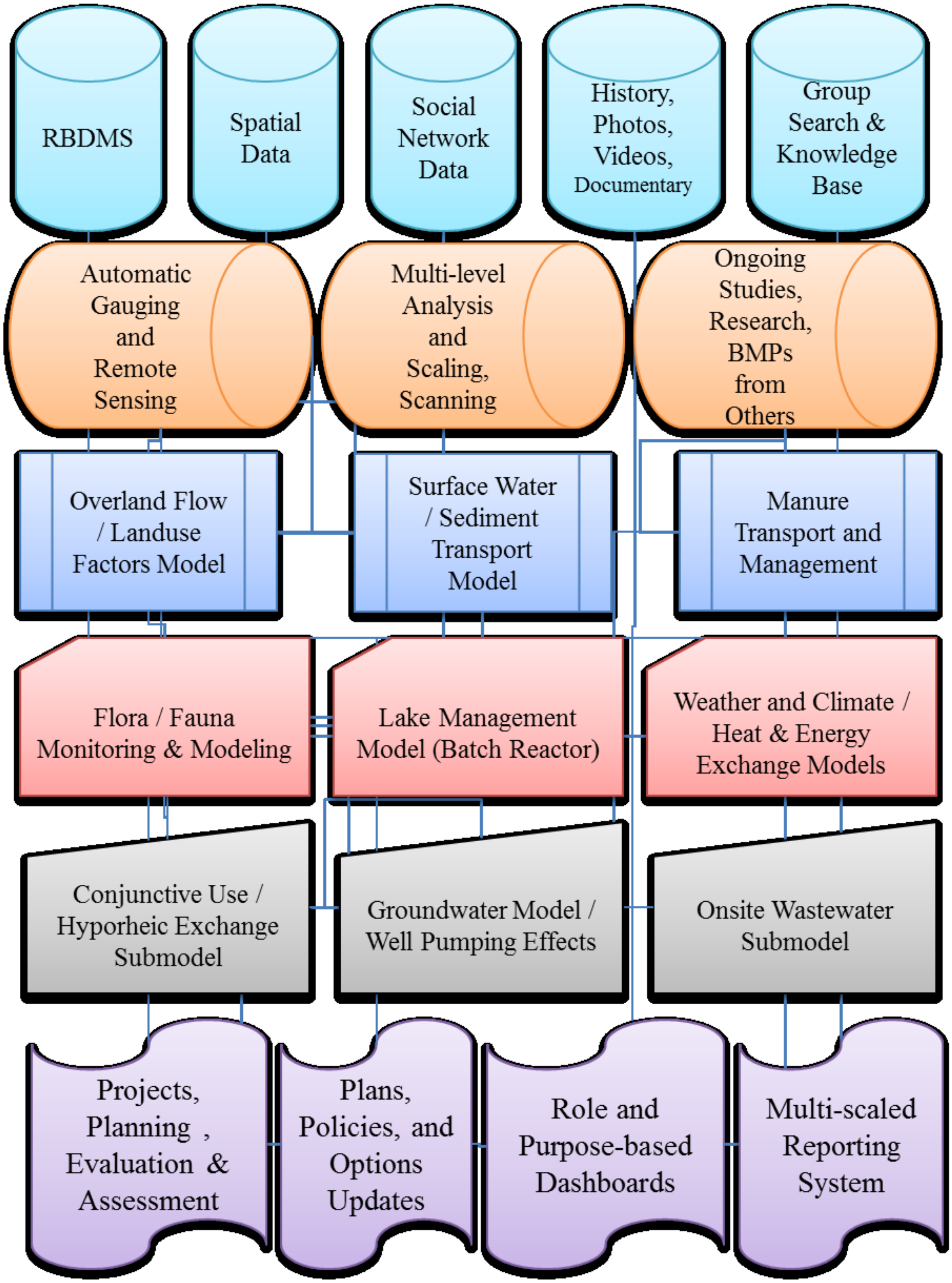


EXHIBIT 23. BCWA POLICIES

Doc Date	**Last Updated**	**Policy Title**
8/24/2004	8/14/2013	Policy 1 - Nutrient Trading Program
5/9/2013	8/14/2013	Policy 2 - BCWA Site Application Review Process
9/13/2006	8/14/2013	Policy 3 - Referral Review Policy: Land Use Development Applications
8/9/2006	8/14/2013	Policy 4 - Review Policy for Manure Management and Stabled or Confined Animal Nutrient Generation
2/11/2011	8/14/2013	Policy 5 - Meeting Attendance and BCWA Distribution List
4/9/2012	8/14/2013	Policy 6 - BCWA Weighted Vote
4/9/2008	8/14/2013	Policy 7 - Evergreen Lake Temperature By-Pass
10/14/2009	8/14/2013	Policy 8 - Bear Creek Reservoir Aeration System Management
5/11/2011	8/14/2013	Policy 9 - Wastewater Management Policy for Aspen Park/Conifer Village Center
6/12/2013	6/12/2013	Policy 10 - Water Quality Monitoring Priority Tier Designations
8/14/2013	8/14/2013	Policy 11 - Supplement - 1) Clear Creek County ISDS Vault and Privy Regulations and 2) Jefferson County ISDS Vault and Privy Regulations
3/15/2013	8/14/2013	Policy 12 - Maintain Program Elements Consisting of Vision, Mission, Targets, and Administrative Activities
8/14/2013	8/14/2013	Policy 13 - Draft Watershed Boundary
8/14/2013	8/14/2013	Policy 14 - Draft Data Collection in the Bear Creek Watershed
8/14/2013	8/14/2013	Policy 15 - Draft Nonpoint Source Management Strategies, Implementation Tools and BMPs in the Bear Creek Watershed
8/14/2013	8/14/2013	Policy 16 - Membership in the Bear Creek Watershed Association
8/9/2013	8/9/2013	Policy 17 - Recycling Programs
10/9/2013	10/9/2013	Policy 18 - Illegal Waste Dumping
10/14/2013	10/14/2013	Policy 19 - Nutrient Trading Program Eligibility
11/7/2013	11/7/2013	Policy 20 - Preferred Management Strategies EGL and BCR
12/7/2013	12/7/2013	Policy 21 - Online Management Process
12/7/2013	12/7/2013	Policy 22 - Project Evaluation Process
2/21/2014	2/21/2014	Policy 23 - System of Wastewater Treatment Works
3/6/2014	3/6/2014	Policy 24 - DMR Reporting

EXHIBIT 24. BCWA NEWSLETTER EXAMPLE WITH ACM DSS INCLUSION

BCWA PINNACLE

Volume 3 January 8, 2014

Sediment delta formation in Evergreen Lake caused by the flooding event in September 2013.

The Bear Creek Watershed Association protects and restores water and environmental quality within the Bear Creek Watershed from the effects of land use.

Clear Creek County
Jefferson County
City of Lakewood
Town of Morrison
Aspen Park Metropolitan District
Bear Creek Cabins
Brook Forest Inn
Conifer Sanitation Association
Conifer Metropolitan District
Denver Water Department
Evergreen Metropolitan District
Forrest Hills Metropolitan District
Genesee Sanitation & Water District
Geneva Glen
Jefferson County School District
Kittredge Water & Sanitation District
Singing River Ranch
The Fort Restaurant
Tiny Town Foundation, Inc.
West Jefferson County Metropolitan District
Evergreen Trout Unlimited
U.S. Army Corps of Engineers

BCWA Policy 21—The BCWA has established an online management process as a dynamic component of the Bear Creek Watershed Management Plan. This online management process is an interactive decision support tool to help manage natural resources and protect water and environmental quality in the watershed. The process characterizes the watershed, identifies problems, solutions and projects. The BCWA membership utilizes the online management process to help administer Bear Creek Watershed program elements. The BCWA will allow all designated members and active participants access to the online management system.

Bear Creek Watershed Association, Colorado

Flood Chemistry Bear Creek Reservoir and Evergreen Lake

After the September 2013 flood event, the Association started a water quality evaluation to document short-term and long-term changes to water quality caused by this significant flood event. In Bear Creek Reservoir the estimated September inflow was about 31,000 ac-ft. The peak flood chemistry showed a Total Phosphorus load in excess of 14,000 pounds, a Total Nitrogen load of 82,000 pounds and the Total Suspended Sediment load was about 1.7 million pounds. Bed-load may have exceeded a 1/2 million tons. In comparison the entire Total Phosphorus load in 2012 was 3,298 pounds. More Total Phosphorus was loaded into the reservoir in September than measured from 2007-2012. The reservoir also received a high organic matter load, as seen in the photo. This organic load will decay over the next few years and influence reservoir chemistry. A similar massive nutrient loading occurred in Evergreen Lake. Evergreen Lake received about 20,650 ac-ft of runoff. The peak flood chemistry showed a Total Phosphorus load in excess of 1,650 pounds, a Total Nitrogen load of 22,550 pounds and the Suspended Sediment load was about 900 tons (750 cubic-yards) with an estimated bedload of about 13,500 tons (11,200 cubic-yards). It is very likely that Evergreen Lake will need dredging to reduce this massive sediment load. The Association monitored watershed nutrients beginning near Mt. Evans following the flood event. From a water quality perspective, the watershed showed remarkable resilience. Although Bear Creek Reservoir returned to normal pool by the end of October, the water quality in the reservoir may be altered for years to come. This storm event has provided valuable insight into big-event nutrient loading. The Bear Creek Watershed Association is applying an adaptive management process to adjust monitoring, strategies and options, and redefine restoration projects throughout the watershed.

Bear Creek Reservoir Chemistry Comparison

2013 Total Pounds/ Month	August	September
Total Nitrogen	3,340	81,560
Nitrate/Nitrite as N, dissolved	95	17,610
Nitrogen, ammonia	391	4,128
Phosphorus, total	336	13,986
Total Dissolved Phosphorus	231	2,528
Residue, Non-Filterable (TSS)	18.400	1.720.000

EXHIBIT 25. TRAITS OF A SUCCESSFUL WATERSHED MANAGER

Date: October 1, 2013
From: Russell N. Clayshulte, Manager
Re: Watershed Management Short Essay

RNC Consulting LLC
Water Quality Professional

The Code of a Watershed Manager (20-Principles to manage by):

1. Watersheds require a “big picture” view and understanding.
2. Everything is connected and everything and everyone in the watershed is important.
3. Details are important, but they don’t necessarily define the watershed.
4. An effective watershed manager takes pride in their work.
5. Be flexible and dynamic.
6. Be tough and fair.
7. Be the voice for the watershed.
8. Be a good listener and learn to say more.
9. If you’re making people mad, remember they are listening to you; make it count.
10. There is no right or wrong style to managing a watershed and its people; be adaptive.
11. Move toward your vision, as well as the watershed vision; always remember that a vision can change. A good manager must establish a personal vision, a “big picture” for the watershed.
12. Set achievable goals.
13. Strike a balance in progress; keep moving forward, while a respected manager keeps their promises.
14. Never forget who you work for and what the people who live and work in the watershed want; sometimes you must back a position that you don’t like (in the western code this was called “ride for the brand”).
15. Politics can drive critical discussions, but watershed science must remain the basis.
16. Sometimes you just need to move dirt.
17. Remember that some things just can’t be fixed today; plan for the long-term.
18. Knowledge is power.
19. There is never too much data.
20. Sometimes you need to just stop and walk the watershed; it has a story to tell you.

[Aldo Leopold] … understood how the boundaries of a community include all the parts of the watershed, he understood the land. A watershed is an opportunity to manifest a harmony between people and the land. I didn’t choose to become a watershed manager, it chose me…

…I found a passion in watersheds.
Along the edge of Front Range Mountains, a community intricately links dirt and water. A place of trees and buildings where urban brushes at the wild.
We extract a price, heavy payment to simplify being. We drag data and numbers from streams. Poke and push the bugs and fish into uneasy obedience. We preserve and preserver. We are the users, the destroyers, agents of change. Yet despite it all, the watershed remains resilient. So I and others become the champions, the land stewards, the land poets.

APPENDIX B. ACM DSS ONLINE SYSTEM OVERVIEW

B-1 Resulting Online Toolset from Collaborative Design and Testing Process

The online toolset developed as *part* of the ACM DSS *process* is only one component of the overall Phase I development process. As described in Appendix A, Exhibit 21, each phase also includes community capacity building and cooperative efforts to improve watershed program effectiveness going forward. In addition to the online knowledge storehouse and reporting system, each phase emphasizes a more mature level of research, social structure, project focus, and process development. Both complete understanding of Chapter 2 framework components and Chapter 3 methodology, which employs Appendix A. process development forms, would be required of an engineering facilitator to conduct the ACM DSS process. Continual use and expansion of ACM DSS online tools will facilitate the process and help to ensure that the watershed program continues to progress over time.

B-2 System Components

As explained in Methods Section 3.5, only popular open source software was used to prevent the system from rapidly becoming obsolete and to permit updates to enhance functionality over time (Figure B-1). The core system consists of a Joomla CMS, supported by an online MySQL RBDMS to support both Joomla data needs and for the ACM DSS data tables supporting the toolset.

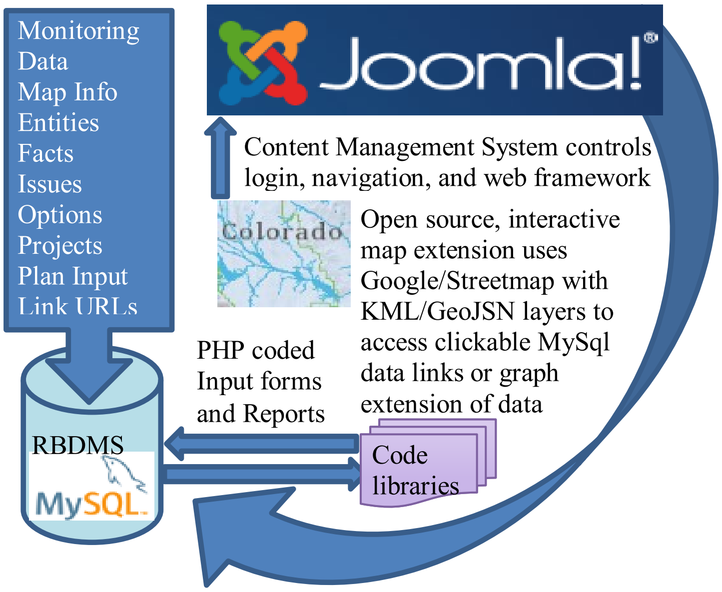


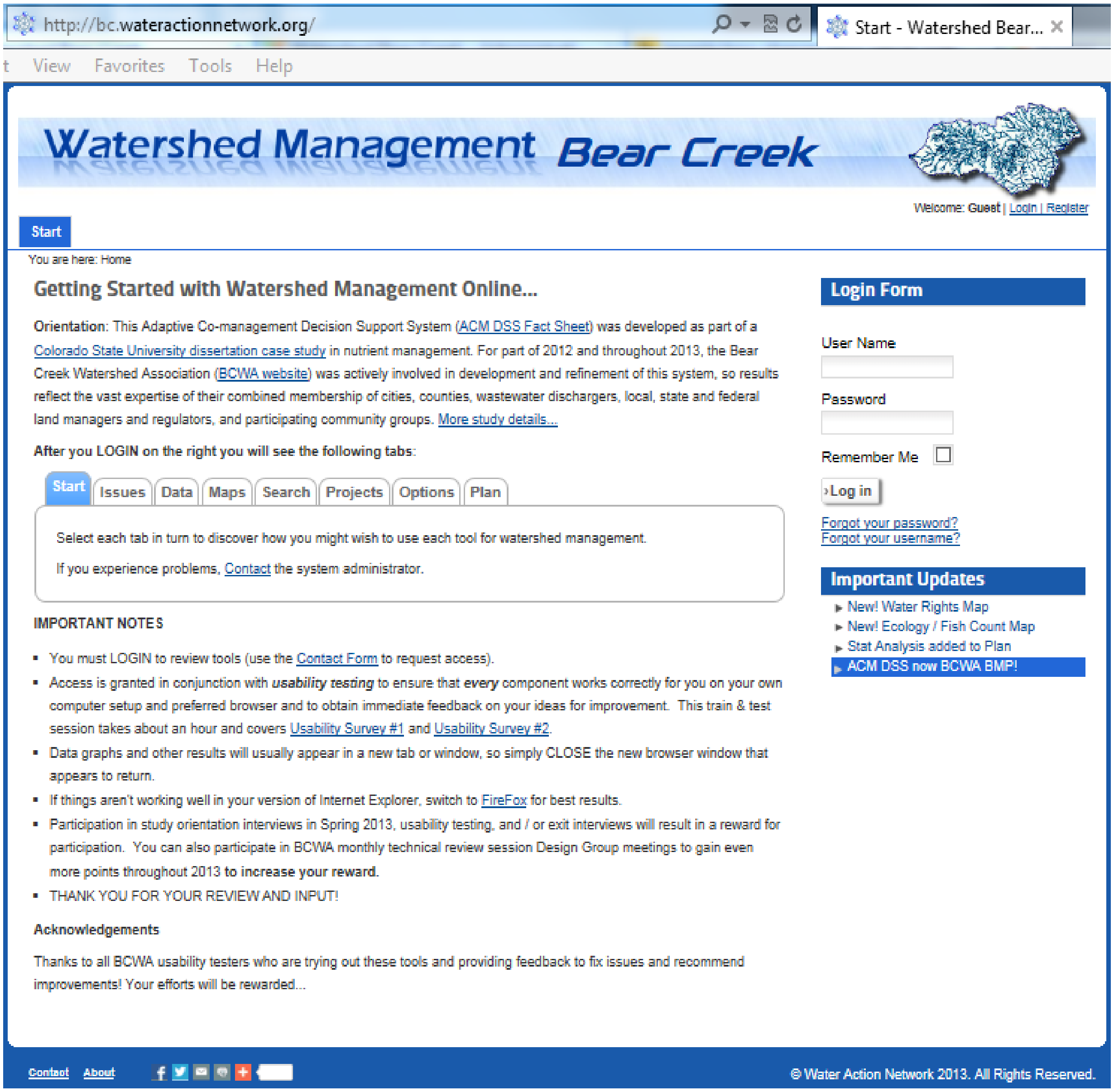
Figure B-1. Schematic of ACM DSS Online Platform

PHP was chosen as the main programming language because it is easy to form, so many programmers can adapt to it. JQuery and JavaScript libraries, as well as, other code libraries for specific interactive map functionality are referenced in the PHP code to develop additional capabilities. Resulting tools are accessed by horizontal tab navigation and menus developed using Joomla extensions.

B-3 ACM DSS Orientation

When a user visits the ACM DSS – *Watershed Management Online* application (http://bc.wateractionnetwork.org), they are first presented with just the Start tab (Figure B-2), until they login at the right, at which point the rest of the tabs become visible.

Users can click through the tab list in the middle of the Start page for crisp directions on the use of each tool. News and updates are presented to the right of the orientation information.



Getting Started with Watershed Management Online...

Orientation: This Adaptive Co-management Decision Support System (ACM DSS Fact Sheet) was developed as part of a Colorado State University dissertation case study in nutrient management. For part of 2012 and throughout 2013, the Bear Creek Watershed Association (BCWA website) was actively involved in development and refinement of this system, so results reflect the vast expertise of their combined membership of cities, counties, wastewater dischargers, local, state and federal land managers and regulators, and participating community groups. More study details...

After you LOGIN on the right you will see the following tabs:

Select each tab in turn to discover how you might wish to use each tool for watershed management.

If you experience problems, Contact the system administrator.

IMPORTANT NOTES

- You must LOGIN to review tools (use the Contact Form to request access).
- Access is granted in conjunction with ***usability testing*** to ensure that ***every*** component works correctly for you on your own computer setup and preferred browser and to obtain immediate feedback on your ideas for improvement. This train & test session takes about an hour and covers Usability Survey #1 and Usability Survey #2.
- Data graphs and other results will usually appear in a new tab or window, so simply CLOSE the new browser window that appears to return.
- If things aren't working well in your version of Internet Explorer, switch to FireFox for best results.
- Participation in study orientation interviews in Spring 2013, usability testing, and / or exit interviews will result in a reward for participation. You can also participate in BCWA monthly technical review session Design Group meetings to gain even more points throughout 2013 **to increase your reward.**
- THANK YOU FOR YOUR REVIEW AND INPUT!

Acknowledgements

Thanks to all BCWA usability testers who are trying out these tools and providing feedback to fix issues and recommend improvements! Your efforts will be rewarded...

Login Form

User Name

Password

Remember Me ☐

›Log in

Forgot your password?
Forgot your username?

Important Updates

- New! Water Rights Map
- New! Ecology / Fish Count Map
- Stat Analysis added to Plan
- ACM DSS now BCWA BMP!

© Water Action Network 2013. All Rights Reserved.

Figure B-2. ACM DSS Start Tab for User Orientation and Important Updates
(http://bc.wateractionnetwork.org)

No user is allowed access until they have completed an *in-person orientation*, which also serves for obtaining valuable initial tools input and further usability testing. Such system *personalization* is an important aspect of the spiral model of development. The ACM DSS process is not intended to permit anyone to participate without formal training and analysis of how well the system works on each device – or does not. Even in later stages, more facilitators can be created to permit more group leaders and eventually community members to participate directly in this controlled orientation. This personal training and usability-testing requirement differs from most other systems, which may represent a useful departure in system deployment design. The *Start tab* provides the same Fact Sheet and Study Summary used to provide interviewees information to meet requirements of research using human subjects. These documents would have to be adapted to each ACM DSS process implementation for orientation to ensure that each participant is fully aware or their responsibilities and the potential risks of being involved in such targeted collaboration efforts. Personal training ensures that these documents have been reviewed with each participant, so that each new user is aware of ACM DSS process goals, so any resulting potential concerns can be fully addressed individually from the outset.

B-3.1 User Access Policy

At the BCWA December 2013 board meeting, the ACM DSS was adopted as a permanent BCWA best management practice per BCWA Policy 21 (Appendix A. Exhibit 19). The policy explicitly required that each new organizational representative systems user first obtain permission from the BCWA board before ACM DSS access can be permitted. Additionally, each new user is required to complete training and usability testing with the developer / facilitator, who was also designated as the BCWA ACM DSS system administrator, to ensure proper understanding of its goals and application. This will further ensure that until the system reaches a more stable phase of development, each new user will continue to provide important, incremental perspective to enable ACM DSS tool improvement and expansion, while fixing any user-specific issues. The ACM DSS Quarterly Report ensures continual system expansion through the inclusion of new, targeted organizational participants for training every quarter (Appendix A. Exhibit 20).

B-3.2 Benefits

The Start tab (Home) allows non-participants to learn about the application to determine if they would like to participate. It provides information about the study process, new features, quick tips, and an orientation for each tool in simple terms by interacting with the tabs just as one would in the application itself. Interested parties can access the contact form in the footer to ask questions or request access. This information reinforces in-person training provided for each new user.

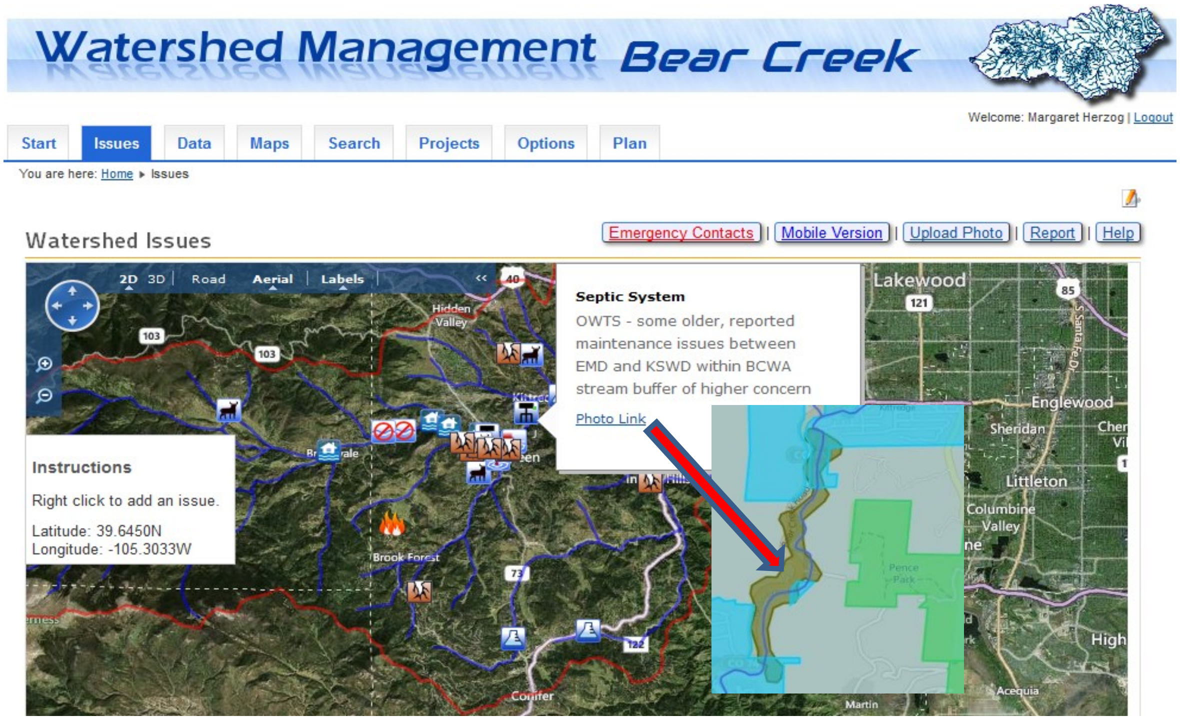
B-3.3 Next Steps

Short training video access could be provided on each instructional tab in the Start Page. Each quarter a summary of new features, corrections, and new user input will be highlighted in the ACM DSS report (Appendix A.

Exhibit 20) and online in the News section. Users will be able to review the quarterly report archive and eventually, a continual list of updates, to gauge development over time.

B-4 Issues Reporting

The need for an issues reporting tool arose early in development during three public seminars and workshops in Spring 2013. These events revealed that BCWA members and community members had much knowledge to share about specific issues throughout the watershed, but limited means to do so. To enable a user's ability to report issues, a mobile version of the application was developed to automatically record a user's position in the field, which marker can be moved from the location of the mobile device to a nearby stream issue. Since this application is for management purposes, not real time emergency reporting, a distinct red button was displayed prominently to ensure that users have contact information for any contingency. The various icons reveal the number and types of issues encountered in different areas of the watershed (Figure B-3). A photo to help visualize the reported issue can also be attached.



Septic System

OWTS - some older, reported maintenance issues between EMD and KSWD within BCWA stream buffer of higher concern

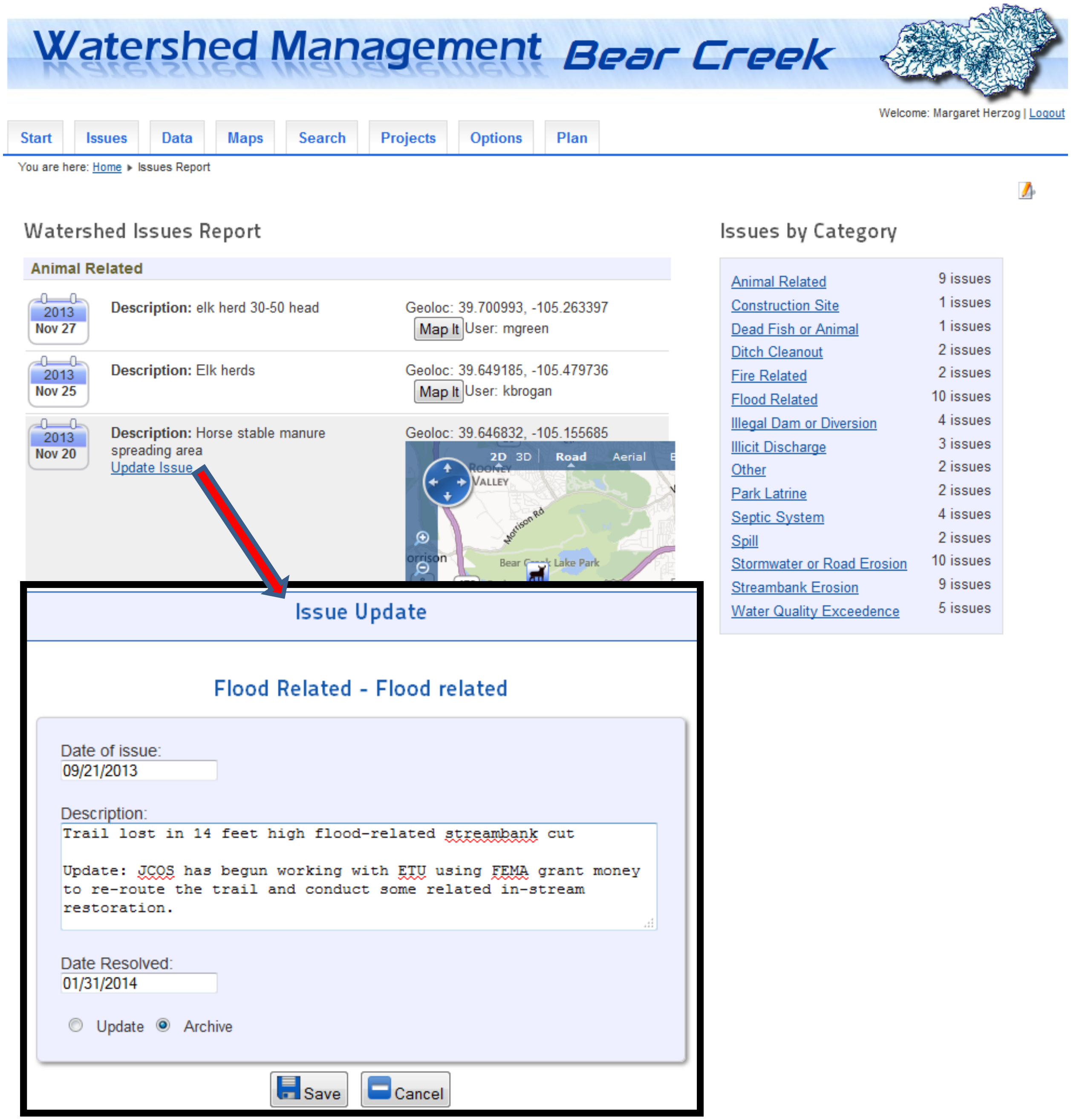
Instructions

Right click to add an issue.

Latitude: 39.6450N
Longitude: -105.3033W

Figure B-3. ACM DSS Issues Reporting Desktop Tool and Mobile App with Emergency Contacts

The Watershed Issues Report is accessed from the Issues Reporting tab by selecting the Report button at the top of the Issues Tab (Figure B-4). It allows users to review all issues reported to date by issue type and author. User can also update their own issues, including listing the date resolved, or if the issue is no longer a problem and needs to be archived.



Watershed Issues Report

Animal Related

2013 Nov 27	**Description:** elk herd 30-50 head	Geoloc: 39.700993, -105.263397 Map It User: mgreen
2013 Nov 25	**Description:** Elk herds	Geoloc: 39.649185, -105.479736 Map It User: kbrogan
2013 Nov 20	**Description:** Horse stable manure spreading area Update Issue	Geoloc: 39.646832, -105.155685

Issues by Category

Animal Related	9 issues
Construction Site	1 issues
Dead Fish or Animal	1 issues
Ditch Cleanout	2 issues
Fire Related	2 issues
Flood Related	10 issues
Illegal Dam or Diversion	4 issues
Illicit Discharge	3 issues
Other	2 issues
Park Latrine	2 issues
Septic System	4 issues
Spill	2 issues
Stormwater or Road Erosion	10 issues
Streambank Erosion	9 issues
Water Quality Exceedence	5 issues

Issue Update

Flood Related - Flood related

Date of issue:
09/21/2013

Description:
Trail lost in 14 feet high flood-related streambank cut

Update: JCOS has begun working with ETU using FEMA grant money to re-route the trail and conduct some related in-stream restoration.

Date Resolved:
01/31/2014

○ Update ● Archive

Save Cancel

Figure B-4. Issues Report with User Update and Archiving Options

B-4.1 Benefits

A primary benefit of the Issues Reporting Tool is revealing patterns by nutrient type. As expected, the Turkey and Cub Creek drainages to the south received less user issue reporting than the main stem of Bear Creek. This demonstrates that more attention to participants in these areas in needed to provide a fuller picture of watershed-wide concerns.

Another benefit is the sense of ACM DSS ownership users who report issues develop by having the opportunity to share their knowledge. After reporting an issue, users were found to be more interested in exploring the knowledge base and monitoring data, and then becoming further involved in project and options development and plan input. Issues can now be linked to projects, which further encourage users who report an issue to also document a potential solution. Each tool is easy-to-use and the additional knowledge quickly becomes useful for sharing among the participants. Contributors gain a sense of pride in this way.

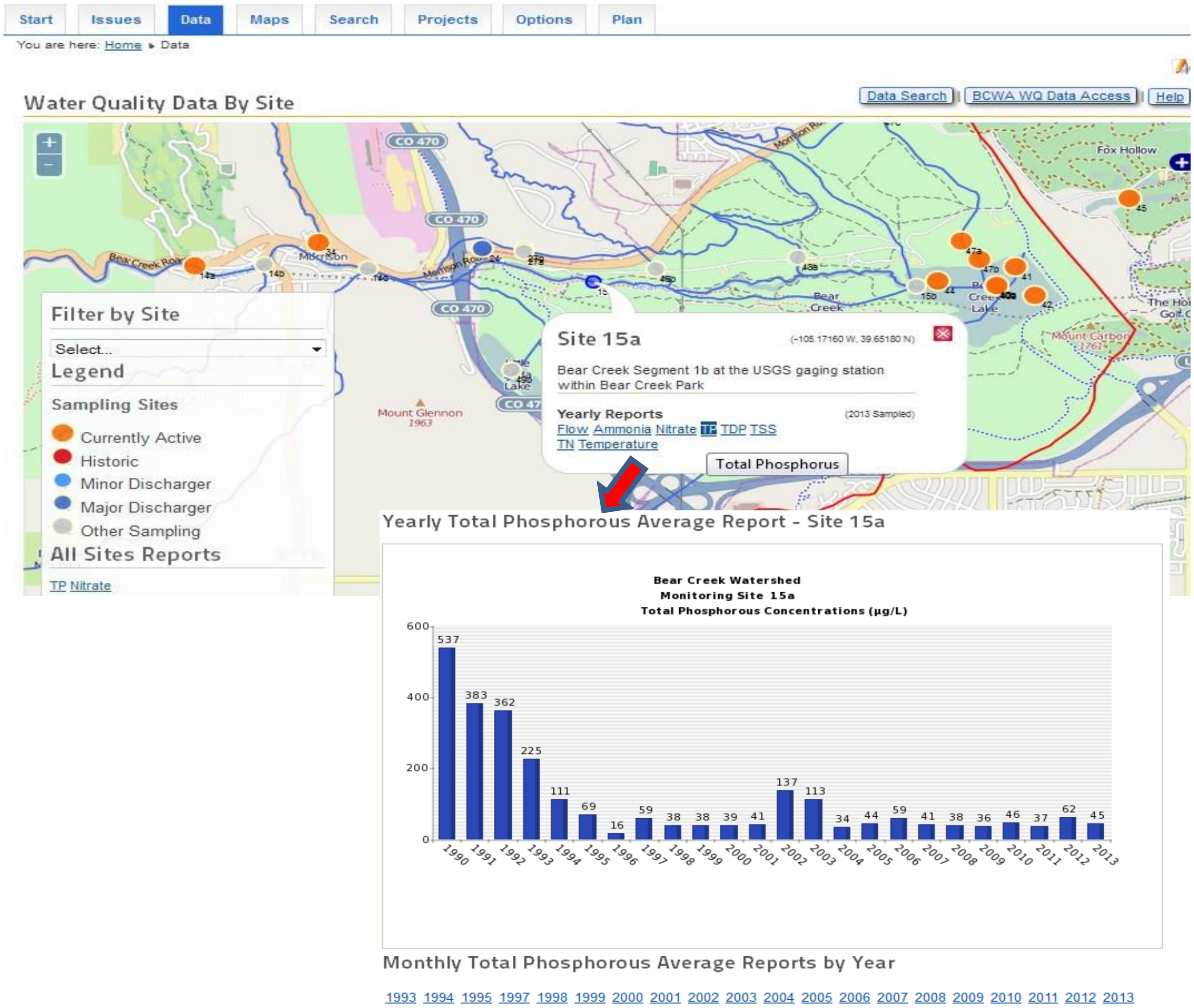
B-4.2 Next Steps

Currently the Issues Reporting tool is only available to BCWA members to ensure that it is focused on nutrient management in a way that respects their purposes. However, the issues reporting mobile tool could be set up specifically for direct community participation as a means to interest them in joining the new Bear Creek / Turkey Creek Alliance (BTCA) 501(c)3 nonprofit corporation being developed as a more inclusive community participation and funding mechanism. Community-wide issue reporting would be entered separately from the BCWA issues reporting and screened by a BCWA member or volunteer for validity. It could then be moved into the BCWA exclusive system or kept in a separate system to overlay. Another way to foster community involvement is to make a public version available at events and workshops to allow anyone who wishes to add issues as they see them. Important discoveries in the patterns and perceptions of the community could be revealed through even intermittent access opportunities provided in this way. It would also determine the level of interest the community would have in using other aspects of the ACM DSS process in later phases of development (Exhibit 21). Rather than direct citizen access, expansion is also ensured through including more group leaders over time, such as public landowners and fish and bird interest groups.

B-5 Monitoring Data Access

Although BCWA makes all data readily available to state regulators, BCWA members, and the public through its website, not many unsophisticated users attempt to sift through the lengthy annual reports and annual master spreadsheets. By creating an online tool to access most sampling data by site in an interactive map (Figure B-5), BCWA members have begun to examine the data more effectively on their own.

After selecting a parameter of interest, the user is presented with a graph of annual averages to review trends at the select monitoring site over time, as shown in Figure B-5.



Water Quality Data By Site

Filter by Site

Legend

Sampling Sites

- ● Currently Active
- ● Historic
- ● Minor Discharger
- ● Major Discharger
- ● Other Sampling

All Sites Reports

Site 15a (-105.17160 W, 39.65180 N)

Bear Creek Segment 1b at the USGS gaging station within Bear Creek Park

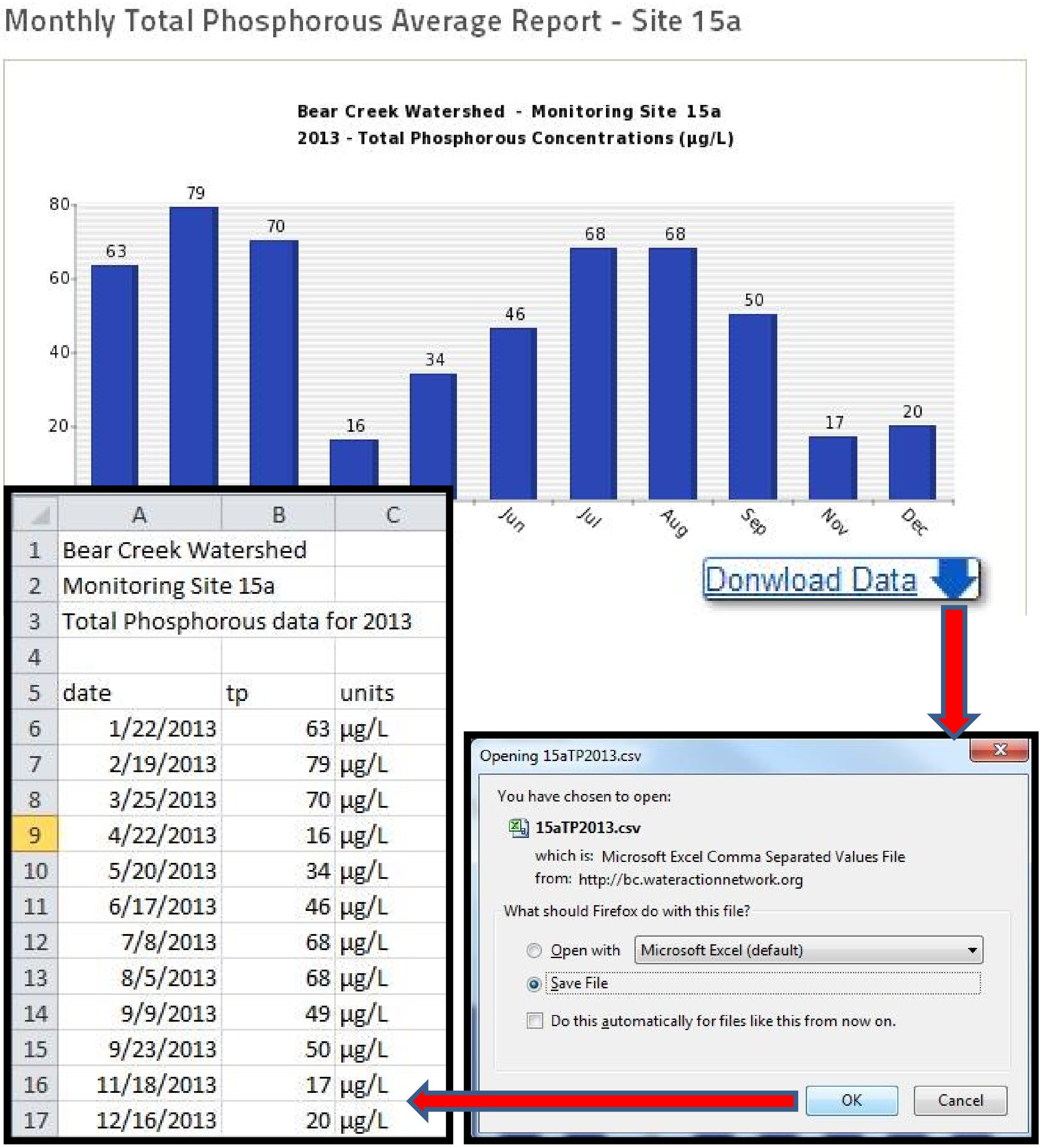
Yearly Reports (2013 Sampled)

Yearly Total Phosphorous Average Report - Site 15a

Monthly Total Phosphorous Average Reports by Year

Figure B-5. Monitoring Data Access and Summary Graphs by Water Quality Paramter

By selecting the option to view monthly data for any year, the graph of monthly monitoring data is shown (Figure B-6). At this point, the user also has the option of downloading the sampling results by date for the selected period



Monthly Total Phosphorous Average Report - Site 15a

	A	B	C
1	Bear Creek Watershed		
2	Monitoring Site 15a		
3	Total Phosphorous data for 2013		
4			
5	date	tp	units
6	1/22/2013	63	µg/L
7	2/19/2013	79	µg/L
8	3/25/2013	70	µg/L
9	4/22/2013	16	µg/L
10	5/20/2013	34	µg/L
11	6/17/2013	46	µg/L
12	7/8/2013	68	µg/L
13	8/5/2013	68	µg/L
14	9/9/2013	49	µg/L
15	9/23/2013	50	µg/L
16	11/18/2013	17	µg/L
17	12/16/2013	20	µg/L

Opening 15aTP2013.csv

You have chosen to open:

15aTP2013.csv

which is: Microsoft Excel Comma Separated Values File

from: http://bc.wateractionnetwork.org

What should Firefox do with this file?

○ Open with Microsoft Excel (default)

● Save File

☐ Do this automatically for files like this from now on.

Figure B-6. Monthly Monitoring Data Access and Raw Data Download

TP is the main pollutant of concern because of WQCC Control Reg. 74, which BCWA is responsible to manage to attempt to limit phosphorus to BCR to reduce related nuisance algae blooms and higher TP outflow concentrations, worsening problems downstream of the reservoir. Therefore, in addition to graphs of concentration, if streamflow was also monitored when the sample was collected, a conversion to Total Phosphorus mass load in pounds per month was calculated. Since cyanobacteria can fix their own nitrogen, maintaining TN to TP ratio above

16 seems to allow other algae to outcompete, so this measure is also graphed to further assist in nutrient management (Figure B-7).

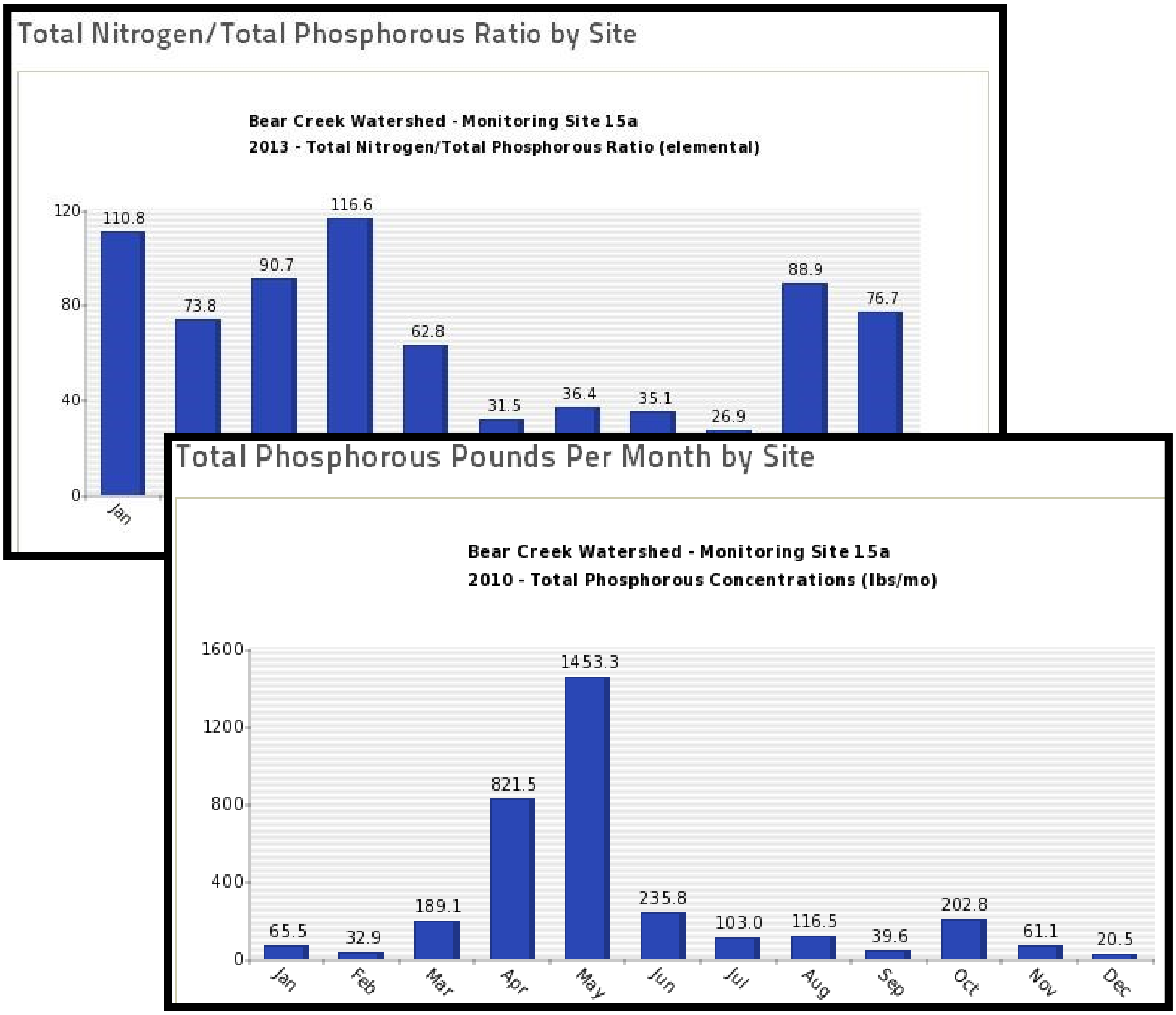
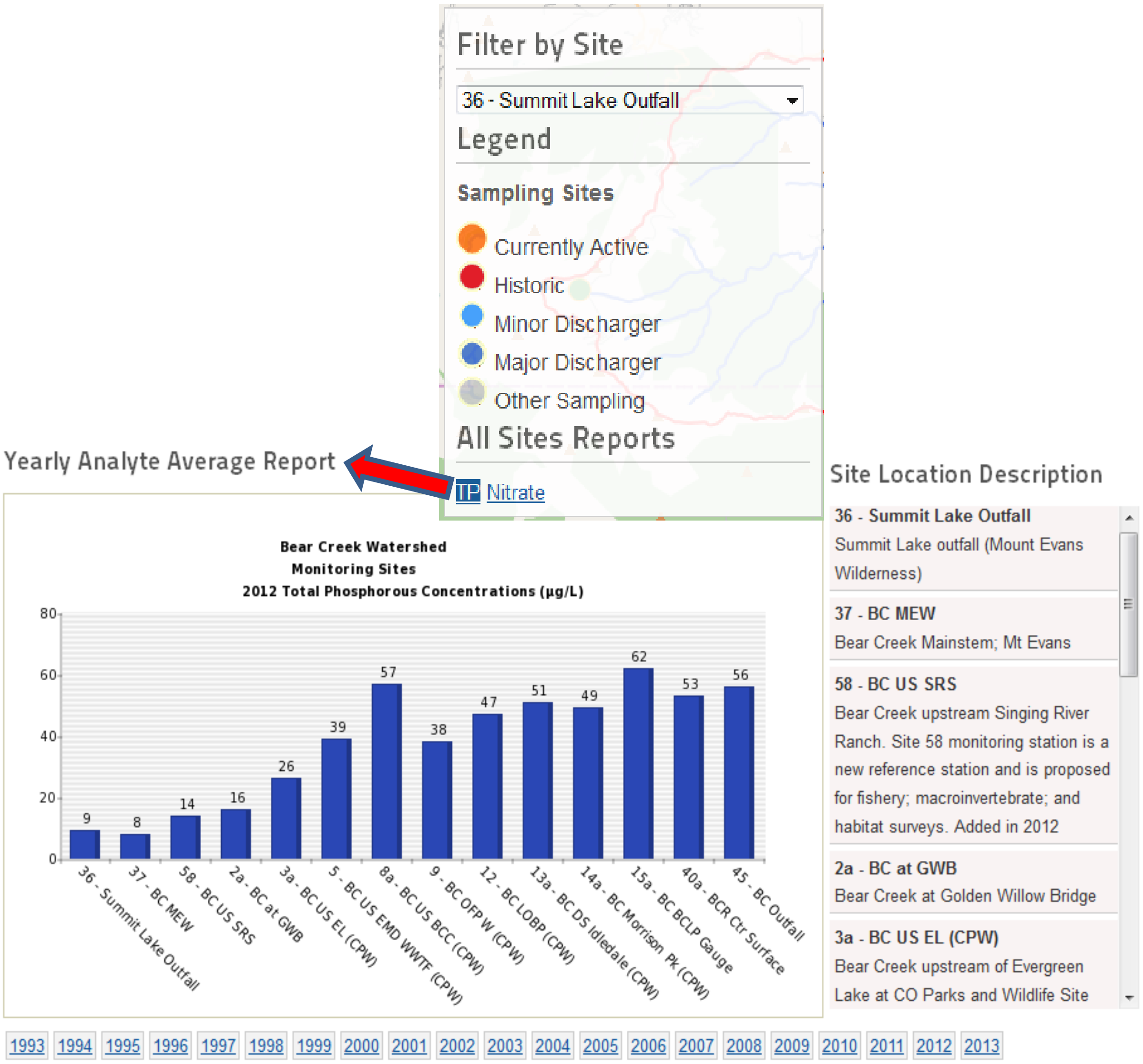


Figure B-7. Annual and Monthly Average Graph Access from Interactive Map

To allow users to compare values between sites, graphs are provided below the legend to review monitoring results from the top of the watershed at Mt. Evans Summit Lake Outfall to the BCR Outfall along Bear Creek (Figure B-8). Originally, all tributary inflows were also shown, but it became confusing to see trends that way, so additional graphs will be redesigned for tributaries later. Each Site Location is also detailed along the side of the graph to make it easier to become familiar with them. This is particularly helpful for BCWA board meetings and technical review sessions, because monitoring sites are often referred to by number during discussion, and this list shows the site details associated with each. Sites can also be accessed by the data access map to find sites to bracket nutrient sources for analysis.



36 - Summit Lake Outfall
Summit Lake outfall (Mount Evans Wilderness)

37 - BC MEW
Bear Creek Mainstem; Mt Evans

58 - BC US SRS
Bear Creek upstream Singing River Ranch. Site 58 monitoring station is a new reference station and is proposed for fishery; macroinvertebrate; and habitat surveys. Added in 2012

2a - BC at GWB
Bear Creek at Golden Willow Bridge

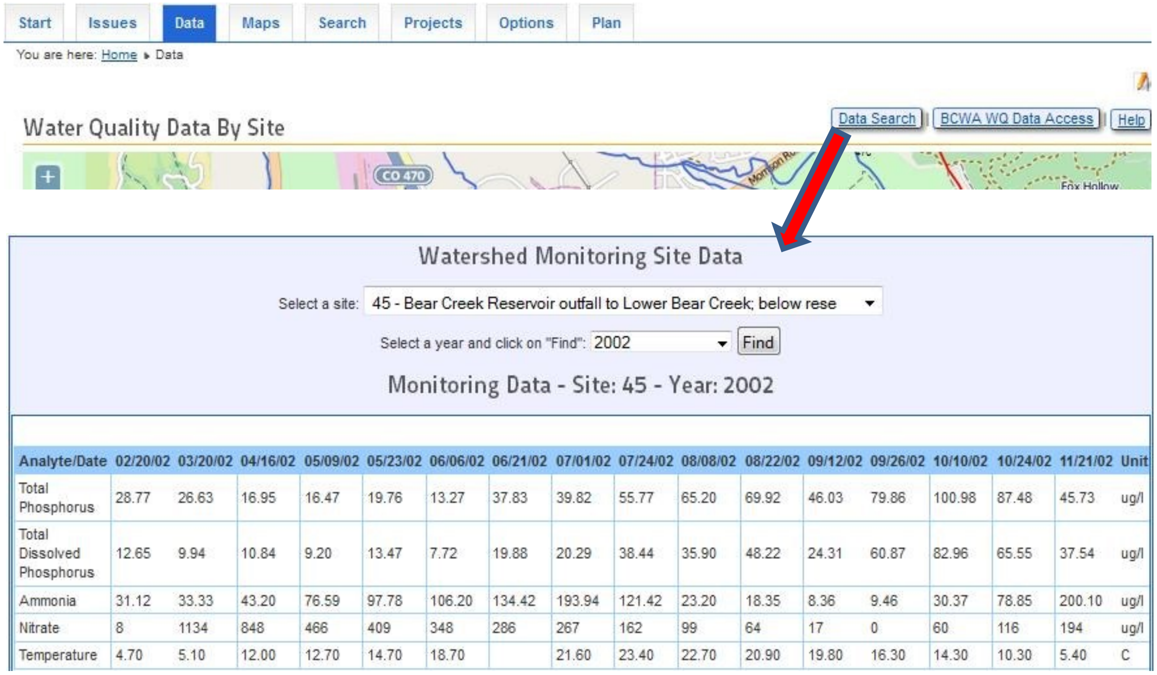
3a - BC US EL (CPW)
Bear Creek upstream of Evergreen Lake at CO Parks and Wildlife Site

Figure B-8. Access to Bear Creek Analytical Results by Station

Data Access from the map provided graphs tracking each water quality parameter by site over time. Alternatively, the Data Search button shown in Figure B-9 provides access by year and site of all water quality parameters collected by date. This dynamic database query is very helpful, because if a user were to access the master spreadsheets instead of this online database, it would not be possible to view the data in this integrated way.

B-5.1 Benefits

Even though BCWA monitoring data is well organized in annual master reports and spreadsheets, having online, interactive map-based access still appears to increase usage and collaboration. The data search tool allows viewing all parameters together to look for patterns, as well. Real time calculations of TP loading and N:P ratios over time eliminate the need to calculate this information in separate pages of a spreadsheet or report. It is also easier to discuss in meetings or one-on-one wherever internet access is available. This contributes to ACM by having the most up-to-date data and analysis to respond to changes with follow-up studies or management changes with greater agility.



Water Quality Data By Site

Watershed Monitoring Site Data

Select a site: 45 - Bear Creek Reservoir outfall to Lower Bear Creek; below rese

Select a year and click on "Find": 2002 Find

Monitoring Data - Site: 45 - Year: 2002

Analyte/Date	02/20/02	03/20/02	04/16/02	05/09/02	05/23/02	06/06/02	06/21/02	07/01/02	07/24/02	08/08/02	08/22/02	09/12/02	09/26/02	10/10/02	10/24/02	11/21/02	Unit
Total Phosphorus	28.77	26.63	16.95	16.47	19.76	13.27	37.83	39.82	55.77	65.20	69.92	46.03	79.86	100.98	87.48	45.73	ug/l
Total Dissolved Phosphorus	12.65	9.94	10.84	9.20	13.47	7.72	19.88	20.29	38.44	35.90	48.22	24.31	60.87	82.96	65.55	37.54	ug/l
Ammonia	31.12	33.33	43.20	76.59	97.78	106.20	134.42	193.94	121.42	23.20	18.35	8.36	9.46	30.37	78.85	200.10	ug/l
Nitrate	8	1134	848	466	409	348	286	267	162	99	64	17	0	60	116	194	ug/l
Temperature	4.70	5.10	12.00	12.70	14.70	18.70		21.60	23.40	22.70	20.90	19.80	16.30	14.30	10.30	5.40	C

Figure B-9. Dynamic Monitoring Data Search by Site and Year

B-5.2 Next Steps

Statistical analysis that currently has to be completed in Minitab software for hypothesis testing, trend analysis, and variability plots would be best shown here directly. However, statistical results are included as part of the watershed and lake management plan input already (Appendix B-10). Using nearby stream stations to adjust flow to monthly averages from daily averages rather than projecting the data over the month based on a single flow meter flow rate taken during sampling may also prove accuracy and precision of results. Currently the master spreadsheet is not available until well after the end of the year, so loading monthly lab results directly into the system will ensure that all data is more readily available as it is produced. Temperature data may also be more efficiently processed and stored in the online database, but because of the number of records involved, it has not been yet been included. Weekly stream and reservoir temperature summary statistics could be added as a start.

B-6 Interactive Thematic Maps

Early on in the research, it became evident that not being able to visualize issues distributed throughout the watershed was leading to confusion as to the scale of various problems. Therefore, a variety of interactive, thematic maps were developed in the ACM DSS maps tab for clarification. The goal was to build more consistent, shared understanding and to encourage participants to further explore watershed issues on their own. The GIS methods discussed in Section 3.3.3 were used for this purpose.

B-6.1 General Maps

Several general maps needed for state reporting and model input were included as static maps to allow users to access them, though they did not have as much rich data to generate more interactive tools. These included population, elevation, soil, and vegetation (Figure B-10). Other general maps can be added as new tabs later.

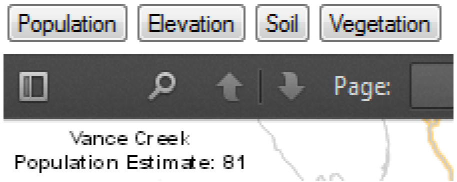
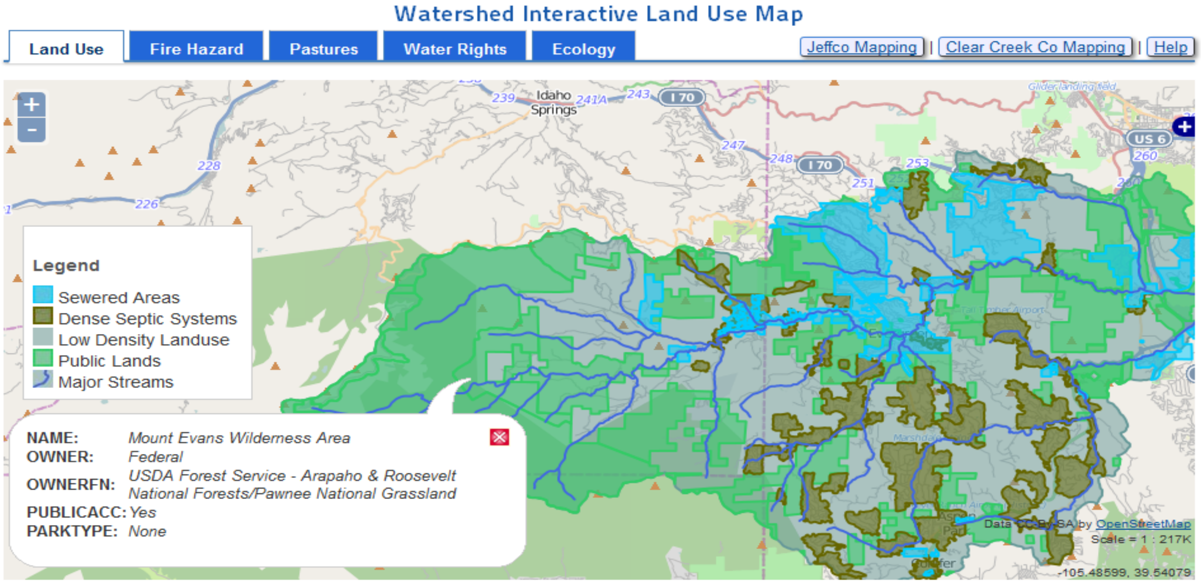


Figure B-10. General Static Maps

B-6.2 Land Use

Landuse proved to be a particularly important theme. This map greatly simplifies areas into four main types: sewered service areas supplied by municipalities and sanitation districts, high-density septic areas where properties were typically within 200 feet of each other or less, low-density landuse areas representing larger ranches and landholdings where horse properties are potentially a nutrient issue, and public lands, often in forest or riparian vegetation (Figure B-11).



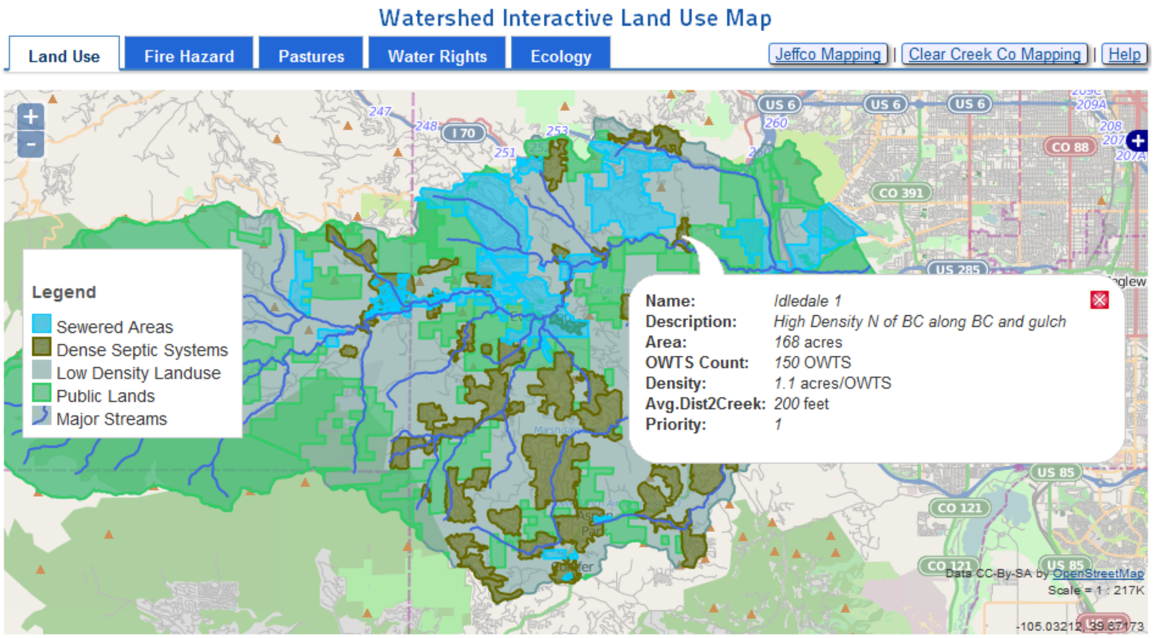
NAME: Mount Evans Wilderness Area
OWNER: Federal
OWNERFN: USDA Forest Service - Arapaho & Roosevelt National Forests/Pawnee National Grassland
PUBLICACC: Yes
PARKTYPE: None

Figure B-11. Interactive Land Use Map

Producing this accessible map was important for several reasons. First, most users had no idea how fortunate they were to have so much public land throughout the watershed. BCWA also had unexpectedly little history in effectively engaging public landowners in comprehensive watershed management. This map helped demonstrate why it was important to include public lands more directly.

Secondly, the density and location of septic systems was poorly understood, leading to numbering OWTS from 6,000 to 27,000 during discussions and in various reports and studies. This discrepancy was addressed, as described in Section 3.3.3, by carefully analyzing county parcel maps, databases, wells, aerial imagery, and districts, which indicated the total number of OWTS likely to be closer to 9,300. ACM DSS issues reporting (Appendix B-4) indicated that most concern is focused along the few concentrations of OWTS left along the Bear Creek corridor. However, the map clearly demonstrates that most OWTS are actually more heavily concentrated throughout the Turkey Creek and Cub Creek subbasins (Figure B-12).

It is important to attempt to understand why such a clear north-south delineation separating serviced areas from OWTS areas exists. The most likely rationale is that neither Turkey nor Cub Creek contain enough water, being on the southern slope of flatter areas to provide a reliable surface water supply. Therefore, residential and commercial wells supply almost all water. Since most residential wells are exempt from augmentation requirements though they are tributary to the stream network, it is usually required for owners to return water to the aquifer over time through an OWTS leach field (now termed a *soil treatment area* in new state and county regulations).



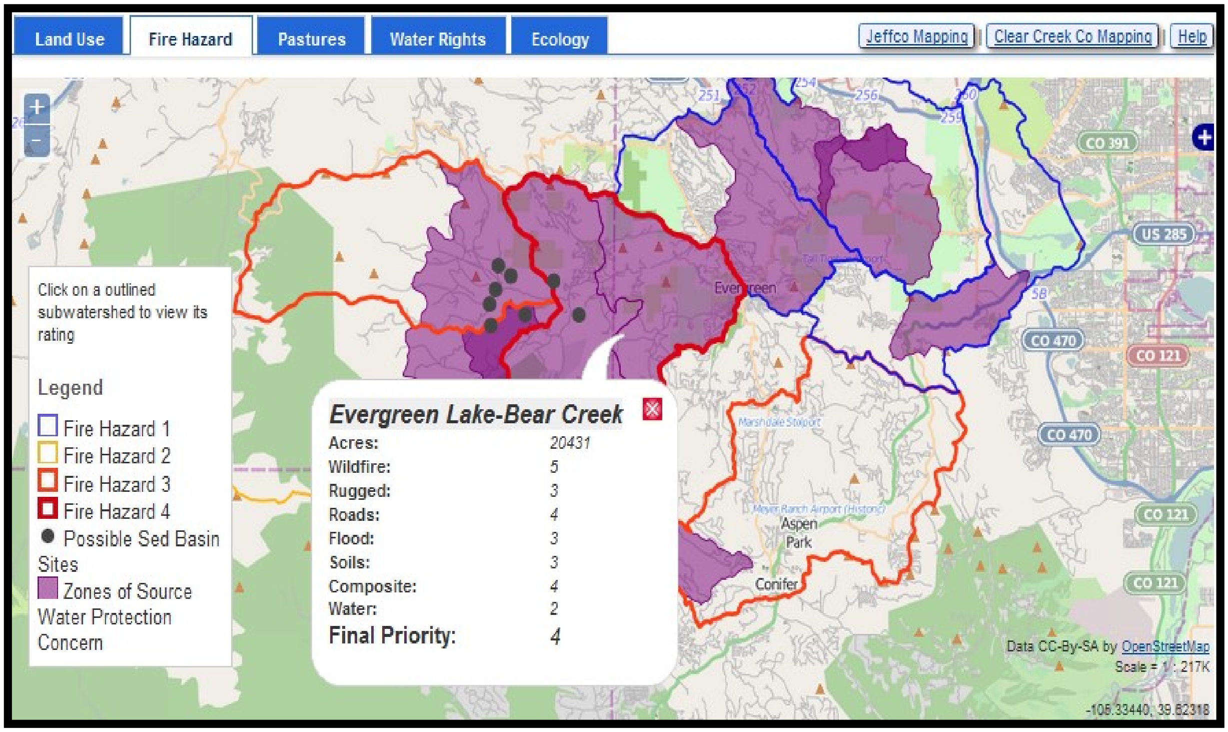
Name: *Idledale 1*
Description: *High Density N of BC along BC and gulch*
Area: *168* acres
OWTS Count: *150* OWTS
Density: *1.1* acres/OWTS
Avg.Dist2Creek: *200* feet
Priority: *1*

Figure B-12. Interactive Landuse Map including data for each OWTS high-density Areas

Otherwise, this would more directly violate Colorado water law *first in time, first in right* appropriations doctrine. This map also indicates that if water supply were offered *with* wastewater service, many more residents would be likely to connect. By understanding the relationship between Colorado water law and wastewater disposal method, a user may be less likely to assume that converting an OWTS to a sewer connection is a preferred alternative in all circumstances. In fact, Geza et al. (2010) calculated that TP in streams could actually worsen with OWTS to sewer conversion.

B-6.3 Wildfire Hazard

Wildfire hazard along the wildlands- urban interface, which represents much of the Bear Creek Watershed, was of great concern to most BCWA member participants. In the watershed to the south, a major wildfire in the early 2000's affected one of the largest water supply reservoirs for the Denver Metro area. A major rainstorm in the years following the wildfire led to nutrient, sediment, and related water quality issues that were very expensive to remedy. Therefore, BCWA wanted to consider this issue more proactively. The results of a Phase II fire study that had been commissioned (http://jw-associates.org/clearbearcreek.html) was added to the ACM DSS thematic maps (Figure B-13), along with potential sites of sediment control.



Evergreen Lake-Bear Creek

Acres:	20431
Wildfire:	5
Rugged:	3
Roads:	4
Flood:	3
Soils:	3
Composite:	4
Water:	2
Final Priority:	4

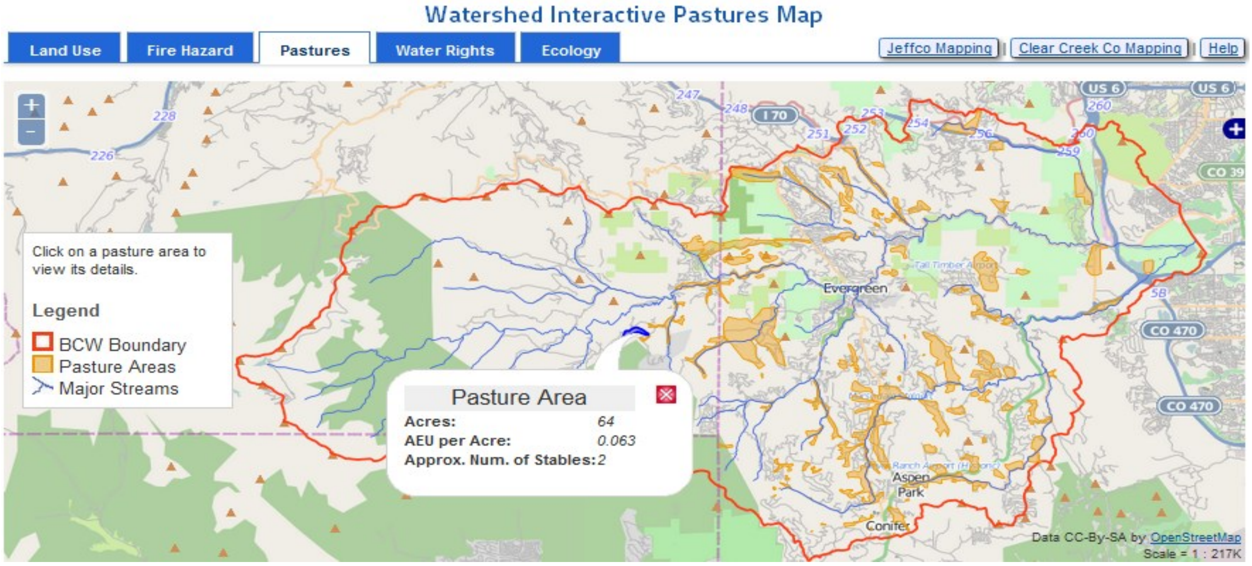
Figure B-13. Wildfire Hazard Zones and Possible Sedimentation Basin Sites

Although originally thought that sites should be pre-permitted, discussion with those mitigating other large wildfires around the state found that only post-mitigation typically proved effective. Rather than above-ground, smaller below-ground basins that would fill up naturally were easier to build and permit quickly and could be more directly positioned where needed (from interviews and presentations of Colorado Springs Utilities, JW Associates, Coalition of the Upper South Platte, and High Park Fire Ft Collins).

B-6.4 Pastures

Before the ACM DSS process began, BCWA had already recognized through *Policy 3. Manure Management* that horse properties could be a potential water quality concern. However, the location and size of horse properties had never been systematically investigated. Using county-supplied images, effort was made to examine all properties at least above ten acres to determine main zones of pastures and stables. This was then used as input into the GWLF-E model to determine the magnitude of horse properties contributions more directly.

The online, interactive map showing areas of major pastures and horse property activity in Figure B-14 can help BCWA target particular owners to share their policy and other horse management BMPs. Once nonprofit funding is available, BCWA may also work with the NRCS and Jefferson Conservation District (JCD) to support landowners in manure management, erosion control, fencing, and stream buffering more systematically. Plans are underway to work with both Clear Creek and Jefferson County 4-H groups to educate young horse riders and other young people participating in agriculture and raising livestock how to protect their land and adjacent streams from erosion, nutrients, and pollutants.



Click on a pasture area to view its details.

Pasture Area

Acres: 64

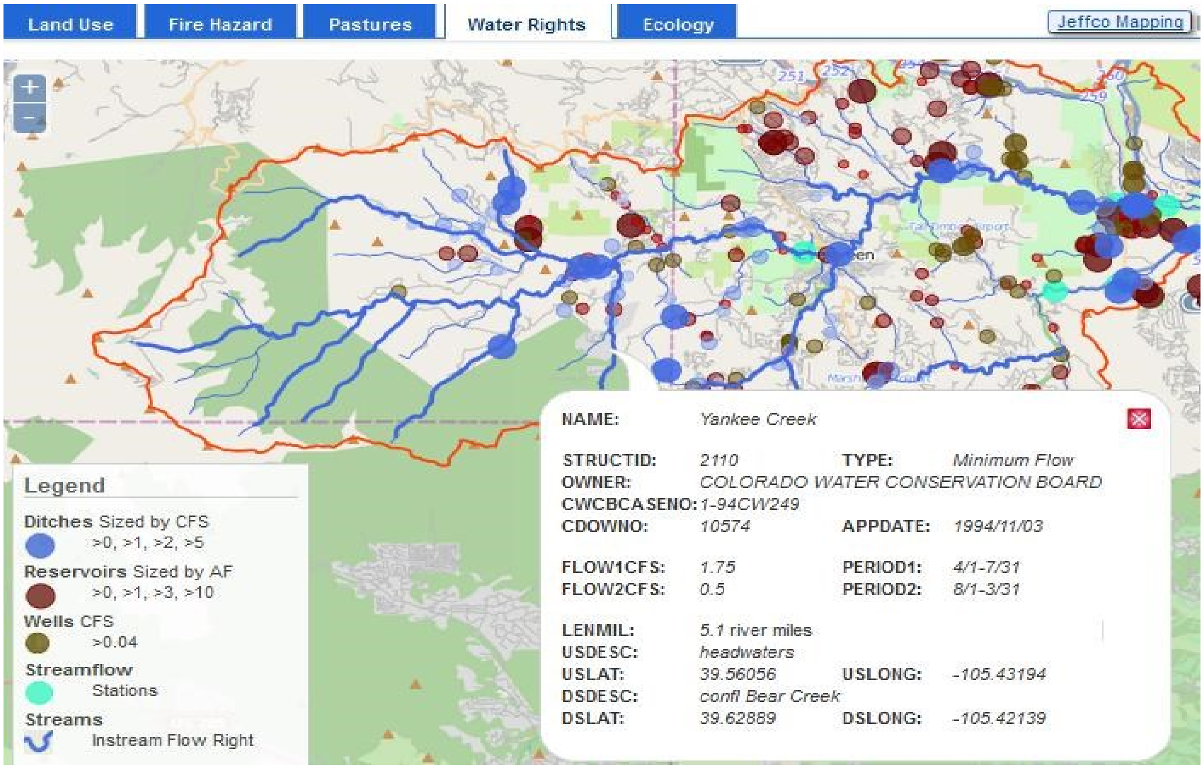
AEU per Acre: 0.063

Approx. Num. of Stables: 2

Figure B-14. Delineation of Large Horse Properties throughout the Bear Creek Watershed

B-6.5 Water Rights

Water quality and water quantity are intricately linked throughout the Bear Creek Watershed. Therefore, it was critical to develop a water rights map depicting stream withdrawals (called diversions) reservoir storage rights, high-capacity wells, and instream flow rights for non-consumptive use (Figure B-15). What is striking about the data is that in many reaches that seem highly protected in public lands, water rights allow complete stream dry-up. If a stream flow regime reaches a threshold, riparian vegetation and aquatic organisms may be affected, and invasive species may be more likely to out-compete. The instream flow rights all have appropriation dates in the mid-1990's, so they are all *junior* water rights. Therefore, instream flow rights do not protect the stream from dry-up during low flow periods when *senior* water rights make a call during times of over-appropriation of the flows. Instream flow rights do however protect the stream from further development or illicit ponds and withdrawals, so these rights could be exercised through BCWA member commitment to protecting them. Senior water rights can also be bought or donated to the statewide instream flow program and the Colorado Water Trust can help organizations navigate these complicated and costly transfers.



NAME: *Yankee Creek*

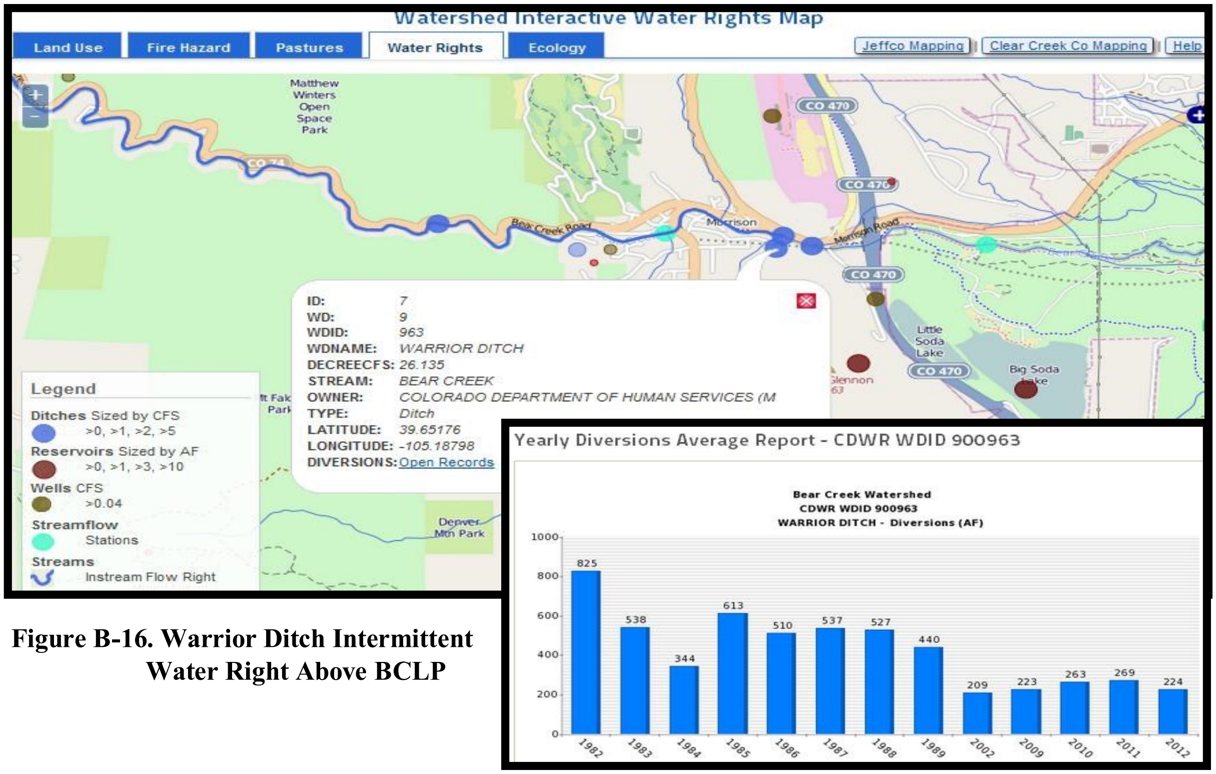
STRUCTID: *2110* TYPE: *Minimum Flow*
OWNER: *COLORADO WATER CONSERVATION BOARD*
CWCBCASENO: *1-94CW249*
CDOWNO: *10574* APPDATE: *1994/11/03*

FLOW1CFS: *1.75* PERIOD1: *4/1-7/31*
FLOW2CFS: *0.5* PERIOD2: *8/1-3/31*

LENMIL: *5.1 river miles*
USDESC: *headwaters*
USLAT: *39.56056* USLONG: *-105.43194*
DSDESC: *confl Bear Creek*
DSLAT: *39.62889* DSLONG: *-105.42139*

Figure B-15. State-managed CO Water Conservation Board Instream Flow Rights

Warrior ditch is another interesting study in the interactive Water Rights map in Figure B-16. Although it used to extract more water, those rights were moved to other points of diversions or owners on the same ditch, so it appears that no water rights diversions were taken for over a decade. However, in 2009 Warrior Ditch began to withdraw water just west of Bear Creek Lake Park again, increasing the number of days that Bear Creek may be completely dewatered through the park to the confluence with Bear Creek.



ID: 7
WD: 9
WDID: 963
WDNAME: WARRIOR DITCH
DECREECFS: 26.135
STREAM: BEAR CREEK
OWNER: COLORADO DEPARTMENT OF HUMAN SERVICES (M
TYPE: Ditch
LATITUDE: 39.65176
LONGITUDE: -105.18798
DIVERSIONS: Open Records

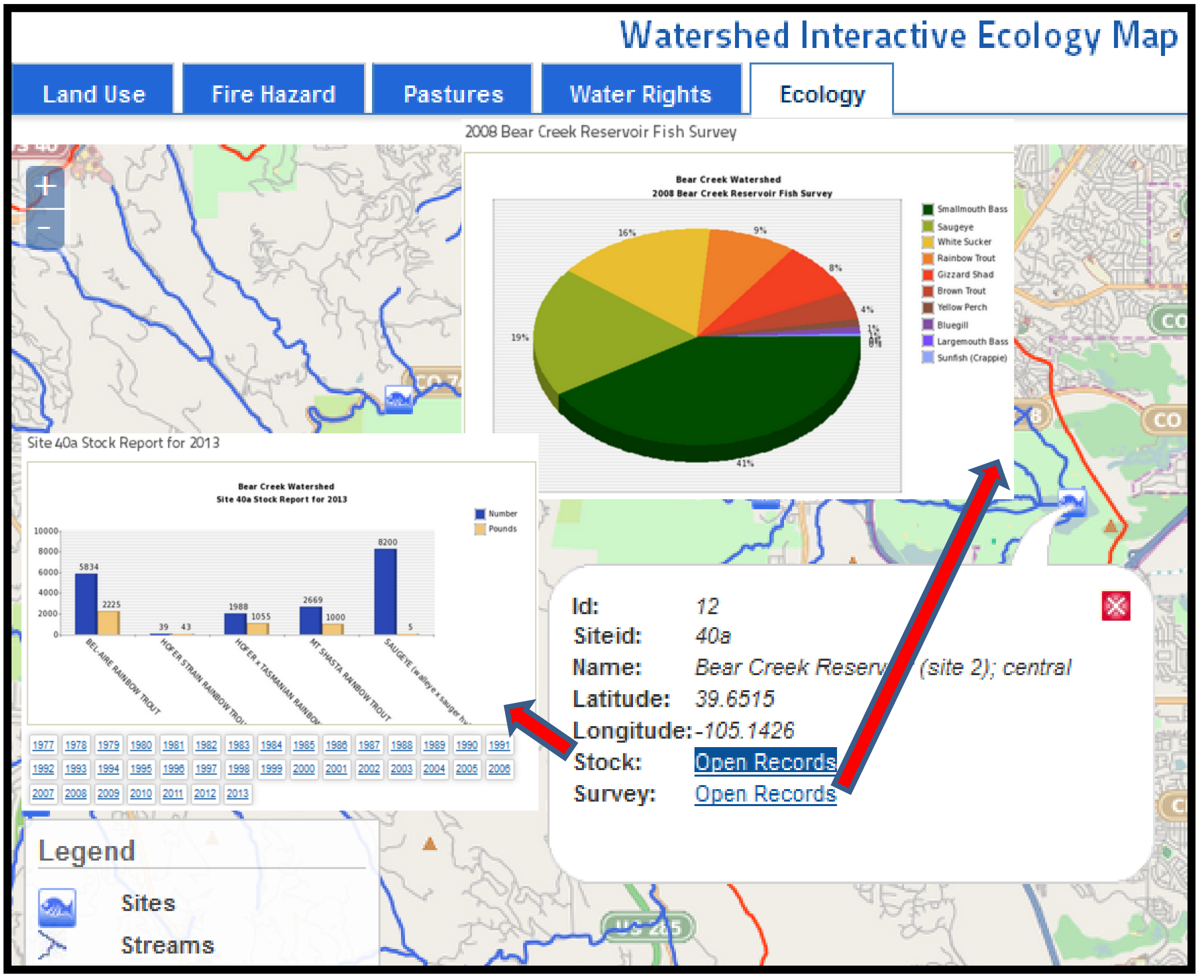
Yearly Diversions Average Report - CDWR WDID 900963

Figure B-16. Warrior Ditch Intermittent Water Right Above BCLP

B-6.6 Ecology

BCWA members were concerned that state water quality regulations focus on absolute TP concentrations, disallowing a single exceedance in five years in most cases. This can lead to excessive monitoring costs without much benefit if the exceedance is not representative, so participants were interested in keeping better track of how the actual ecology was responding: the food web of fish, birds, mammals, macroinvertebrates, zooplankton, phytoplankton, bacteria, and other biological indicators of habitat health.

For these reasons, a separate thematic map devoted to ecology was constructed (Figure B-17). Currently, the map includes fish stocking at BCR, fish counts in streams and lakes, and macroinvertebrates scores in streams. More data could be added once citizen science tools for stream surveys to determine riparian habitat and wildlife could be documented.

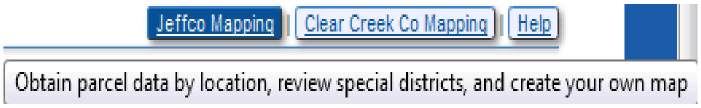


Id: 12
Siteid: 40a
Name: Bear Creek Reserv (site 2); central
Latitude: 39.6515
Longitude: -105.1426
Stock: Open Records
Survey: Open Records

Figure B-17. Fish Counts and Stocking Records in Ecology Tab

B-6.8 County Mapping Access

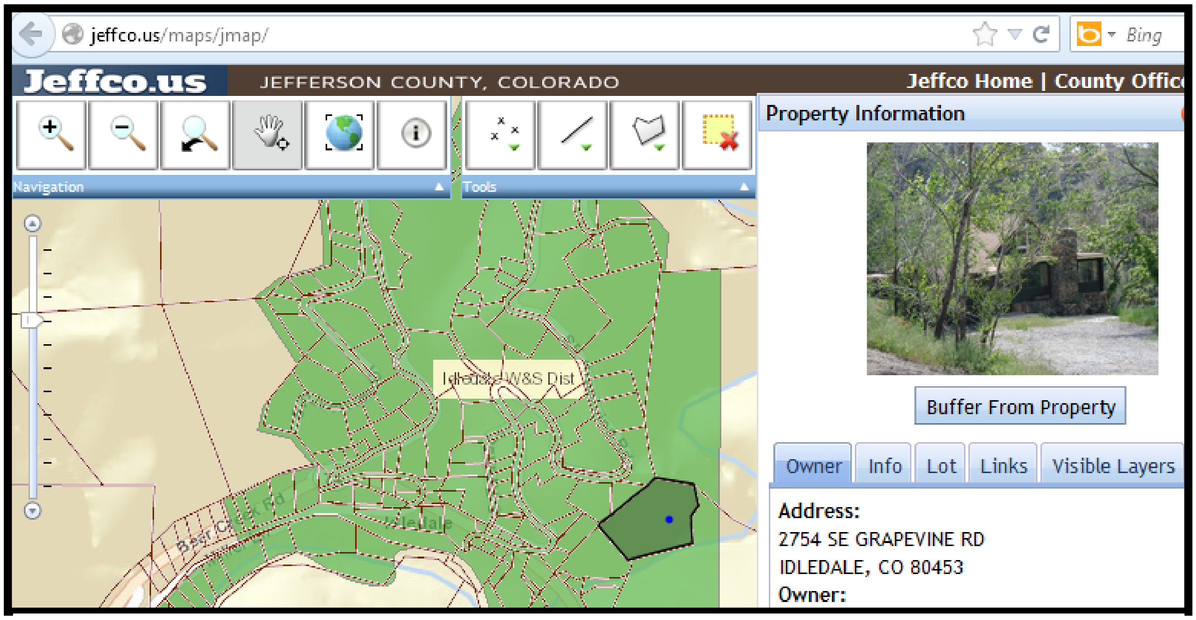
It is often necessary to contact individual homeowners and commercial properties about specific problems and opportunities. However, it would be unwise to collect and maintain such information in the watershed database. Therefore, in the United States, most counties maintain online maps and databases of this information available to the public, which were simply linked for the two principal counties (Figure B-18). County parcel information includes the address, owner, property taxes, home size, and other useful information of public record.



Obtain parcel data by location, review special districts, and create your own map

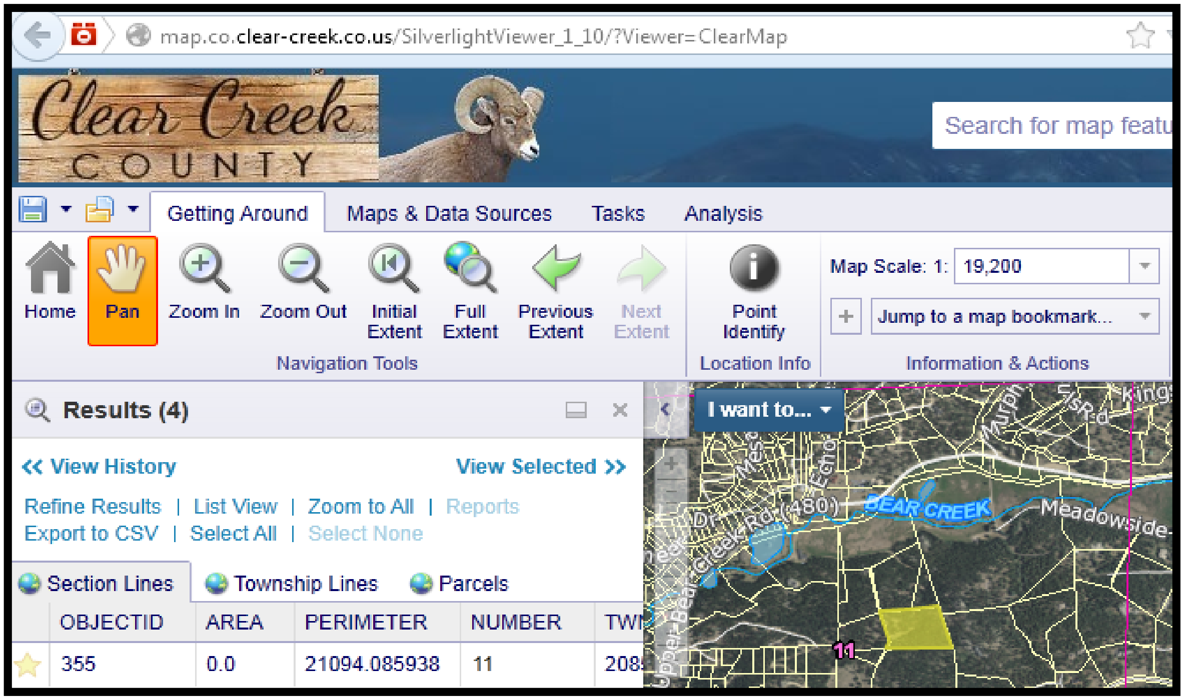
Figure B-18. Link to County Mapping Tools with Parcel Data

The interactive county maps in Figures B-19 and B-20 demonstrate how ACM DSS leverages existing information. A future goal may be to include instructional videos describing how to use each county map for watershed management purposes.



Address:
2754 SE GRAPEVINE RD
IDLEDALE, CO 80453
Owner:

Figure B-19. Jeffco JMAP Online Parcel Mapping Tool



OBJECTID	AREA	PERIMETER	NUMBER	TWI
355	0.0	21094.085938	11	208

Figure B-20. Clear Creek County ClearMap Parcel Mapping Tool

B-6.9 Benefits

The primary benefit of the ACM DSS Interactive Thematic Maps section was to provide participants with greater shared understanding of the location and aerial extent of potential nutrient source issues and other visual content. Additional tabs can easily be added to the map section for each new theme participants desire to explore. Having each map associated with related data, graphs, and other links improves engagement and learning. Results can be used during BCWA board and TRS meeting discussions. As new information becomes available, mapped results and the underlying attributes can be updated in real time to produce *living* maps that do not lose value with time.

B-6.10 Next Steps

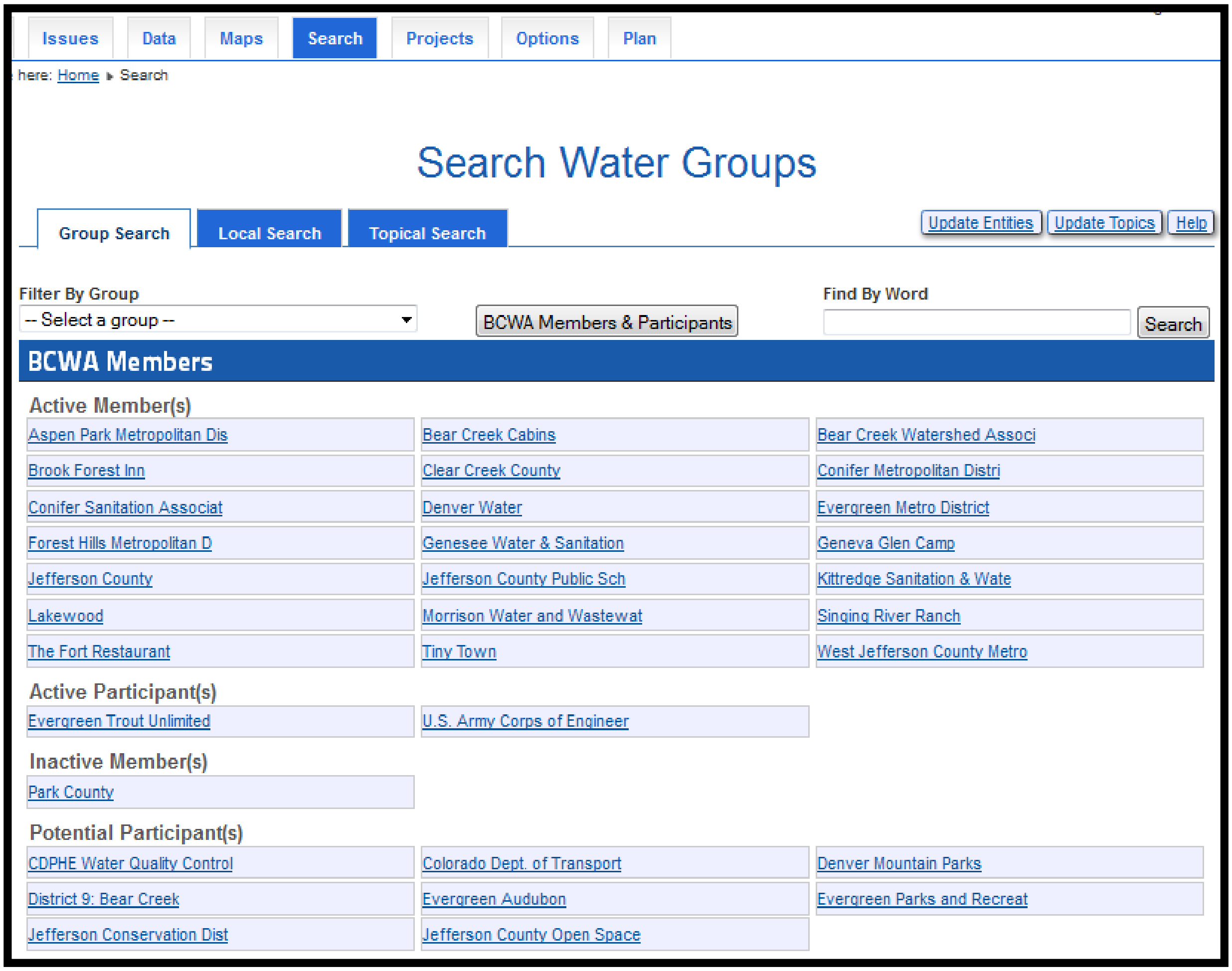
In subsequent phases of ACM DSS development, more interactive thematic maps will be added and expanded exploration tools, such as animation, can be tested.

B-7 Search Tools

Watershed managers are typically very dedicated, often serving their community for decades. Therefore, when a watershed manager retires, a huge knowledge gap may develop. ACM counteracts this risk in several ways.

B-7.1 Group Search

The Group Search (Figure B-21) encourages participants to collaborate with other groups in their area, those who have worked on similar projects, or those of similar types that might have management tips to share. By reducing the role of the watershed manager as the sole network hub, the watershed community is more able to maintain communication even if the watershed manager is not available. Collaboration through sharing information and resources can also be improved by this ACM DSS focus.



Search Water Groups

BCWA Members

Active Member(s)

Aspen Park Metropolitan Dis
Bear Creek Cabins
Bear Creek Watershed Associ
Brook Forest Inn
Clear Creek County
Conifer Metropolitan Distri
Conifer Sanitation Associat
Denver Water
Evergreen Metro District
Forest Hills Metropolitan D
Genesee Water & Sanitation
Geneva Glen Camp
Jefferson County
Jefferson County Public Sch
Kittredge Sanitation & Wate
Lakewood
Morrison Water and Wastewat
Singing River Ranch
The Fort Restaurant
Tiny Town
West Jefferson County Metro

Active Participant(s)

Evergreen Trout Unlimited
U.S. Army Corps of Engineer

Inactive Member(s)

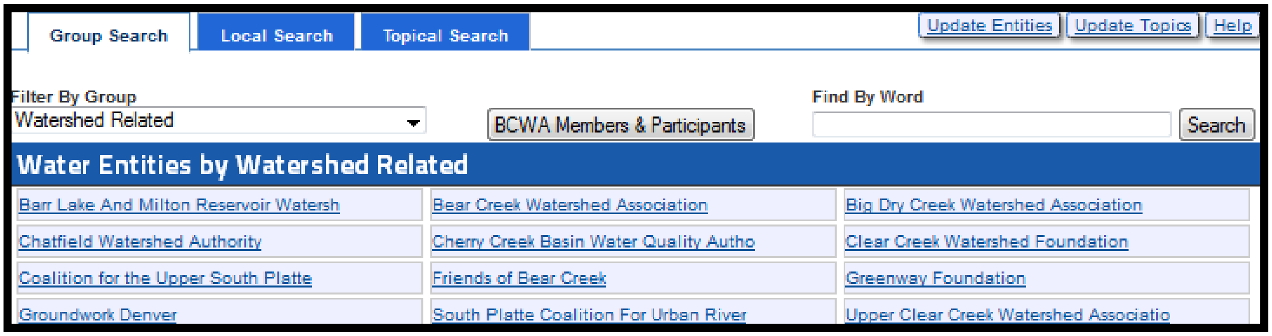
Park County

Potential Participant(s)

CDPHE Water Quality Control
Colorado Dept. of Transport
Denver Mountain Parks
District 9: Bear Creek
Evergreen Audubon
Evergreen Parks and Recreat
Jefferson Conservation Dist
Jefferson County Open Space

Figure B-21. Search Water Groups by Type
Selecting the BCWA option provides a list of all members and participants,
Selecting a group provides additional links and information about each of them

Not just local groups are included in the Group search, but groups by type statewide. For example, knowing about surrounding watershed related groups could help participants collaborate basin-wide or learn from others watersheds successes (Figure B-22).



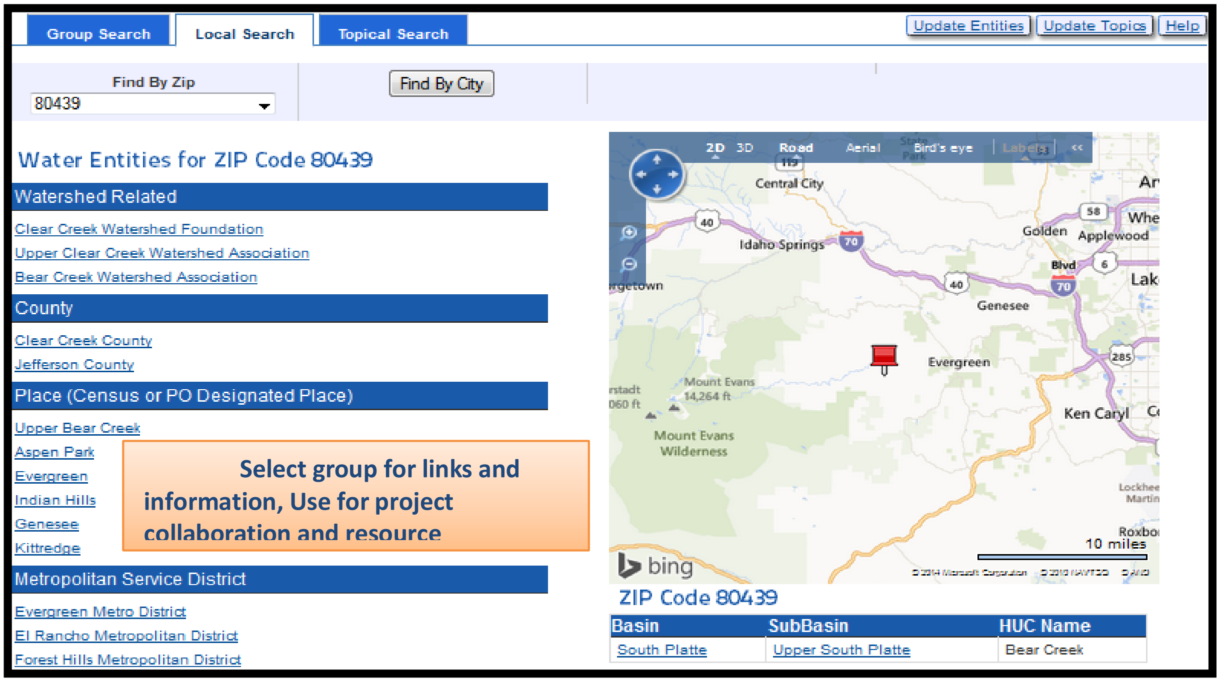
Water Entities by Watershed Related

Barr Lake And Milton Reservoir Watersh	Bear Creek Watershed Association	Big Dry Creek Watershed Association
Chatfield Watershed Authority	Cherry Creek Basin Water Quality Autho	Clear Creek Watershed Foundation
Coalition for the Upper South Platte	Friends of Bear Creek	Greenway Foundation
Groundwork Denver	South Platte Coalition For Urban River	Upper Clear Creek Watershed Associatio

Figure B-22. Filter by Group Type Helps Participants Learn from Others with Similar Water-related Roles

B-7.2 Local Search

The local search allows participants to discover other water-related groups within their immediate surroundings with which to partner. Figure B-23 demonstrates a zip code-based search. A user can also search by city. A zip code search in Colorado typically encompasses a larger area than a city search.



Water Entities for ZIP Code 80439

Watershed Related

Clear Creek Watershed Foundation
Upper Clear Creek Watershed Association
Bear Creek Watershed Association

County

Clear Creek County
Jefferson County

Place (Census or PO Designated Place)

Upper Bear Creek
Aspen Park
Evergreen
Indian Hills
Genesee
Kittredge

Metropolitan Service District

Evergreen Metro District
El Rancho Metropolitan District
Forest Hills Metropolitan District

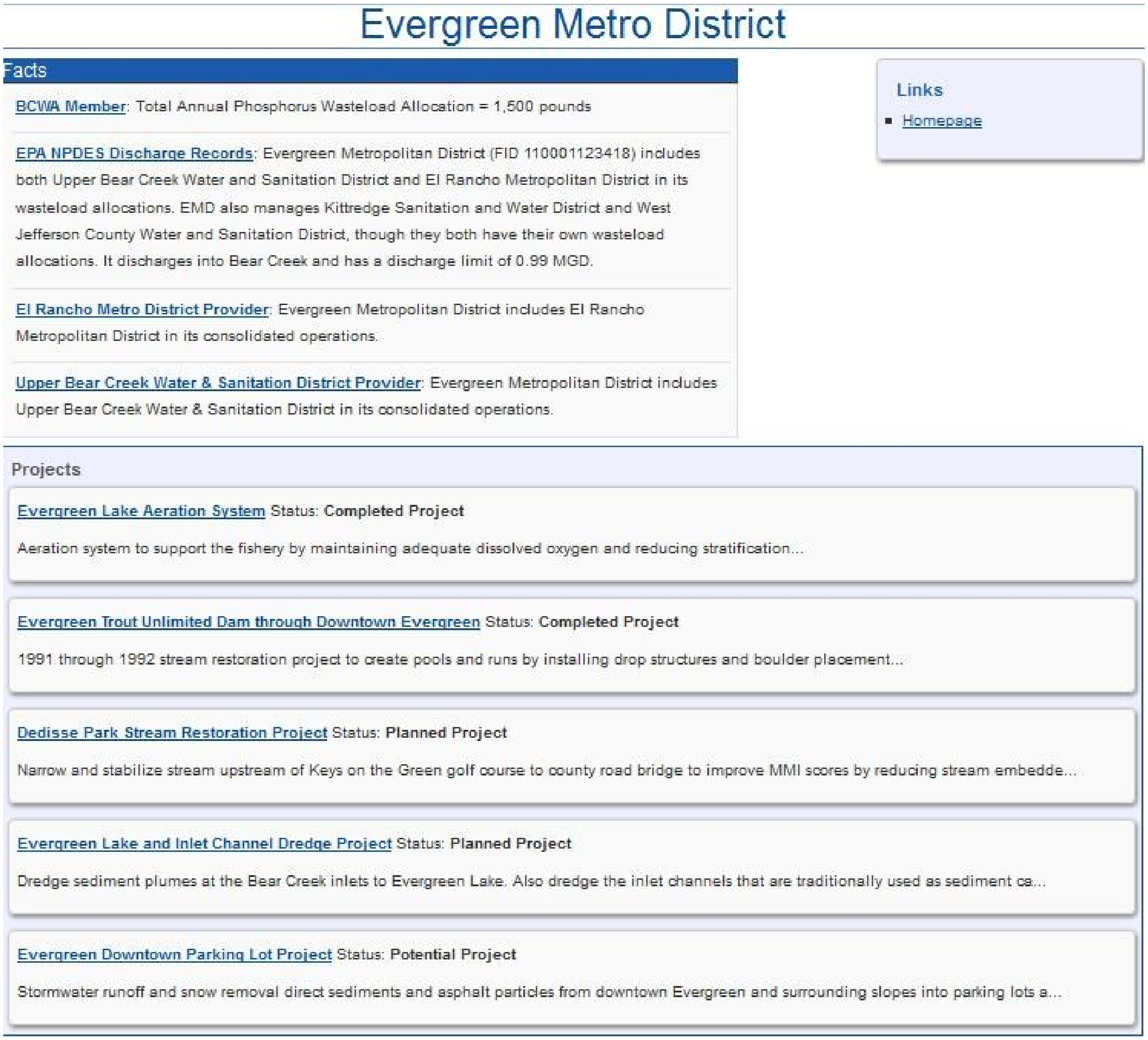
Select group for links and information, Use for project collaboration and resource

ZIP Code 80439

Basin	SubBasin	HUC Name
South Platte	Upper South Platte	Bear Creek

Figure B-23. Search by Zip (or City) to find Groups by Location

Under the map, the basin and subbasin links direct to USGS and EPA data and information specific to the larger South Platte basin. The subbasin-level, the Upper South Platte Basin, is the lowest level at which information is typically stored in national databases. Results are organized by group type and include a link with more information to any item selected including facts, links, and project involvement as shown in Figure B-24.



Evergreen Metro District

Facts

BCWA Member: Total Annual Phosphorus Wasteload Allocation = 1,500 pounds

EPA NPDES Discharge Records: Evergreen Metropolitan District (FID 110001123418) includes both Upper Bear Creek Water and Sanitation District and El Rancho Metropolitan District in its wasteload allocations. EMD also manages Kittredge Sanitation and Water District and West Jefferson County Water and Sanitation District, though they both have their own wasteload allocations. It discharges into Bear Creek and has a discharge limit of 0.99 MGD.

El Rancho Metro District Provider: Evergreen Metropolitan District includes El Rancho Metropolitan District in its consolidated operations.

Upper Bear Creek Water & Sanitation District Provider: Evergreen Metropolitan District includes Upper Bear Creek Water & Sanitation District in its consolidated operations.

Links

- Homepage

Projects

Evergreen Lake Aeration System Status: **Completed Project**

Aeration system to support the fishery by maintaining adequate dissolved oxygen and reducing stratification...

Evergreen Trout Unlimited Dam through Downtown Evergreen Status: **Completed Project**

1991 through 1992 stream restoration project to create pools and runs by installing drop structures and boulder placement...

Dedisse Park Stream Restoration Project Status: **Planned Project**

Narrow and stabilize stream upstream of Keys on the Green golf course to county road bridge to improve MMI scores by reducing stream embedde...

Evergreen Lake and Inlet Channel Dredge Project Status: **Planned Project**

Dredge sediment plumes at the Bear Creek inlets to Evergreen Lake. Also dredge the inlet channels that are traditionally used as sediment ca...

Evergreen Downtown Parking Lot Project Status: **Potential Project**

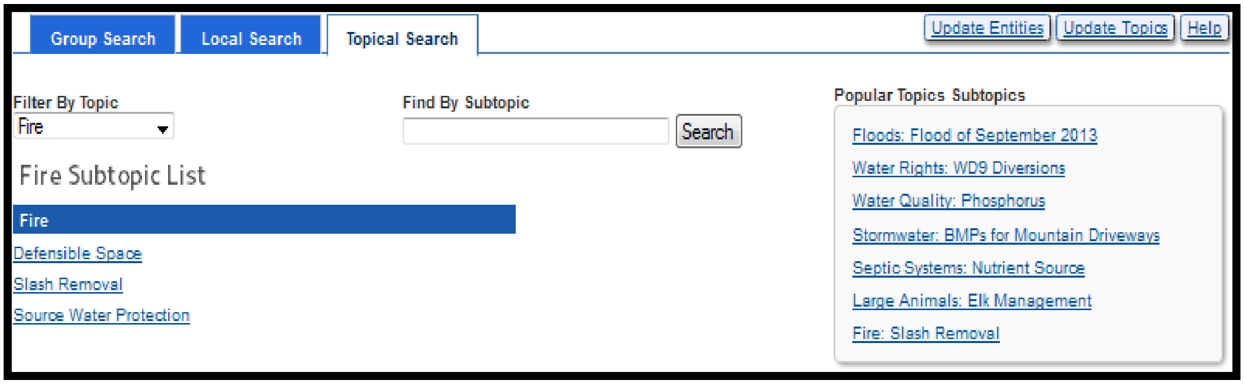
Stormwater runoff and snow removal direct sediments and asphalt particles from downtown Evergreen and surrounding slopes into parking lots a...

Figure B-24 Example Group page with Facts and Links

All projects the group has participated in automatically also appear in their page to assist in finding future partners and to aid shared learning

B-7.3 Topical Search

A topical knowledge base is an important way to record historical information and watershed knowledge. Often a member or manager that has been involved for decades must retire and their specific knowledge and resource links are lost. The Topical Search tab of the ACM DSS allows participants to select a topic to see related subtopics (Figure B-25). Entering any word in a topic or subtopic launches a global search, or one of the popular topics of current interest may be selected directly from a list.



Filter By Topic: Fire

Fire Subtopic List

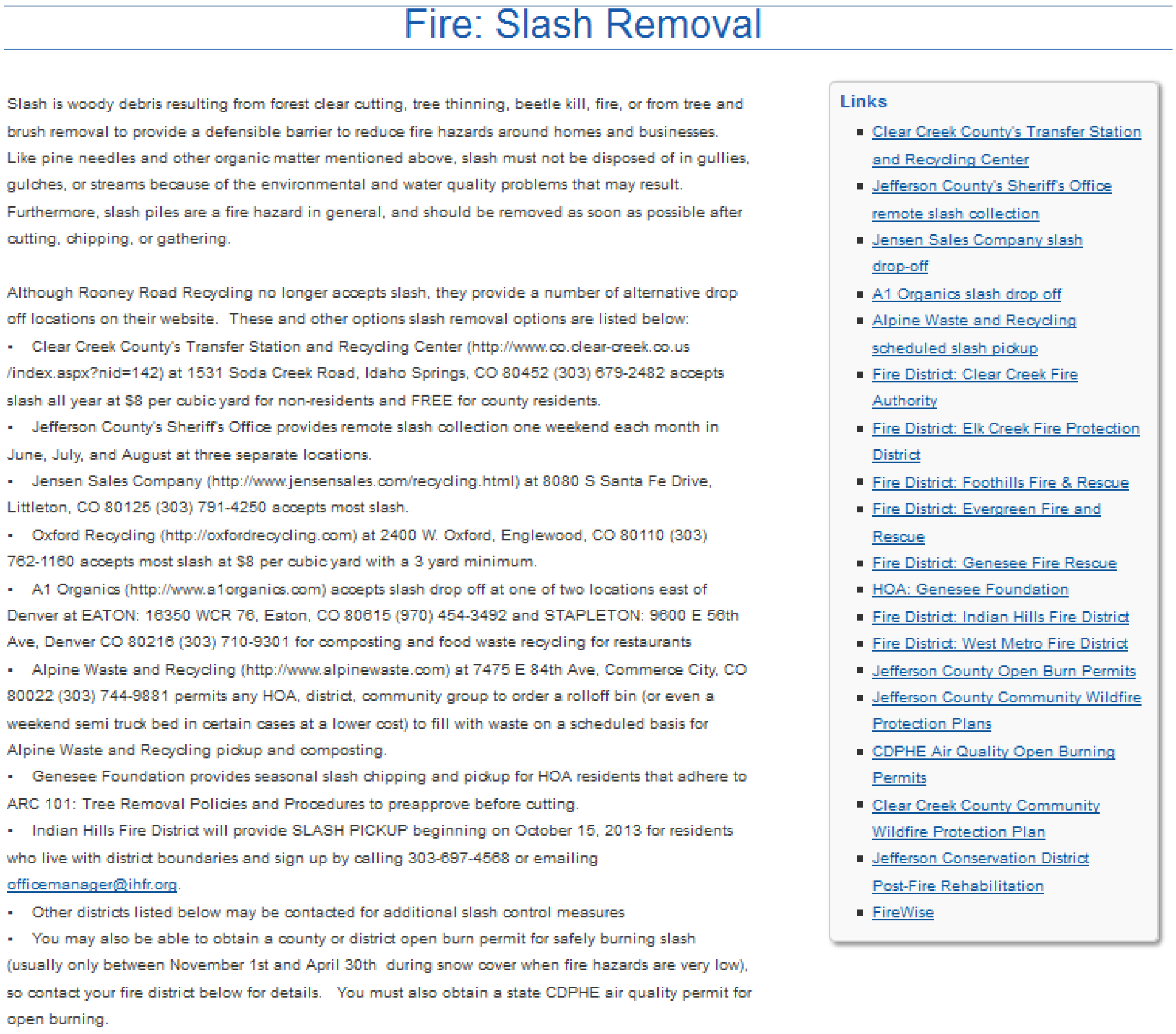
- Fire
- Defensible Space
- Slash Removal
- Source Water Protection

Popular Topics Subtopics

- Floods: Flood of September 2013
- Water Rights: WD9 Diversions
- Water Quality: Phosphorus
- Stormwater: BMPs for Mountain Driveways
- Septic Systems: Nutrient Source
- Large Animals: Elk Management
- Fire: Slash Removal

Figure B-25. Topic Search, Filter by Topic: Fire to produce Three Subtopics for Review

Every page of the knowledge base includes links and descriptive details to direct the user to other resources of interest. Although currently the system is not designed as a *wiki* application, which allows in-page links to automatically reference other pages of information, a wiki may be considered in Phase II. An example of how comprehensive each topic can be developed is demonstrated in Figure B-26. This topic concerns managing slash to reduce wildfire hazards, one of the most prominent issues for economic health, water quality, and source water protection. Therefore, several weeks were required to compile resources, conduct interviews, and brainstorm solutions that are now universally available to participants.



Fire: Slash Removal

Slash is woody debris resulting from forest clear cutting, tree thinning, beetle kill, fire, or from tree and brush removal to provide a defensible barrier to reduce fire hazards around homes and businesses. Like pine needles and other organic matter mentioned above, slash must not be disposed of in gullies, gulches, or streams because of the environmental and water quality problems that may result. Furthermore, slash piles are a fire hazard in general, and should be removed as soon as possible after cutting, chipping, or gathering.

Although Rooney Road Recycling no longer accepts slash, they provide a number of alternative drop off locations on their website. These and other options slash removal options are listed below:

- Clear Creek County's Transfer Station and Recycling Center (http://www.co.clear-creek.co.us/index.aspx?nid=142) at 1531 Soda Creek Road, Idaho Springs, CO 80452 (303) 679-2482 accepts slash all year at $8 per cubic yard for non-residents and FREE for county residents.
- Jefferson County's Sheriff's Office provides remote slash collection one weekend each month in June, July, and August at three separate locations.
- Jensen Sales Company (http://www.jensensales.com/recycling.html) at 8080 S Santa Fe Drive, Littleton, CO 80125 (303) 791-4250 accepts most slash.
- Oxford Recycling (http://oxfordrecycling.com) at 2400 W. Oxford, Englewood, CO 80110 (303) 762-1160 accepts most slash at $8 per cubic yard with a 3 yard minimum.
- A1 Organics (http://www.a1organics.com) accepts slash drop off at one of two locations east of Denver at EATON: 16350 WCR 76, Eaton, CO 80615 (970) 454-3492 and STAPLETON: 9600 E 56th Ave, Denver CO 80216 (303) 710-9301 for composting and food waste recycling for restaurants
- Alpine Waste and Recycling (http://www.alpinewaste.com) at 7475 E 84th Ave, Commerce City, CO 80022 (303) 744-9881 permits any HOA, district, community group to order a rolloff bin (or even a weekend semi truck bed in certain cases at a lower cost) to fill with waste on a scheduled basis for Alpine Waste and Recycling pickup and composting.
- Genesee Foundation provides seasonal slash chipping and pickup for HOA residents that adhere to ARC 101: Tree Removal Policies and Procedures to preapprove before cutting.
- Indian Hills Fire District will provide SLASH PICKUP beginning on October 15, 2013 for residents who live with district boundaries and sign up by calling 303-697-4568 or emailing officemanager@ihfr.org.
- Other districts listed below may be contacted for additional slash control measures
- You may also be able to obtain a county or district open burn permit for safely burning slash (usually only between November 1st and April 30th during snow cover when fire hazards are very low), so contact your fire district below for details. You must also obtain a state CDPHE air quality permit for open burning.

Links

- Clear Creek County's Transfer Station and Recycling Center
- Jefferson County's Sheriff's Office remote slash collection
- Jensen Sales Company slash drop-off
- A1 Organics slash drop off
- Alpine Waste and Recycling scheduled slash pickup
- Fire District: Clear Creek Fire Authority
- Fire District: Elk Creek Fire Protection District
- Fire District: Foothills Fire & Rescue
- Fire District: Evergreen Fire and Rescue
- Fire District: Genesee Fire Rescue
- HOA: Genesee Foundation
- Fire District: Indian Hills Fire District
- Fire District: West Metro Fire District
- Jefferson County Open Burn Permits
- Jefferson County Community Wildfire Protection Plans
- CDPHE Air Quality Open Burning Permits
- Clear Creek County Community Wildfire Protection Plan
- Jefferson Conservation District Post-Fire Rehabilitation
- FireWise

Figure B-26. Example Subtopic from Topical Knowledge Base: Slash Removal Description and Options

B-7.4 Benefits

Since it would be difficult to incorporate SNA directly into the ACM DSS, the Group Search serves as a more practical way to help participants become aware of potential partners and resources. The Location Search attracted participants interested particularly in knowing other groups in their immediate surrounding. The Topical Knowledge Base search by word or topic provides a faster way to access information that may already be known by some BCWA members, but not by all, or in less detail.

B-7.5 Next Steps

More groups and more details about each one, especially projects in which they have already worked with BCWA or member organizations should be more thoroughly researched. Through visits or interviews, groups for which additional information was desired were added to the Group Search tool to seek additional input directly. In this way, the ACM DSS itself becomes a relationship-building tool. The Knowledge Base could be expanded over time by using retired BCWA members, the BCWA manager, BCWA member organizations, and retired community leaders for curation support. As the spiral model incorporates new stakeholders in each subsequent phase, ACM DSS toolset curation and quality may expand as more participants gain access over time.

B-8 Projects

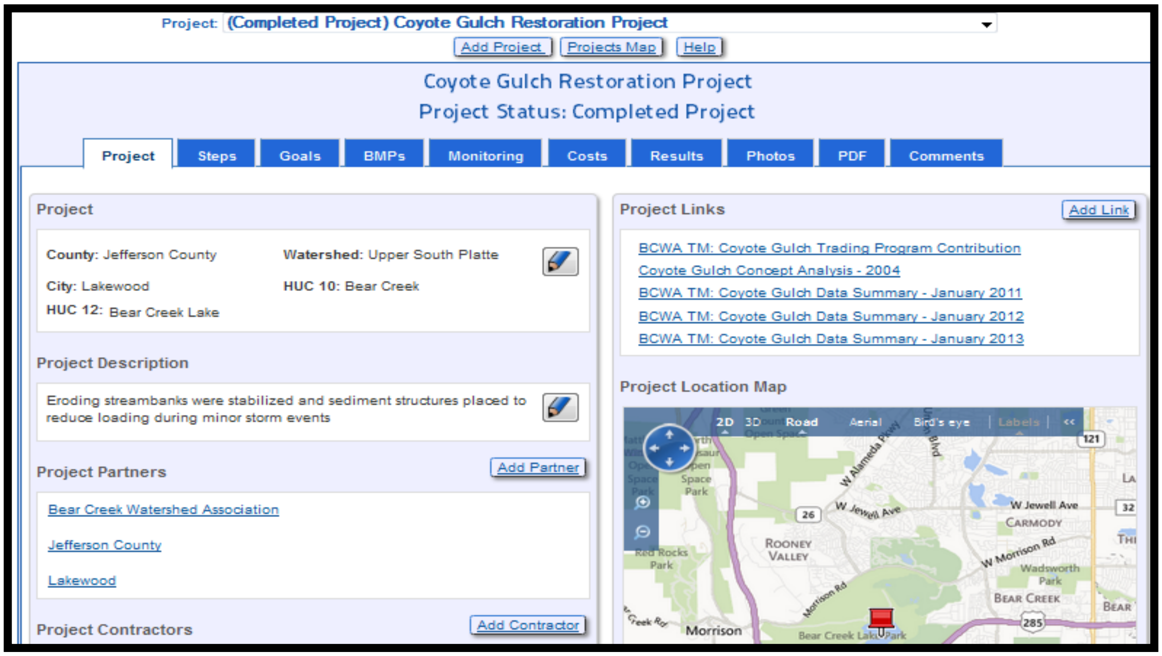
ACM DSS Projects are an important way for BCWA members to describe their efforts in detail. Figure B-27 demonstrates completed, planned, and in-progress projects that have already been entered.

(Potential Project) Bendemeer Sanitation connection
(Potential Project) Bluebell Wildfire
(Potential Project) Connecting BCLP to Municipal Water Supply and Sewage
(Potential Project) decentralized system
(Potential Project) Evergreen Downtown Parking Lot Project
(Potential Project) Fire Hazard Mitigation Strategy #1: Prepermit sedimentation basin locati
(Potential Project) forest hill contection
(Potential Project) JCPS Mt Evans OELS Fire Hazard Mitigation
(Potential Project) Lair O' The Bear JCOS Flood Repair
(Potential Project) Manure Management
(Potential Project) Septage Receiving Station
(Potential Project) Septic Tank Management
(Planned Project) Dedisse Park Stream Restoration Project
(Planned Project) Evergreen Lake and Inlet Channel Dredge Project
(Implementing Project) Summit Lake Latrines
(Completed Project) Bear Creek Lake Aeration System
(Completed Project) Coyote Gulch Restoration Project
(Completed Project) Evergreen Lake Aeration System
(Completed Project) Evergreen Trout Unlimited Dam through Downtown Evergreen
(Completed Project) Evergreen Trout Unlimited O'Fallon Park Restoration

Figure B-27. Project List of Completed, In-Progress, and Potential Projects

As an example, see the Coyote Gulch Restoration Project shown in Figure B-28. Project information is organized into ten tabs that can be rapidly developed from existing information.

1. Project tab – location, partners, contractors, links, and map
2. Steps – major steps needed to secure funding, complete, and assess the project
3. Goals – why the project was funded
4. BMPs – best management practices employed in project implementation
5. Monitoring – full list of all assessment procedures to be used to verify project benefits
6. Costs – total project costs, including costs associated with linked options (Figure B-29)
7. Results – project benefits in terms of nutrient and sediment reductions, etc.
8. Photos – project photos to use in annual reporting, evaluation, and visualizing BMPs
9. PDF – automatically produced Project Fact Sheet from other tabbed inputs
10. Comments – user supplied comments as to the success or questions about the project



Project: (Completed Project) Coyote Gulch Restoration Project

Coyote Gulch Restoration Project
Project Status: Completed Project

Project

County: Jefferson County
Watershed: Upper South Platte
City: Lakewood
HUC 10: Bear Creek
HUC 12: Bear Creek Lake

Project Description

Eroding streambanks were stabilized and sediment structures placed to reduce loading during minor storm events

Project Partners

Bear Creek Watershed Association
Jefferson County
Lakewood

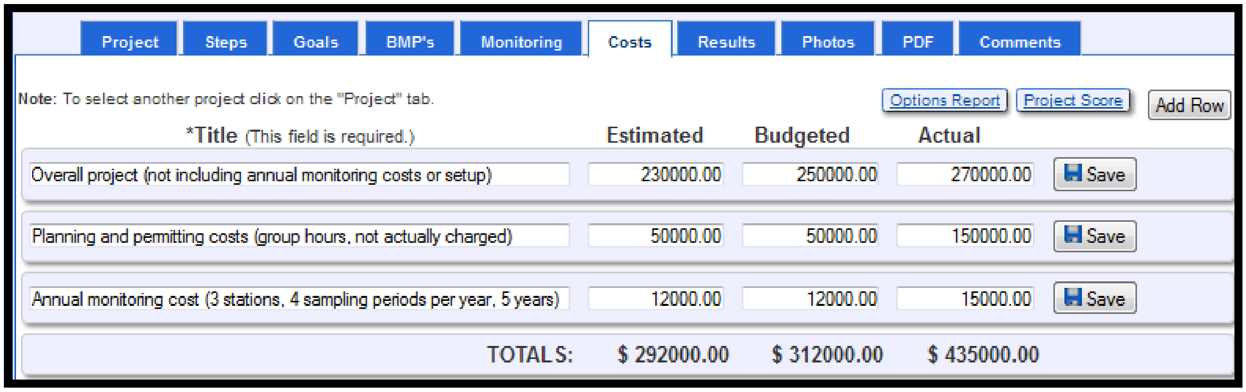
Project Contractors

Project Links

BCWA TM: Coyote Gulch Trading Program Contribution
Coyote Gulch Concept Analysis - 2004
BCWA TM: Coyote Gulch Data Summary - January 2011
BCWA TM: Coyote Gulch Data Summary - January 2012
BCWA TM: Coyote Gulch Data Summary - January 2013

Project Location Map

Figure B-28. Project Details – General Information Tab



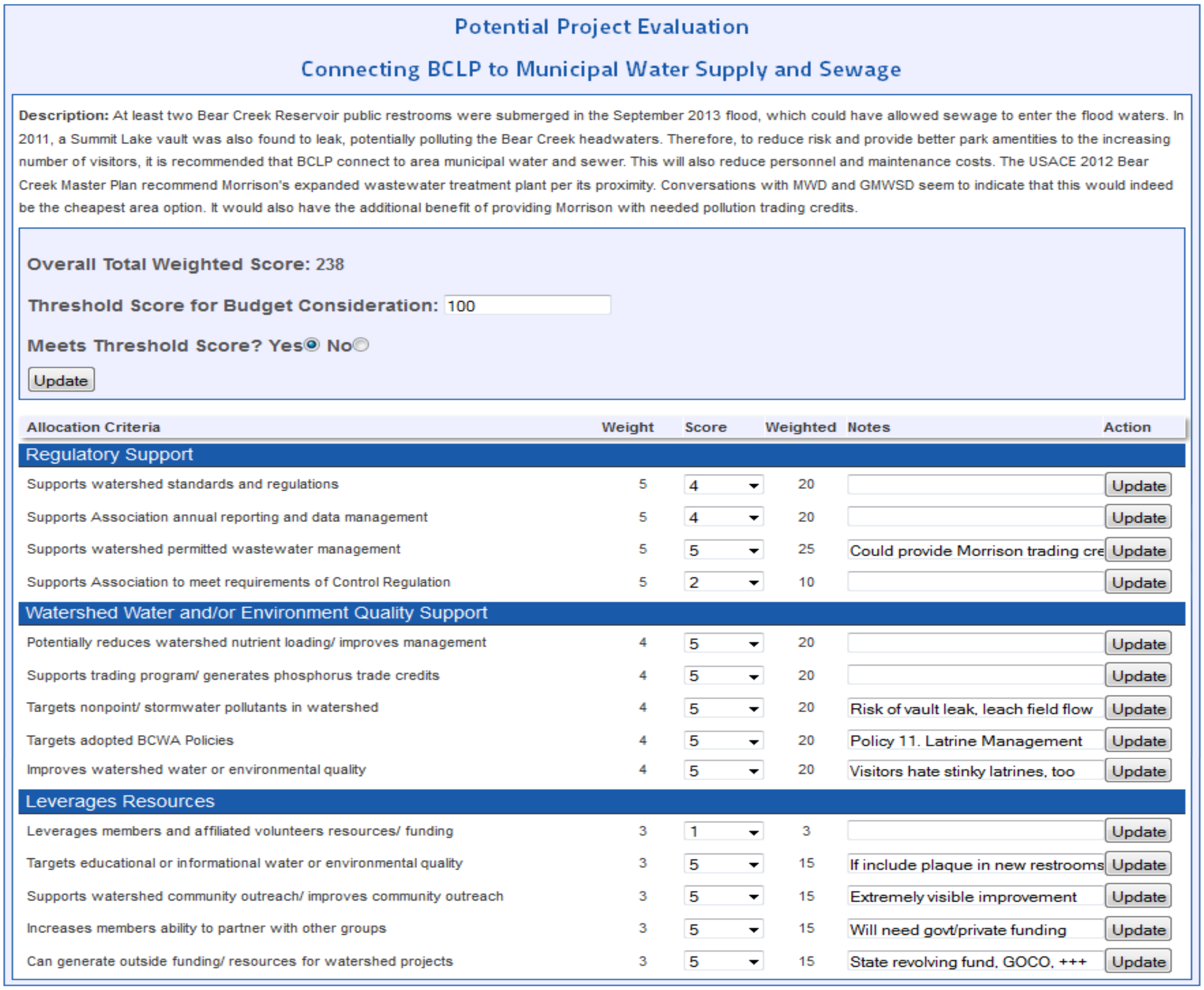
Note: To select another project click on the "Project" tab.

*Title (This field is required.)	Estimated	Budgeted	Actual	
Overall project (not including annual monitoring costs or setup)	230000.00	250000.00	270000.00	Save
Planning and permitting costs (group hours, not actually charged)	50000.00	50000.00	150000.00	Save
Annual monitoring cost (3 stations, 4 sampling periods per year, 5 years)	12000.00	12000.00	15000.00	Save
TOTALS:	$ 292000.00	$ 312000.00	$ 435000.00	

Figure B-29. Project Costs Include Preliminary and Monitoring Costs, not just Construction Costs

B-8.2 Project Evaluation and Assessment

During the ACM DSS process, it became evident that when a respected member suggested a project during a BCWA board meeting, it was often immediately voted upon for funding with little consideration of actual costs and benefits, despite limited member dues as the only source of BCWA funding. Therefore, based on previous experience in business and nonprofits, a simple project scoring tool and a more vigorous three-stage evaluation process was developed to help BCWA make future decisions with more rigor (Figure B-30). In response, BCWA adopted Policy 23 – *BCWA Project Evaluation Process* to formalize this process for all future funding requests (Appendix A. Exhibit 14).


Potential Project Evaluation

Connecting BCLP to Municipal Water Supply and Sewage

Description: At least two Bear Creek Reservoir public restrooms were submerged in the September 2013 flood, which could have allowed sewage to enter the flood waters. In 2011, a Summit Lake vault was also found to leak, potentially polluting the Bear Creek headwaters. Therefore, to reduce risk and provide better park amentities to the increasing number of visitors, it is recommended that BCLP connect to area municipal water and sewer. This will also reduce personnel and maintenance costs. The USACE 2012 Bear Creek Master Plan recommend Morrison's expanded wastewater treatment plant per its proximity. Conversations with MWD and GMWSD seem to indicate that this would indeed be the cheapest area option. It would also have the additional benefit of providing Morrison with needed pollution trading credits.

Overall Total Weighted Score: 238

Threshold Score for Budget Consideration: 100

Meets Threshold Score? Yes ● **No** ○

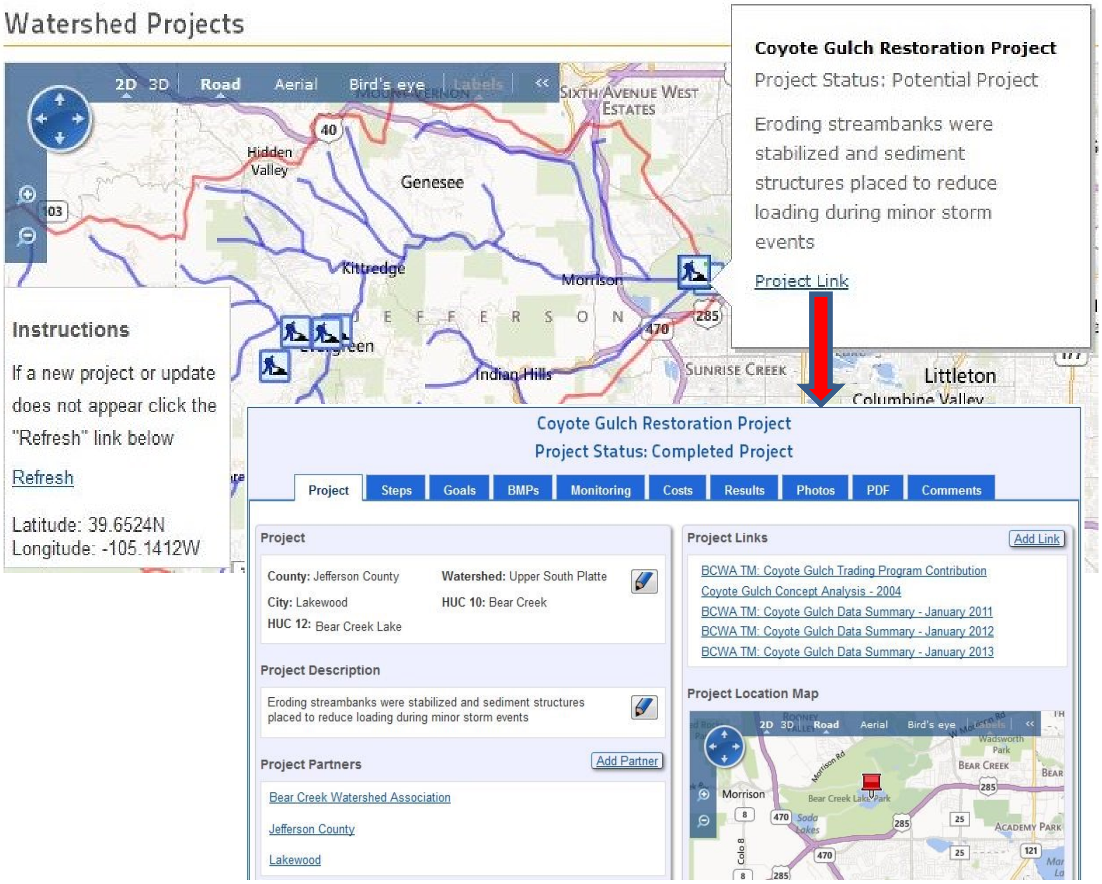
Allocation Criteria	Weight	Score	Weighted	Notes	Action
Regulatory Support					
Supports watershed standards and regulations	5	4	20		Update
Supports Association annual reporting and data management	5	4	20		Update
Supports watershed permitted wastewater management	5	5	25	Could provide Morrison trading cre	Update
Supports Association to meet requirements of Control Regulation	5	2	10		Update
Watershed Water and/or Environment Quality Support					
Potentially reduces watershed nutrient loading/ improves management	4	5	20		Update
Supports trading program/ generates phosphorus trade credits	4	5	20		Update
Targets nonpoint/ stormwater pollutants in watershed	4	5	20	Risk of vault leak, leach field flow	Update
Targets adopted BCWA Policies	4	5	20	Policy 11. Latrine Management	Update
Improves watershed water or environmental quality	4	5	20	Visitors hate stinky latrines, too	Update
Leverages Resources					
Leverages members and affiliated volunteers resources/ funding	3	1	3		Update
Targets educational or informational water or environmental quality	3	5	15	If include plaque in new restrooms	Update
Supports watershed community outreach/ improves community outreach	3	5	15	Extremely visible improvement	Update
Increases members ability to partner with other groups	3	5	15	Will need govt/private funding	Update
Can generate outside funding/ resources for watershed projects	3	5	15	State revolving fund, GOCO, +++	Update

Figure B-30. BCWA Adopted Project Scoring System with Threshold Required for Further Consideration

In addition to improving funding priorities, more experience in formal evaluation will allow BCWA to consider more advanced options analysis and decision support tools in later stages of ACM DSS process development. As additional funding sources allow BCWA to consider a more diverse portfolio, public and private donors will demand optimized performance. Therefore, the ACM DSS project tools for ongoing assessment will be particularly important to demonstrate baselines and metrics of actual benefits and costs realized compared to those predicted. Appendix A. Exhibit 11 also lists many of the criteria that will be developed into a *performance dashboard* in Phase II or III to track watershed improvement progress more easily over time.

B-8.3 Projects Map

Participants found the watershed project map very useful, because it demonstrates where BCWA resources have been focused (Figure B-31). Over time, this will be a powerful way to review progress. By selecting one of the projects shown in the map, the user can quickly access the full project details and ongoing assessment information to see how well it has performed over time, and project partners.



Watershed Projects

Coyote Gulch Restoration Project
Project Status: Potential Project

Eroding streambanks were stabilized and sediment structures placed to reduce loading during minor storm events

Project Link

Instructions

If a new project or update does not appear click the "Refresh" link below

Refresh

Latitude: 39.6524N
Longitude: -105.1412W

Coyote Gulch Restoration Project
Project Status: Completed Project

Project

County: Jefferson County
Watershed: Upper South Platte
City: Lakewood
HUC 10: Bear Creek
HUC 12: Bear Creek Lake

Project Description

Eroding streambanks were stabilized and sediment structures placed to reduce loading during minor storm events

Project Partners

Bear Creek Watershed Association
Jefferson County
Lakewood

Project Links

BCWA TM: Coyote Gulch Trading Program Contribution
Coyote Gulch Concept Analysis - 2004
BCWA TM: Coyote Gulch Data Summary - January 2011
BCWA TM: Coyote Gulch Data Summary - January 2012
BCWA TM: Coyote Gulch Data Summary - January 2013

Project Location Map

Figure B-31. Access to Project Details from Project Map

B-8.4 Benefits

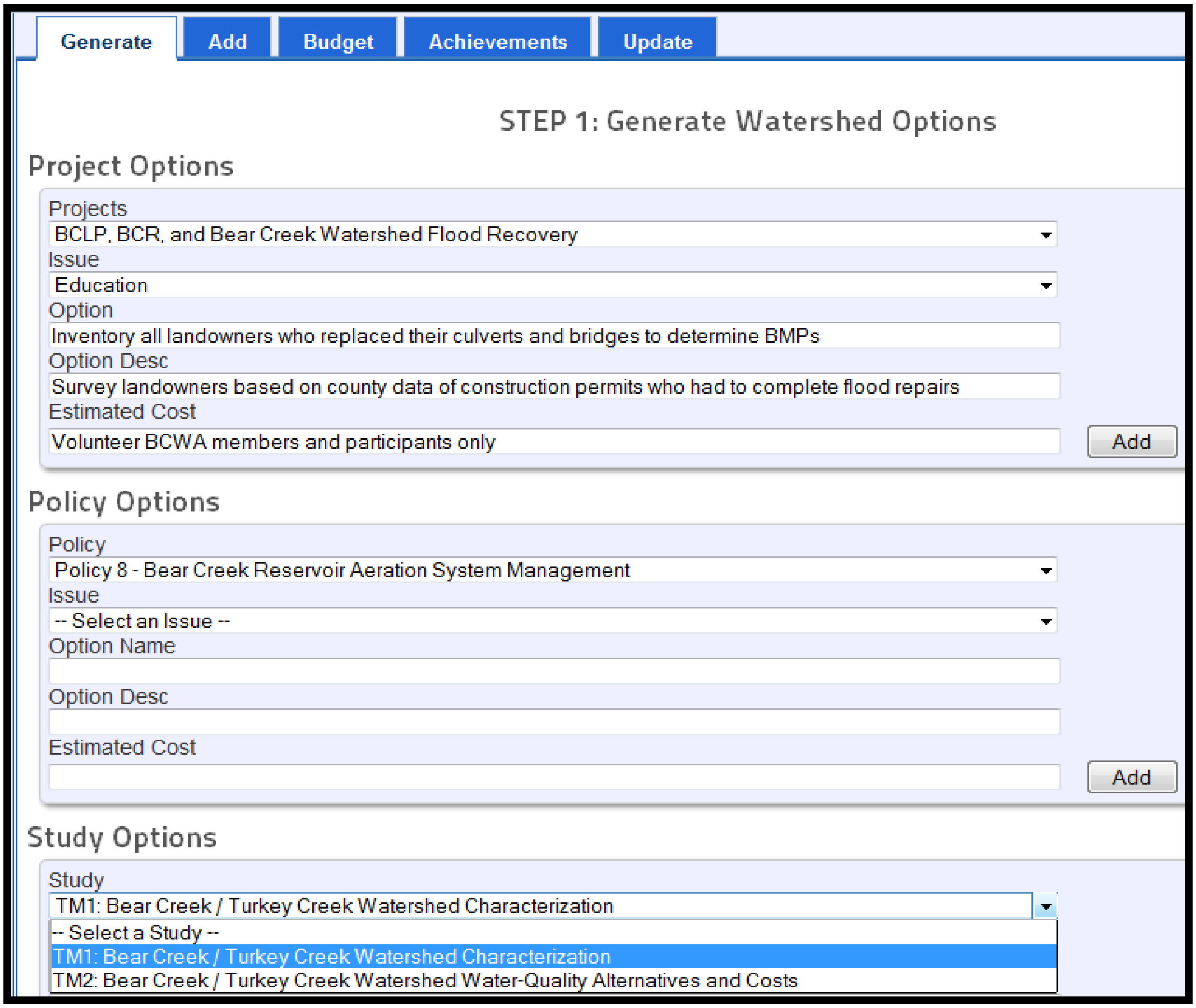
The Project tab was derived from an original *Measurable Results* application developed for statewide watershed project cost / benefits assessment (Herzog et al. 2012). As such, it meets EPA and state reporting needs, while providing easy-to-develop project information for both past and potential projects, including potential project scoring and evaluation and implemented project assessment tools. BCWA members were impressed with the ease-of-use of the project modules to develop an archive a BMPs and projects quickly that can serve as templates and lessons learned for more effective future project selection, implementation, and assessment. Linking to issues and partners was also helpful.

B-8.5 Next Steps

Each member will be asked directly in an interview at least annually to enter additional past projects that contributed to watershed health, as well as, planned or proposed ideas for additional projects that could assist in future nutrient reductions and other improvements. In later phases, more organizational participants can be solicited for additional input. Results can also be used to target upcoming EPA grants and other funding sources that often include a specific focus and short time frame for development.

B-9 Options

The ACM DSS Options tab records small steps toward project planning and assessment and other progress focused on education, policy, or studies that may not otherwise be tracked as carefully, since they might not be considered projects (Figure B-32).



STEP 1: Generate Watershed Options

Project Options

Projects
BCLP, BCR, and Bear Creek Watershed Flood Recovery
Issue
Education
Option
Inventory all landowners who replaced their culverts and bridges to determine BMPs
Option Desc
Survey landowners based on county data of construction permits who had to complete flood repairs
Estimated Cost
Volunteer BCWA members and participants only

Policy Options

Policy
Policy 8 - Bear Creek Reservoir Aeration System Management
Issue
-- Select an Issue --
Option Name

Option Desc

Estimated Cost

Study Options

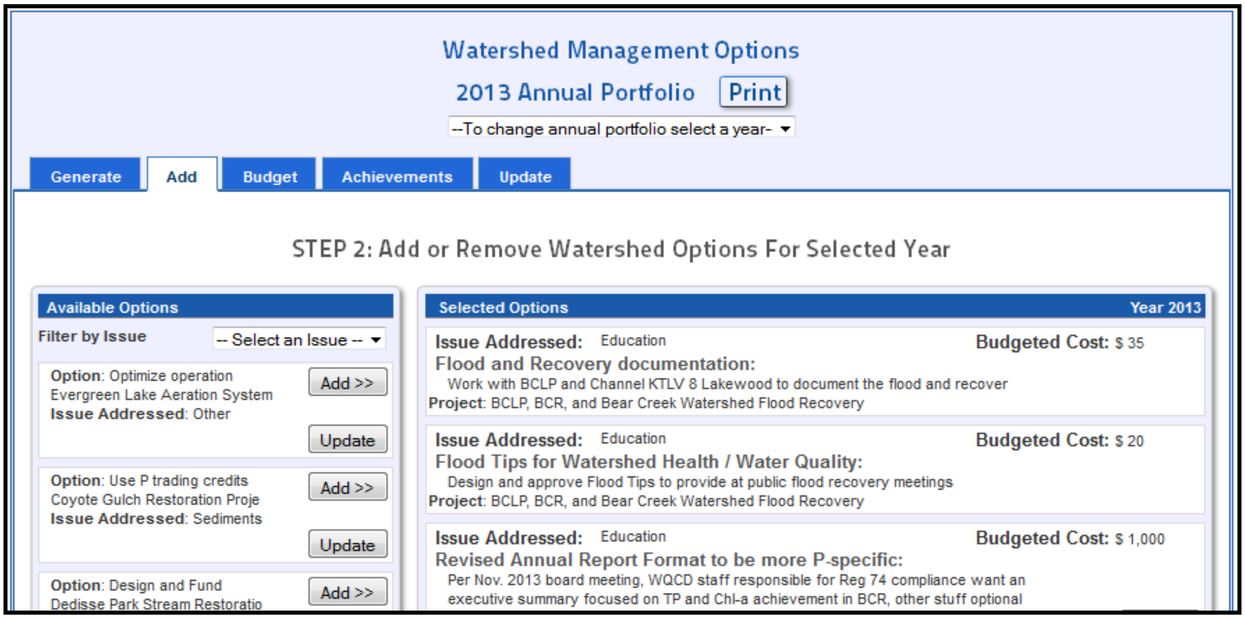
Study
TM1: Bear Creek / Turkey Creek Watershed Characterization
-- Select a Study --
TM1: Bear Creek / Turkey Creek Watershed Characterization
TM2: Bear Creek / Turkey Creek Watershed Water-Quality Alternatives and Costs

Figure B-32. Managing Watershed Activities through the Options Tools

Options associated with a project, roll-up to that project in reports for total project life cost analysis. To add an option to track, the user must decide if it is related to an existing project, policy, or study, so that even a simple call, cost estimate, public meeting, or other activity is included in its progress. In this way, the true cost and steps involved in developing any water quality improvement can be tracked. This is important, because often projects, studies, or educational activities are underfunded because only the direct costs of the materials or contractors are included. There is also no information on the many critical steps involved in pre-planning. Typically, post assessment costs are forgotten or under-estimated. In contrast, the ACM DSS process demands activity assessment to inform next steps.

B-9.1 Prioritizing Group Options

Options requiring BCWA board cooperation or financing need to be added during BCWA board meetings to the annual portfolio. Although the period could be flexible, it was necessary to associate options with a particular year in the case of BCWA for use in the WQCC annual report and other annual deliverables. Options individual organizations choose to be responsible for achieving can be added directly to the portfolio at any time to describe all activities being achieved toward nutrient management. Even if not every option is included in the BCWA annual report, it can be used in statistical summaries and overall cost / benefit analysis over time (Figure B-33). It will also clarify which organizations are involved in which types of activities to enhance understanding for better alignment and project partnering.



Watershed Management Options

2013 Annual Portfolio

STEP 2: Add or Remove Watershed Options For Selected Year

Available Options

Filter by Issue

Option: Optimize operation Evergreen Lake Aeration System
Issue Addressed: Other

Option: Use P trading credits Coyote Gulch Restoration Proje
Issue Addressed: Sediments

Option: Design and Fund Dedisse Park Stream Restoratio

Selected Options **Year 2013**

Issue Addressed: Education **Budgeted Cost:** $ 35
Flood and Recovery documentation:
Work with BCLP and Channel KTLV 8 Lakewood to document the flood and recover
Project: BCLP, BCR, and Bear Creek Watershed Flood Recovery

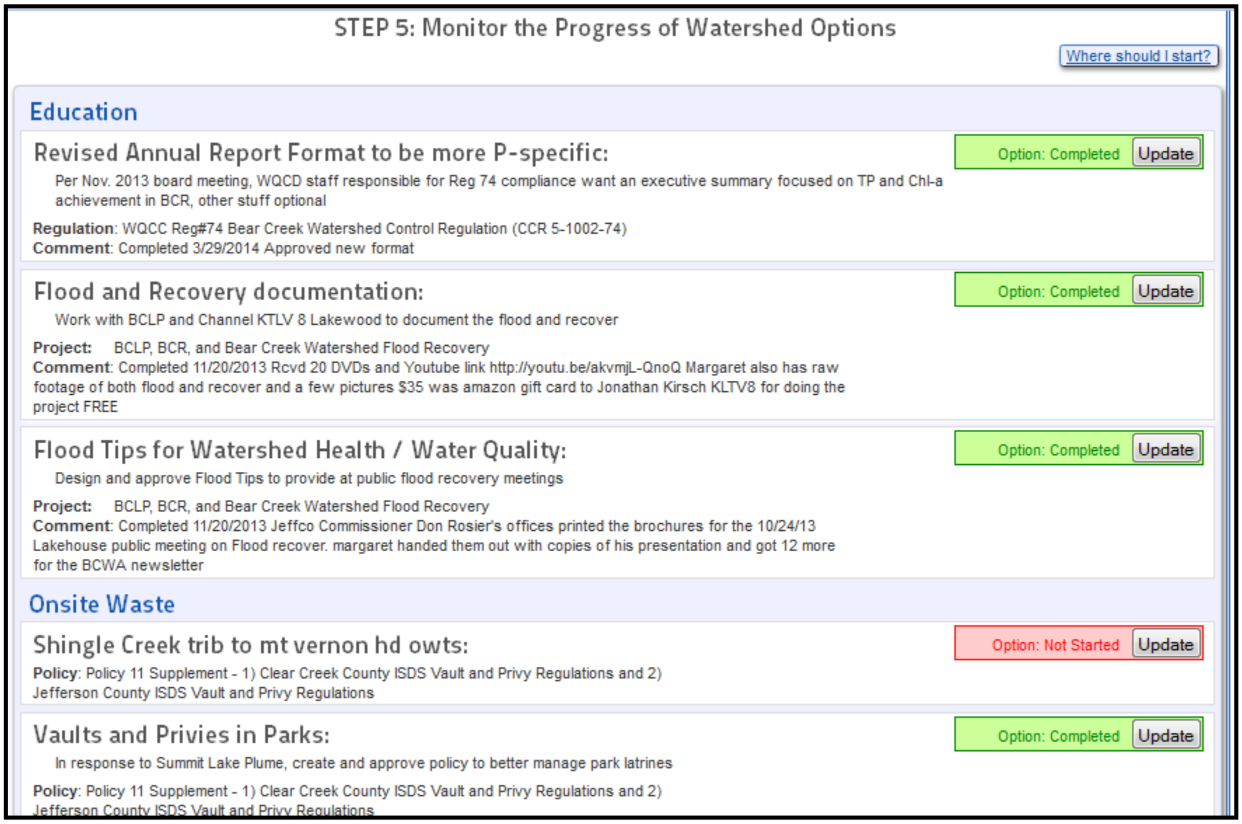
Issue Addressed: Education **Budgeted Cost:** $ 20
Flood Tips for Watershed Health / Water Quality:
Design and approve Flood Tips to provide at public flood recovery meetings
Project: BCLP, BCR, and Bear Creek Watershed Flood Recovery

Issue Addressed: Education **Budgeted Cost:** $ 1,000
Revised Annual Report Format to be more P-specific:
Per Nov. 2013 board meeting, WQCD staff responsible for Reg 74 compliance want an executive summary focused on TP and Chl-a achievement in BCR, other stuff optional

Figure B-33. Add Options for Annual Funding and Tracking

B-9.2 Tracking Options

It is not enough to select options, without incrementally recording activity for more effective progress documentation and planning. Therefore, tabs were included to track the actual costs and achievements of each activity to also roll-up into the overall achievements of related projects and studies, as well as, to track non-project accomplishments (Figure B-34). To enforce tracking, an Update tab is included in the Options module to ensure that every option that an individual organization or the BCWA membership as a group has chosen to pursue is clearly tracked. At each monthly BCWA board and TRS meeting, the option list can be reviewed to report progress to ensure accountability. In this way, the system maintains its relevance, rather than failing for lack of updates.


STEP 5: Monitor the Progress of Watershed Options

Education

Revised Annual Report Format to be more P-specific:

Per Nov. 2013 board meeting, WQCD staff responsible for Reg 74 compliance want an executive summary focused on TP and Chl-a achievement in BCR, other stuff optional

Regulation: WQCC Reg#74 Bear Creek Watershed Control Regulation (CCR 5-1002-74)
Comment: Completed 3/29/2014 Approved new format

Flood and Recovery documentation:

Work with BCLP and Channel KTLV 8 Lakewood to document the flood and recover

Project: BCLP, BCR, and Bear Creek Watershed Flood Recovery
Comment: Completed 11/20/2013 Rcvd 20 DVDs and Youtube link http://youtu.be/akvmjL-QnoQ Margaret also has raw footage of both flood and recover and a few pictures $35 was amazon gift card to Jonathan Kirsch KLTV8 for doing the project FREE

Flood Tips for Watershed Health / Water Quality:

Design and approve Flood Tips to provide at public flood recovery meetings

Project: BCLP, BCR, and Bear Creek Watershed Flood Recovery
Comment: Completed 11/20/2013 Jeffco Commissioner Don Rosier's offices printed the brochures for the 10/24/13 Lakehouse public meeting on Flood recover. margaret handed them out with copies of his presentation and got 12 more for the BCWA newsletter

Onsite Waste

Shingle Creek trib to mt vernon hd owts:

Policy: Policy 11 Supplement - 1) Clear Creek County ISDS Vault and Privy Regulations and 2) Jefferson County ISDS Vault and Privy Regulations

Vaults and Privies in Parks:

In response to Summit Lake Plume, create and approve policy to better manage park latrines

Policy: Policy 11 Supplement - 1) Clear Creek County ISDS Vault and Privy Regulations and 2) Jefferson County ISDS Vault and Privy Regulations

Figure B-34. Update Options to Encourage Continuous Tracking

B-9.3 Benefits

Participants are often hesitant to enter their ideas for progress to the full project level of detail. The options development tools allow participants to describe small steps they are making on a continual basis towards nutrient reduction through educational initiatives, legislative actions, and resource acquisition. It also allows antecedent and post-project follow-up to be more directly documented to roll-up into necessary project development steps and costs.

This will allow the cost and benefits of each action to be documented. It will also serve for even more wide-ranging BMP development and better choice selection over time.

B-9.4 Next Steps

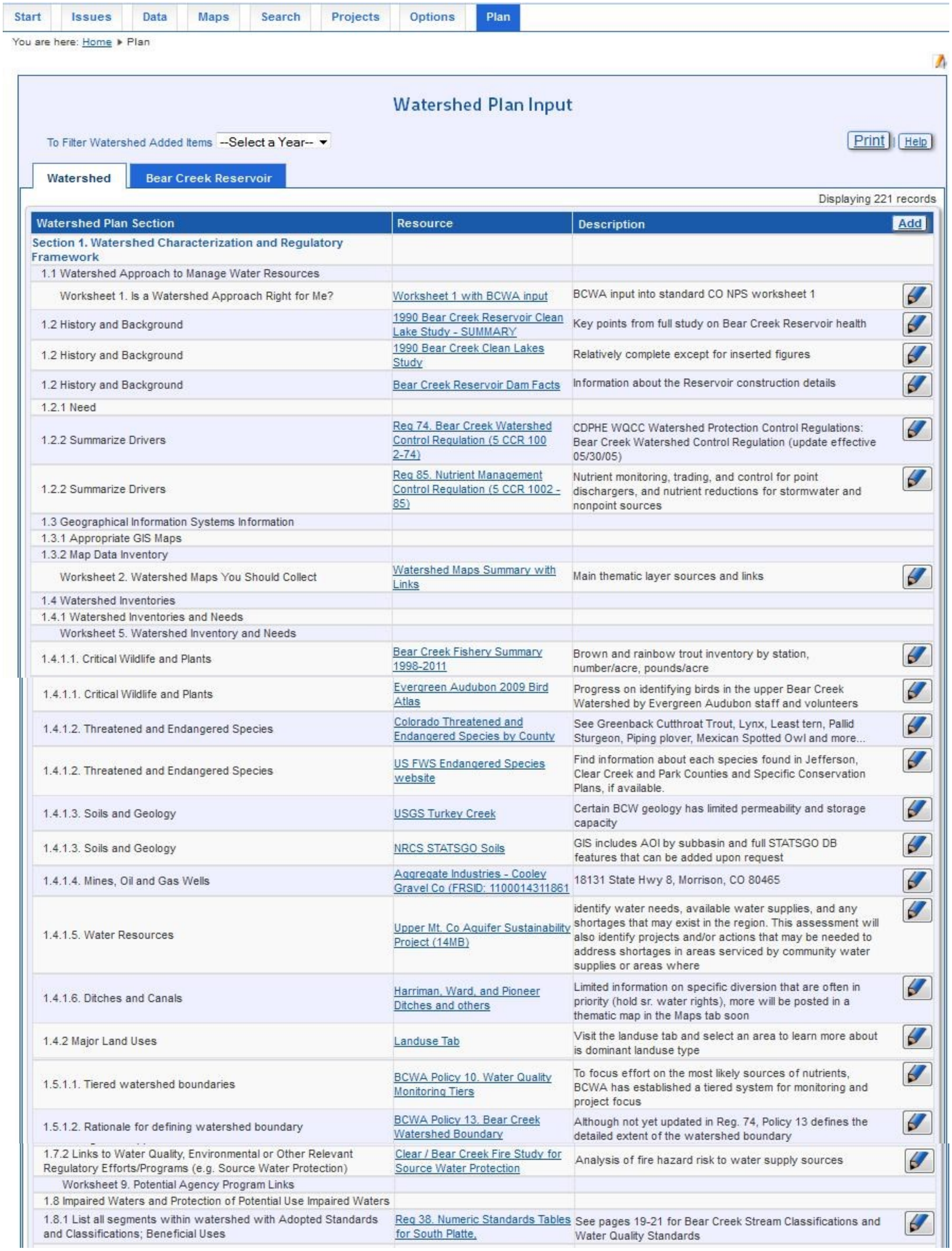
As with project development, until BCWA members and additional participants become used to using ACM DSS on a continual basis, it will be necessary to help them remember to record all options they mention in meetings and interviews into this module. To simplify this process, in Phase II, a *dashboard* will be developed for each BCWA member organization that shows only their goals, projects, and options, issues and plan input to allow them to focus on keeping their information updated. It will also allow them to track the direct impact their organization is having on overall water quality and health.

B-10 Watershed Planning

As discussed in Section 2.8, state and federal funding is often contingent on producing a Watershed Plan. Although the ACM DSS does not produce a plan directly, by developing input to both a Watershed Plan outline that fully meets state and federal requirements it will simplify development. The Lake Management planning portion for BCR is also important to concentrate focus on developing lake-specific data and models to more actively control trophic status and nutrient enrichment effects.

B-10.1 Watershed Plan Input

Rather than trying to develop a static Watershed Plan document directly, BCWA felt it could make more progress and remain more adaptive by building the plan over time from policy and study pieces. Therefore, a system was developed in the ACM DSS to allow any BCWA member to upload information into the Watershed Plan outline that would assist in developing the particular section (Figure B-35). This quickly made it visually evident where gaps existed in the outline. At any time, BCWA members or volunteers, such as retired professional in a particular specialty could then take the pieces to build a more formal plan for that portion. A new policy could then be established as to how watershed and lake planning pieces will be developed and implemented over time.



Watershed Plan Input

To Filter Watershed Added Items --Select a Year--

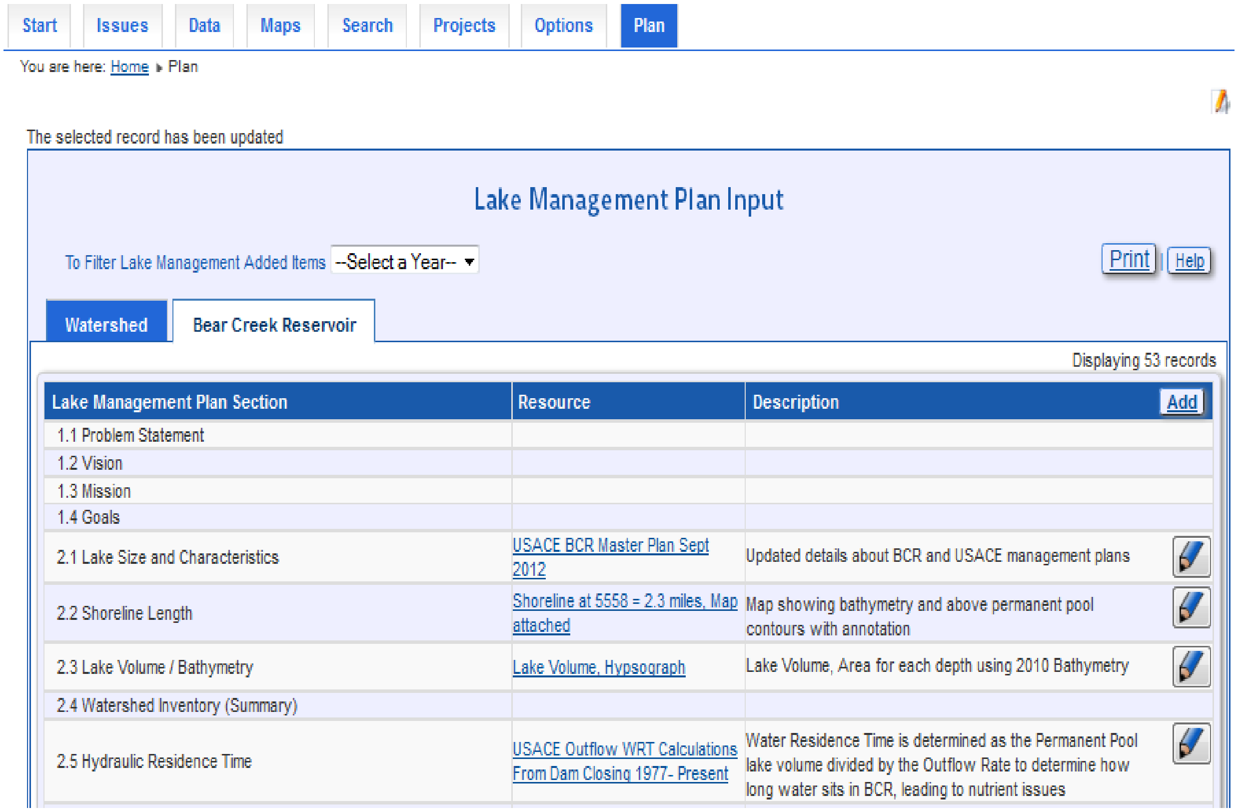
Displaying 221 records

Watershed Plan Section	Resource	Description
Section 1. Watershed Characterization and Regulatory Framework		
1.1 Watershed Approach to Manage Water Resources		
Worksheet 1. Is a Watershed Approach Right for Me?	Worksheet 1 with BCWA input	BCWA input into standard CO NPS worksheet 1
1.2 History and Background	1990 Bear Creek Reservoir Clean Lake Study - SUMMARY	Key points from full study on Bear Creek Reservoir health
1.2 History and Background	1990 Bear Creek Clean Lakes Study	Relatively complete except for inserted figures
1.2 History and Background	Bear Creek Reservoir Dam Facts	Information about the Reservoir construction details
1.2.1 Need		
1.2.2 Summarize Drivers	Reg 74. Bear Creek Watershed Control Regulation (5 CCR 100 2-74)	CDPHE WQCC Watershed Protection Control Regulations: Bear Creek Watershed Control Regulation (update effective 05/30/05)
1.2.2 Summarize Drivers	Reg 85. Nutrient Management Control Regulation (5 CCR 1002 - 85)	Nutrient monitoring, trading, and control for point dischargers, and nutrient reductions for stormwater and nonpoint sources
1.3 Geographical Information Systems Information		
1.3.1 Appropriate GIS Maps		
1.3.2 Map Data Inventory		
Worksheet 2. Watershed Maps You Should Collect	Watershed Maps Summary with Links	Main thematic layer sources and links
1.4 Watershed Inventories		
1.4.1 Watershed Inventories and Needs		
Worksheet 5. Watershed Inventory and Needs		
1.4.1.1. Critical Wildlife and Plants	Bear Creek Fishery Summary 1998-2011	Brown and rainbow trout inventory by station, number/acre, pounds/acre
1.4.1.1. Critical Wildlife and Plants	Evergreen Audubon 2009 Bird Atlas	Progress on identifying birds in the upper Bear Creek Watershed by Evergreen Audubon staff and volunteers
1.4.1.2. Threatened and Endangered Species	Colorado Threatened and Endangered Species by County	See Greenback Cutthroat Trout, Lynx, Least tern, Pallid Sturgeon, Piping plover, Mexican Spotted Owl and more...
1.4.1.2. Threatened and Endangered Species	US FWS Endangered Species website	Find information about each species found in Jefferson, Clear Creek and Park Counties and Specific Conservation Plans, if available.
1.4.1.3. Soils and Geology	USGS Turkey Creek	Certain BCW geology has limited permeability and storage capacity
1.4.1.3. Soils and Geology	NRCS STATSGO Soils	GIS includes AOI by subbasin and full STATSGO DB features that can be added upon request
1.4.1.4. Mines, Oil and Gas Wells	Aggregate Industries - Cooley Gravel Co (FRSID: 1100014311861	18131 State Hwy 8, Morrison, CO 80465
1.4.1.5. Water Resources	Upper Mt. Co Aquifer Sustainability Project (14MB)	identify water needs, available water supplies, and any shortages that may exist in the region. This assessment will also identify projects and/or actions that may be needed to address shortages in areas serviced by community water supplies or areas where
1.4.1.6. Ditches and Canals	Harriman, Ward, and Pioneer Ditches and others	Limited information on specific diversion that are often in priority (hold sr. water rights), more will be posted in a thematic map in the Maps tab soon
1.4.2 Major Land Uses	Landuse Tab	Visit the landuse tab and select an area to learn more about is dominant landuse type
1.5.1.1. Tiered watershed boundaries	BCWA Policy 10. Water Quality Monitoring Tiers	To focus effort on the most likely sources of nutrients, BCWA has established a tiered system for monitoring and project focus
1.5.1.2. Rationale for defining watershed boundary	BCWA Policy 13. Bear Creek Watershed Boundary	Although not yet updated in Reg. 74, Policy 13 defines the detailed extent of the watershed boundary
1.7.2 Links to Water Quality, Environmental or Other Relevant Regulatory Efforts/Programs (e.g. Source Water Protection)	Clear / Bear Creek Fire Study for Source Water Protection	Analysis of fire hazard risk to water supply sources
Worksheet 9. Potential Agency Program Links		
1.8 Impaired Waters and Protection of Potential Use Impaired Waters		
1.8.1 List all segments within watershed with Adopted Standards and Classifications; Beneficial Uses	Reg 38. Numeric Standards Tables for South Platte.	See pages 19-21 for Bear Creek Stream Classifications and Water Quality Standards

Figure B-35. Excerpts from the Watershed Plan Outline of Linked Components

B-10.2 Lake Management Plan Input

Unlike the Watershed Plan focused on *exogenous* nutrient control, the Lake Management Plan is more specifically focused on what can be done to control lake eutrophication itself. At scale, just like the watershed, the lake can be modeled in terms of inputs and outputs. These include the food chain discussed in more detail in Appendix C, as well as, abiotic weather factors and chemical reactions. By specifically focusing on developing a more specific plan for the lake (Figure B-36), data becomes available for an entire new range of management options that more specifically control undesirable traits.



You are here: Home ▸ Plan

The selected record has been updated

Lake Management Plan Input

To Filter Lake Management Added Items

Displaying 53 records

Lake Management Plan Section	Resource	Description
1.1 Problem Statement		
1.2 Vision		
1.3 Mission		
1.4 Goals		
2.1 Lake Size and Characteristics	USACE BCR Master Plan Sept 2012	Updated details about BCR and USACE management plans
2.2 Shoreline Length	Shoreline at 5558 = 2.3 miles, Map attached	Map showing bathymetry and above permanent pool contours with annotation
2.3 Lake Volume / Bathymetry	Lake Volume, Hypsograph	Lake Volume, Area for each depth using 2010 Bathymetry
2.4 Watershed Inventory (Summary)		
2.5 Hydraulic Residence Time	USACE Outflow WRT Calculations From Dam Closing 1977- Present	Water Residence Time is determined as the Permanent Pool lake volume divided by the Outflow Rate to determine how long water sits in BCR, leading to nutrient issues

Figure B-36. Lake Management Plan Input

B-10.3 Benefits

Effective Watershed and Lake Management Plan development is a daunting process. By using outlines to break the needed elements into specific items, the watershed program can more quickly determine gaps. It is also encouraging to upload studies and develop needed components over time to see how the plan begins to develop from existing knowledge within the group more organically. This planning process enabler will help even less advanced watershed programs to gain rapid progress. In this way, success can encourage additional study and effort to meet all critical planning areas more systematically and completely.

B-10.4 Next Steps

Going beyond mere watershed and lake management planning outlines, tools will need to be developed to help watershed programs create *living* plans that more directly focus on drivers and thresholds to monitor over time and space to directly achieve nutrient management goals. This will be accomplished more directly in ACM DSS process Phases II and III, which would focus on building *dashboards* for more direct issues and benefits tracking.

APPENDIX C. BEAR CREEK WATERSHED CASE STUDY

C-1 Watershed Description

The (Upper) Bear Creek Watershed lies about three miles southwest of Denver, Colorado with a drainage area of approximately 236 square miles. Figure C-1 indicates that the western headwaters originating from Mt. Evans and Summit Lake are primarily in public parks and conservation tracts, while the central area is more developed. The eastern end of the watershed drops into the more densely populated City of Lakewood, which represents the western extent of the Denver Metro area. The Denver Metro area lies east of state highway C-470, which distinctly separates the mountains from the plains.

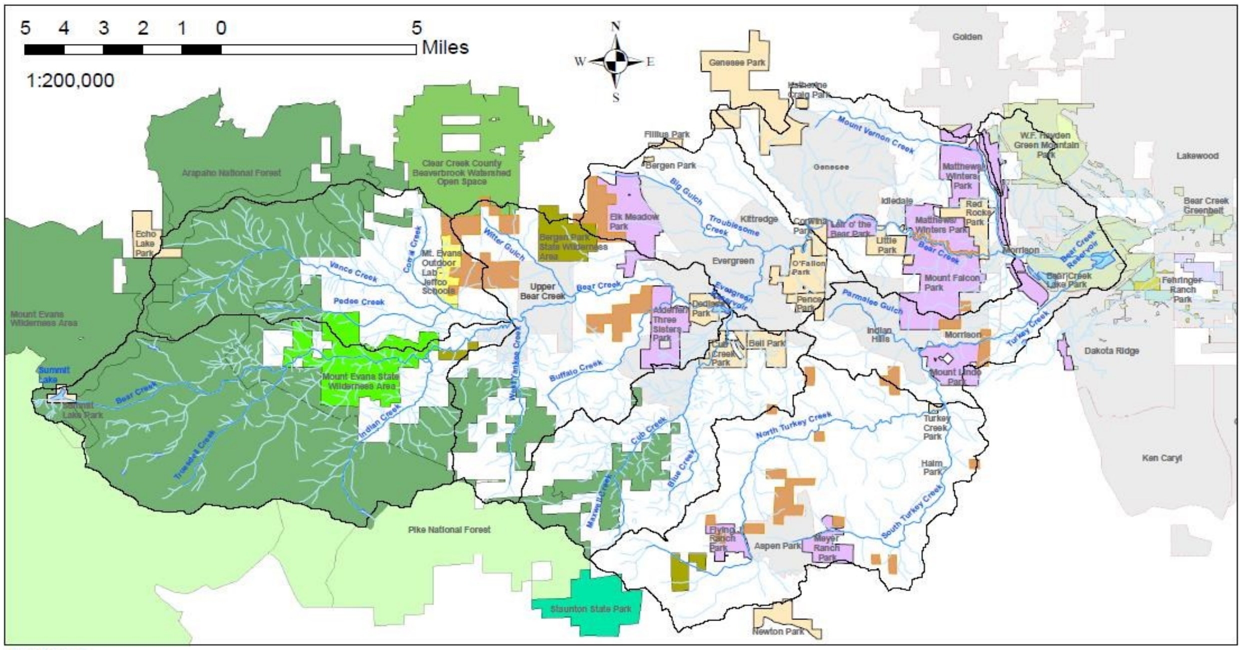


Figure C-1. Bear Creek Watershed Public Lands and Populated Areas

The total population per the 2010 U.S. Census is approximately 43,000 inhabitants (Figure C-2). The Bear Creek Watershed is defined as the hydrologic boundaries to Bear Creek Reservoir (BCR). There are two main tributaries, Turkey Creek flowing in from the southwest and Bear Creek flowing in from the western headwaters at Mt. Evans. Turkey Creek runs along Interstate US-285 from Conifer and Aspen Park to BCR. The lower portion of Bear Creek runs along State Highway SH-74 (Morrison Road) from Evergreen Parkway. Both stream pass under State Highway C-470 and into BCR in Bear Creek Lake Park (BCLP). The Bear Creek Watershed drains into the

Upper South Platte Basin. The South Platte joins the North Platte then drains into the Missouri river system, which eventually reaches the Mississippi River, and finally the Gulf of Mexico. Eutrophication in the Gulf is of particular concern, since 78 percent of coastal water that have been assessed exhibit eutrophication, which contributes to a growing "dead zone" likely to effect important fisheries over time (NAS 2010). The growing anoxic zone in the Gulf of Mexico is one of the reasons why federal EPA nutrient control regulations on point discharges have become more stringent in recent years, which also led to stricter 2013 Colorado state nutrient standards for dischargers.

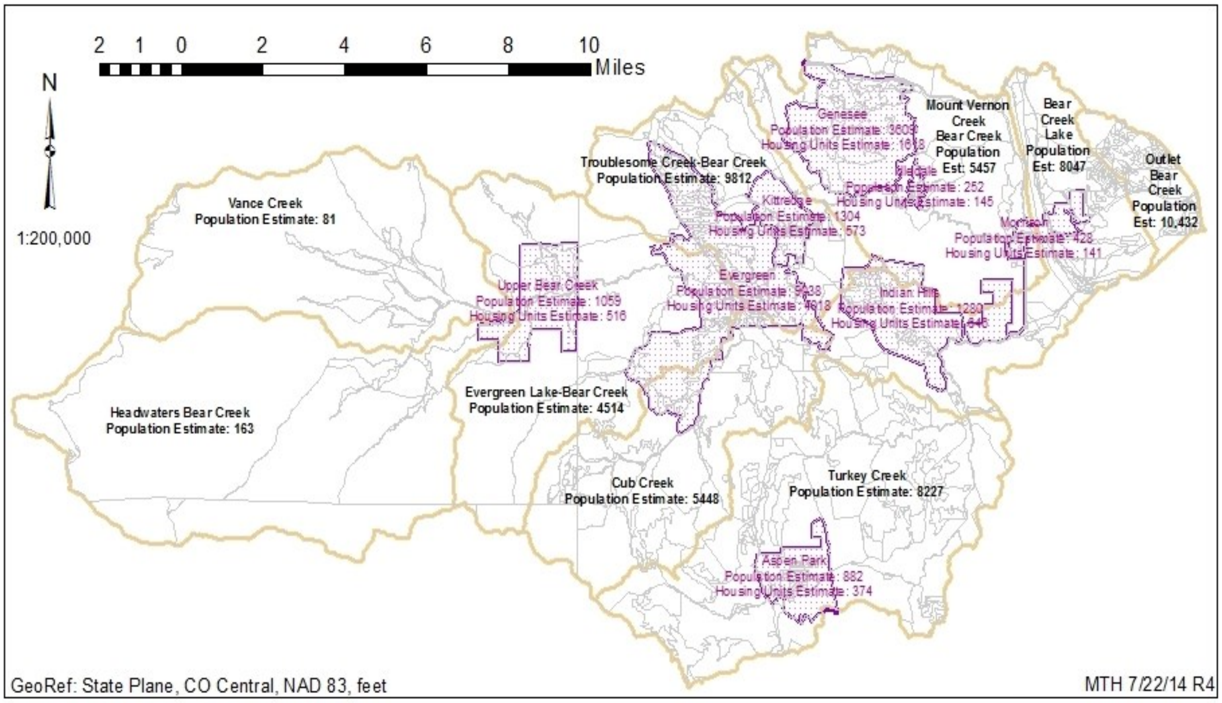


Figure C-2. Bear Creek Watershed Population Estimates

Legend

☐ 2010 Census Blocks ▨ Census Defined Places (CDP) ☐ Bear Creek Subbasins

Notes

TOTAL POPULATION ESTIMATE WITHOUT OUTLET SUBBASIN PORTION: 42,749   TOTAL POPULATION ESTIMATE ALL SUBBASINS: 52,181

2010 U.S. Census block-level and place-based population numbers were obtained from Denver Regional Council of Governments
http://gis.drcog.org/datacatalog/content/blocks-census-2010 with population of blocks that straddled the watershed boundary proportionally applied by area
The Colorado Department of Labor and Statistics estimates that the population of Colorado grew about six percent since 2010,
so the current population of the Bear Creek Watershed may actually be somewhat higher and increasing.
For BCWA administrative purposes, the USGS HUC 12-based Bear Creek Watershed boundary has been partially extended into
the Bear Creek Outlet subbasin downstream, but most of the area of this administrative addition does not drain into Bear Creek Reservoir.

BCLP represents the Bear Creek Watershed terminus. Figure C-3 indicates that only the eastern portion is populated, and more heavily so moving toward the city. Just beyond the City of Lakewood's Bear Creek Greenbelt downstream, Bear Creek takes on a more urban character in its final 7.5 miles to its confluence with the South Platte. The lower reach of Bear Creek below BCR is included in the Metro Denver area Barr-Milton watershed (South Platte Urban watershed) to simplify management as a single urban waters unit. BCR, Chatfield (four times the size of BCR), and Cherry Creek (3.5 times the size of BCR), are known as the USACE Tri-Lakes flood control management unit, and delineate the southern boundary of the Barr-Milton watershed. Bear Creek Watershed is similar to other suburban mountain headwaters under increasing development pressures in the semi-arid southwestern United States. Mining has been limited, but the watershed lies on the desirable western central fringe of the Denver Metro area, one of the areas most accessible to skiing, fishing, and other recreational opportunities. This has led to rapid development. Additional ongoing issues stem from infrastructure of older communities not designed for water quality. Although little agriculture and ranching remains, horse properties are popular on small parcels throughout less densely populated mountain communities. Turkey and Cub Creeks in the southern half of the watershed are dominated by septic systems, while the northern half is mainly served by water and sanitation districts.

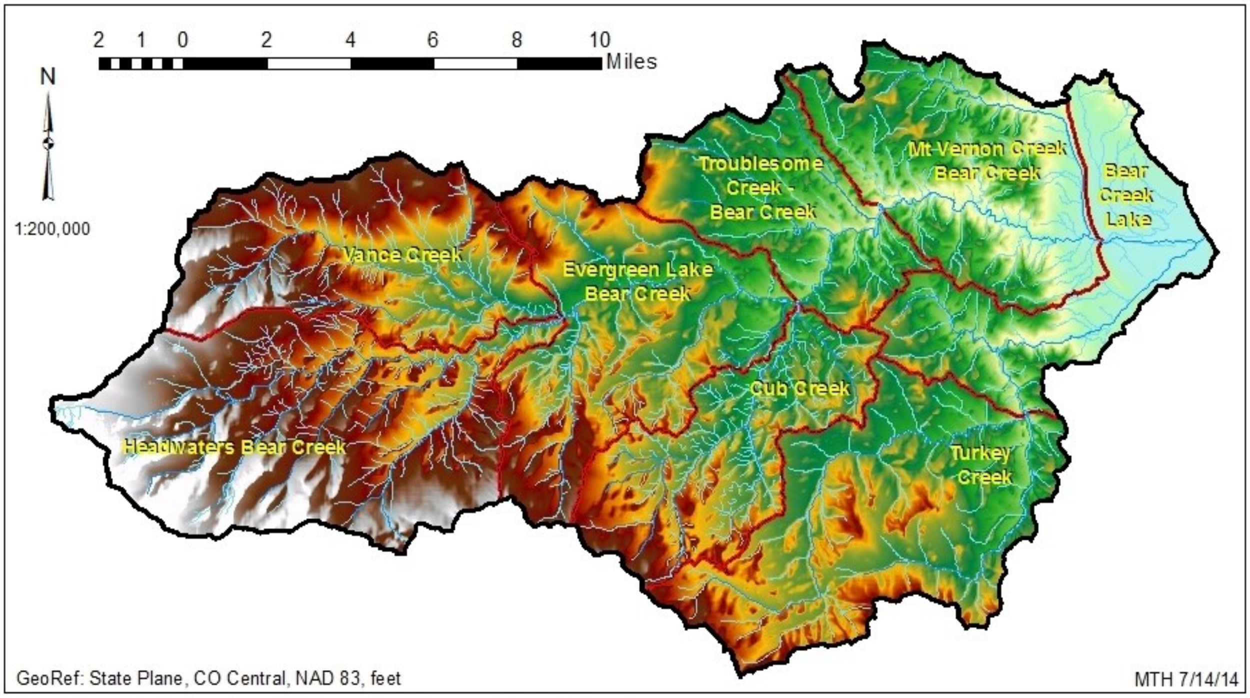


Figure C-3. Bear Creek Watershed Subbasins

Legend

—— Major Streams

▭ Subbasins

High : 14,258 feet MSL at Mt. Evans Peak

Low : 5,558 feet MSLat Bear Creek Reservoir Permanent Pool

Notes

Forty-foot contours from Clear Creek and Jefferson Counties derived from USGS elevation data
were combined with road, water body, and stream breaklines to derive this Digital Elevation Model of Bear Creek Watershed terrain.

Figure C-4 demonstrates how Bear Creek lies in the western portion of the Upper South Platte Basin. Chatfield and Cherry Creek Reservoirs are also managed by the USACE as the Tri-Lakes District. All three reservoirs have Control Regulations developed in the early 1990's in response to an EPA funded Clean Lake Study for each. A Denver Regional Council of Governments (DrCog 1993) Metro Vision Plan 2020 for Water Quality developed as part of this regional block grant process included additional plans to control other nutrient sources beyond WWTFs discharges, but has never been fully implemented.

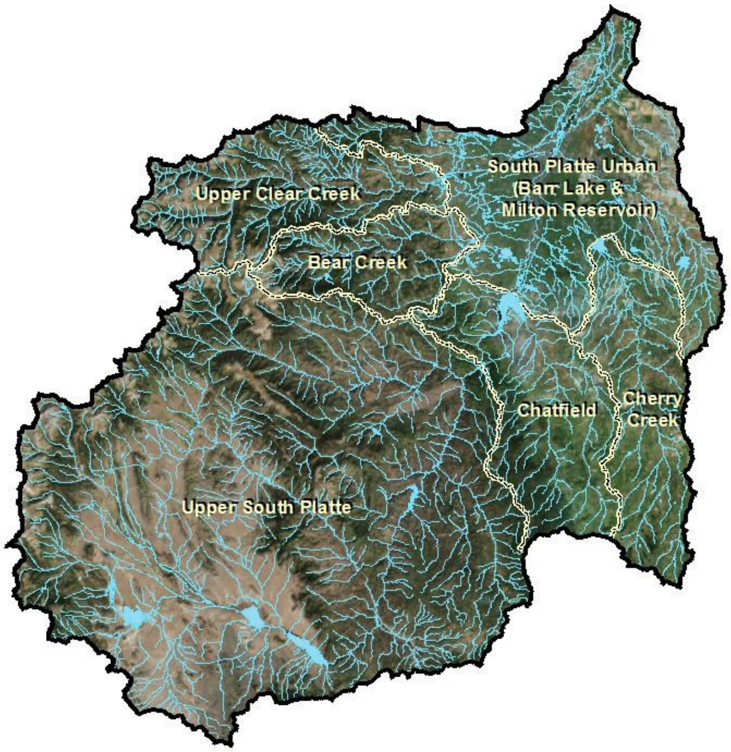


Figure C-4. Upper South Platte Basin – Bear Creek and Surrounding Watersheds

Clear Creek and Jefferson Counties bisect the watershed into the less-developed western region and the more developed eastern-region. A smaller southwest portion of the watershed lies in Park County in mostly public lands, so this county is not actively involved in BCWA activities or funding (Figure C-5).

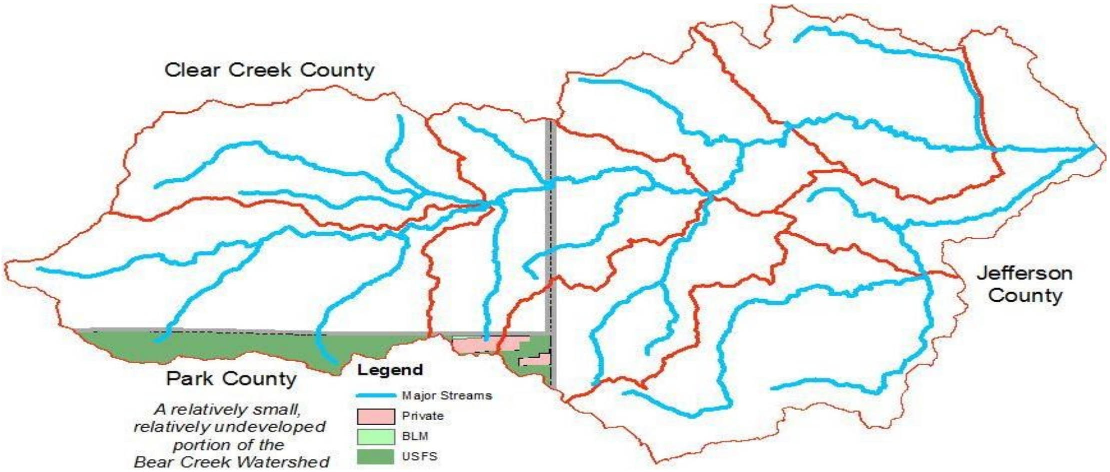


Figure C-5. Limited Impact of Park County Lack of Data and Participation for SW Headwaters

C-2 Bear Creek Reservoir

BCR was authorized for construction in 1968 as part of the USACE Tri-Lakes projects to protect Denver communities after an extreme flood event in 1965. As shown in an excerpt from a historic map in Figure C-6, no lake existed at the location prior to BCR development, though gravel mining had occurred in the area. Designated benefits were for 92.2 percent flood control and 7.8 percent for recreation and fish and wildlife enhancement. In 1982, a 50-year lease granted the City of Lakewood responsibility for developing and managing BCLP recreational facilities (Figure C-6). BCLP receives about 400,000 average visitations annually. (USACE 2012)

Figure C-6. Map of City of Lakewood BCLP Boundary (black), USACE Lands (yellow), and Easements (red) (USACE 2012)

From a historical water rights perspective, Ward and Harriman diversion ditches already withdrew water from Bear Creek for irrigation and water supply purposes since the 1880's (Figure C-7). Diversions for irrigation and water supply can dewater both tributaries in drought years. However, diversion effects on water quality were not a USACE development concern in project planning (USACE 1980).

The USACE BCR Master Plan update states that because the existing water quality is a result of factors unrelated to management actions on USACE project lands, they are not responsible for being a party to BCR 303(d) listing corrective actions (USACE 2012). The report noted that the only USACE responsibility to the Clean Water Act is Section 404 permitting of dredge or fill materials in water bodies or wetlands (USACE 2012).

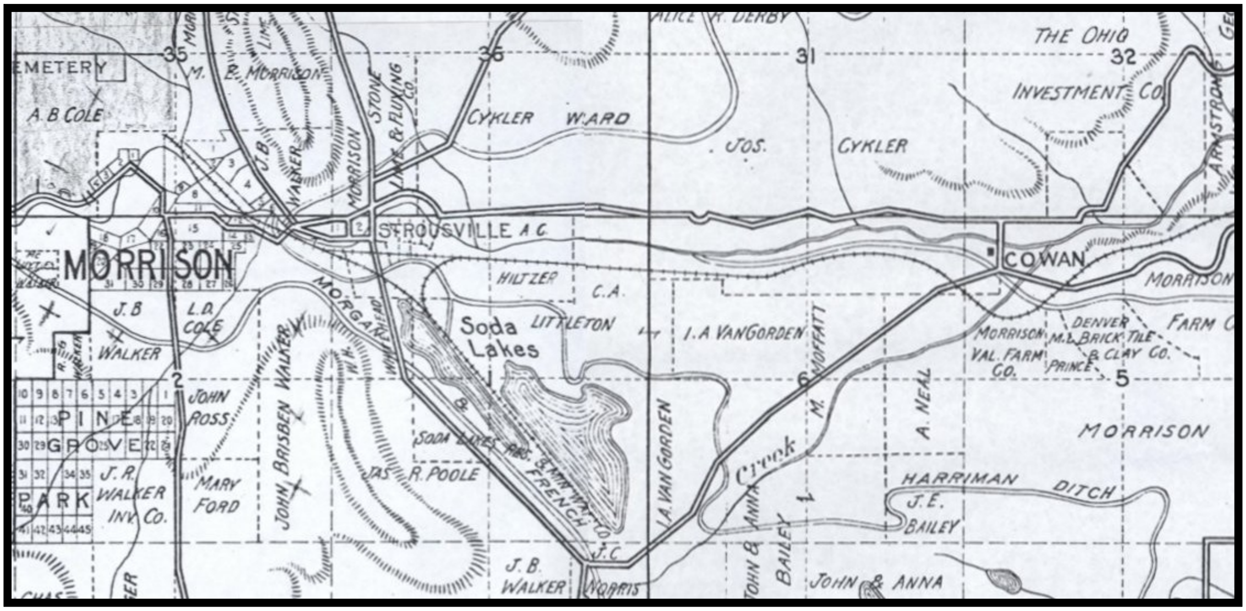


Figure C-7. Historic Map of Bear Creek Lake Park Area
(provided by area resident, source unknown)

USACE involvement in flood risk reduction upstream of BCR would be based on flood damages. Since BCR has not flooded often and floods have been of relatively small magnitude with limited damages, USACE economists would not likely choose to invest in upstream mitigation projects (personal communication with USACE Flood Risk and Floodplain management section, 1/27/14). USACE does provide noxious weed management funding for in-project weed control conducted by the City of Lakewood. It also attempts to maintain a well-seeded dam face to prevent erosion and sediment issues.

Per Figure C-8, the ungated drop inlet permits BCR to be operated as a *run of the river* dam to preserve water rights, maintaining an almost constant permanent pool elevation of 5558 ft MSL. Floodwaters are typically drawn down in a matter of days or weeks to preserve flood pool capacity. Although there is a lower gate to allow for hypolimnetic withdrawal of high nutrient concentrations to improve water quality, there is no record that it has ever been used for this purpose. Although park facilities, including public latrines, lie below the flood control pool of 5635.5 ft. MSL, temporary inundation is expected to cause only minimal damage or water quality concerns.

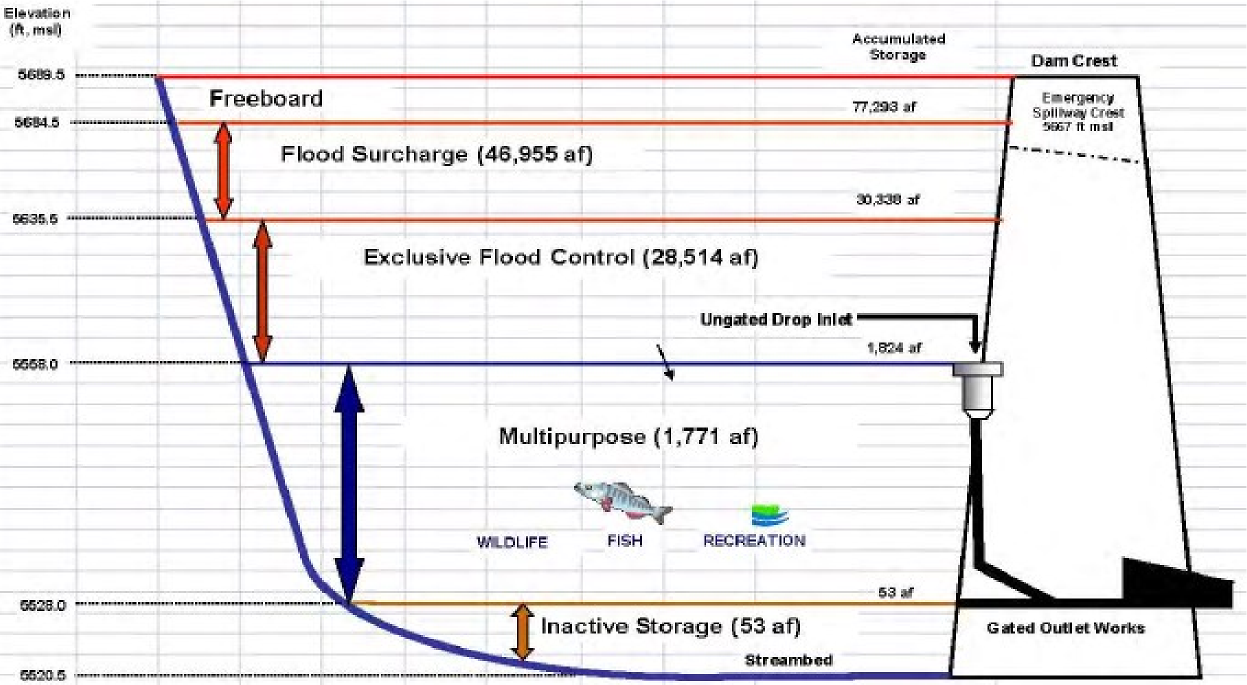


Figure C-8. Bear Creek Reservoir Schematic (Source: USACE 2012)

C-3 Nutrient Management

In 1990, a BCR Clean Lakes Study was conducted by the Denver Regional Council of Governments (DrCog) through an EPA CWA Section 208 regional grant (DrCOG et al. 1990). It was the first comprehensive assessment of BCR since the dam closed in late 1977. The study found BCR to be on the threshold of hypereutrophic trophic status with impaired use. At the time, DrCOG served as the local water quality management agency for the CDPHE WQCD. Later, each watershed developed its own council of county, city, and district point dischargers to manage a site-specific nutrient control regulation for each reservoir terminus. BCWA was originally called the *Jefferson County Mountain Water Quality Association*, but its name was changed to BCWA soon after the 1990 DrCOG study led to its restructuring. In 1993, under the same grant source, DrCog developed a Metro Vision 2020 Clean Water Plan to protect and maintain water quality using IWRM principles to control area wide waste treatment.

BCWA is a watershed-level organization authorized to protect water quality, particularly in controlling eutrophication in the watershed terminus BCR under CO State Control Regulation 74 (“Reg. 74”, WQCC 2005). BCWA membership is comprised of all sixteen wastewater point dischargers in Bear Creek Watershed (see list in Appendix A, Exhibit 1). Point dischargers are regulated under the National Pollution Discharge Elimination System (NPDES). Cities and counties are also members as EPA- designated Municipal

Separate Storm Sewer Systems (MS4s) that discharge polluted stormwater. All BCWA members pay a proportional due each year based on annual wastewater flow estimates. Table C-1 lists the TP wasteload allocation that each discharger is allowed to discharge annually per their NPDES state discharge permit. Exceedances are fined.

Table C-1. WQCC 2005 Reg. 74 Control Regulation Annual Wasteload Allocations per Discharger

Wastewater Treatment Facility	Pounds per year
Evergreen Metropolitan District	1,500
West Jefferson County Metro District	1,500
Genesee Water and Sanitation District	1,015
Town of Morrison	600
Kittredge Sanitation and Water District	240
Forest Hills Metropolitan District	80
Jefferson County Schools - Conifer High School	110
Conifer Center Sanitation Association	40
West/Brandt Foundation - Singing River Ranch	30
Aspen Park Metropolitan District	40[1]
Conifer Metropolitan District	40[1]
The Fort	18[1, 2]
Brook Forest Inn	5
Bear Creek Development Corp. - Tiny Town	5
Jefferson County Schools – Mount Evans Outdoor Lab School	20
Davidson Lodge	5
Geneva Glen Camp	5
Reserve Pool	2
Total Wastewater Treatment Facility Phosphorus Wasteload (lbs. per	5,255

Voting on board issues is proportional to dues paid. BCWA participants include public land managers, federal and state regulatory agencies, public interest groups, the Army Corps of Engineers, and the regional water supply authority, Denver Water (Appendix A, Exhibit 1). Denver Water is the only participant that also pays a small membership fee, because they affect water quality through significant stream withdrawals from both tributaries west of C-470 before they enter BCLP, and because upstream water quality affects their source water supply to their Marston Reservoir Water Treatment Facility.

At first, monitoring focused on BCR itself. The state WQCD had designated the reservoir 303(d) list impaired for Coldwater Aquatic Life because of elevated Chl-a and TP levels. TP, Secchi transparency, and chl-a levels are collected monthly in the reservoir and bimonthly during the July through September *growing season*. In order to focus on the Reg. 74 goal of moving the trophic status closer to mesotrophic from eutrophic, the Carlson Trophic State Index (TSI) is employed to gauge progress. It is interesting to note in Figure C-9 that the goal of reducing TP in most years was achieved quickly between 1990 and 1996 by reducing TP from WWTF effluent discharges by around ninety percent. However, there appears to be no change in the Carlson TSI indices determined by Secchi or chl-a trends over the same period. Nitrogen inputs also remain relatively unchanged (USACE 2012).

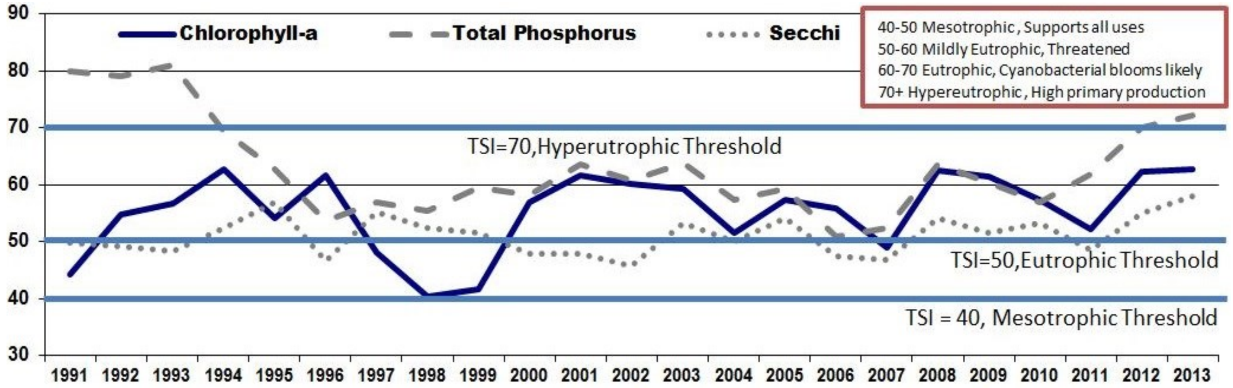


Figure C-9. Carlson Trophic State Index (TSI)
(adapted from BCWA 2013Master.xls, R. Clayshulte, 2014)

The index continues to trend between a TSI of 50 and 60 consistently, and appears to be somewhat modulated by extreme events, such as the drought of 2001-2003 and the September 2013 flood, more recently. Although BCR remains mildly eutrophic, it should be noted that over this same period urban development has increased about 50 percent (CDM 2011).

The Carlson TSI permits any of the three parameters to be used in calculating the index using Equations 1-3. By comparing the three results in case of divergence, it is sometimes possible to determine if nitrogen or light is limiting instead of TP, or if Secchi transparency is more affected by silt particles than phytoplankton biomass.

$$\boldsymbol{TSI\ (SD) = 10(6 - \frac{\ln SD}{\ln 2})}$$

Equation C-1. Carlson TSI based on Secchi Depth (m)

$$\boldsymbol{TSI\ (Chl) = 10(6 - \frac{2.04 - 0.68 \ln Chl}{\ln 2})}$$

Equation C-2. Carlson TSI based on Chlorophyll-a (μg/L)

$$\boldsymbol{TSI\ (TP) = 10(6 - \frac{\ln 48/TP}{\ln 2})}$$

Equation C-3. Carlson TSI based on Total Phosphorus (μg/L)

It is important to note that TSI is not a linear relationship, but that each 10 units of TSI indicate about an order of magnitude difference in the underlying parameters. Therefore, one would expect that a water body should remain within a fixed trophic range unless it receives a significant shock, allowing it to transform to another stable trophic state.

Carlson recommended switching the parameter used if measured throughout the year to chl-a in the summer and TP the rest of the year. He also emphasized that the Carlson TSI should not be equated with a water quality index, since water quality is contingent on the use of the water and the attitude of the local population concerning that particular water body (Carlson 1977).

C-4 Harmful Algae Blooms (HABs)

In 2013, as in other years, harmful algae bloom thresholds were over 200,000 cells/mL Microcytis aeruginosa in the late summer (August-September period). The World Health Organization (WHO) considers counts above 100,000 cells/mL to represent a moderate probability of adverse health effects from ingestion, skin and stomach irritation, and potential for long-term illness related to some cyanobacterial species (WHO 2003). Counts above 10,000 cyanobacterial cells/mL of water begin to effect clarity (Backer 2002), so BCWA clarity has been adversely affected as shown by the eutrophic TSI (SD) and the correlated TSI (chl-a) relates to the high cell count. BCR is not a direct water supply reservoir and swimming is not permitted, so anglers handling fish or fish contaminated with cyanobacteria toxins might be the most likely pathways to irritation or infection. However, there are no reported cases of HAB related effects on humans at BCR. One year some species of near shore animals might have been killed by an unknown agent, though pesticide or another source may have also been the cause (BCWA and BCLP staff reports of the one time incident happening some years prior). Although there are no reported cases, canines whom accompany their owners on BCR visits are more likely to swim or drink the water, so such high levels might put pets at risk of sickness or even death (Backer et al. 2013). Visitors, especially boaters, might also not realize that if they experience respiratory symptoms following their visit to BCR, they may have been exposed to cyanobacteria in both the spray and aerosol (Backer 2008).

C-5 Regulatory Framework

Water quality must be understood in the context of federal, state, and local laws, regulations, and policies. Federal nutrient management regulatory authority of point dischargers stems from the 1972 Clean Water Act (CWA) and its legislative and administrative policy updates through the years. County planning controls landuse, including construction erosion control permits, and environmental health departments control public health issues. Annually, BCWA develops a monitoring plan and quality assurance plan to meet EPA and state regulatory requirements for watershed monitoring. An annual report is presented to the WQCC for approval to meet Reg. 74 requirements.

In order to manage water quality, watershed associations are responsible for complying with each federal, state, and local regulation. It is more effective if managers fully understand the Basis and Purpose of each rule, as provided in the *Statement of Basis and Purpose* included in each Colorado state regulation. Compliance requires both BCWA monitoring of streams and reservoirs throughout the watershed, as well as, review of county construction permits and water rights acquisitions. Each nutrient control project must be assessed for benefits and each water quality exceedance must be investigated.

BCWA maintains a water quality monitoring network watershed-wide, which includes temperature, pH, total suspended sediments (TSS), BCR sediment samples for TP, BCR Secchi depth, BCR Carlson Season Trophic Status Index, specific conductance (SC), e.coli at select locations, flow estimates for ungauged segments, DO, TP, TN, nitrate/nitrite as N, ammonia N, fish counts, periphyton coverage, stream water clarity, and recreational use. USACE measures BCR reservoir levels and back calculates BCR inflows. Proportional Turkey and Bear Creek contributions are not always know because Turkey Creek is ungauged and both tributaries are heavily diverted, leaving little to measure during late summer low flows. Colorado Dept. of Parks and Wildlife (CDPW) collects annual fishery data for brown and rainbow trout at seven stream stations and brook trout at one stream station since 1988. Evergreen Trout Unlimited (ETU) gauges temperature at four additional stations. To date, this data has been stored in individual spreadsheets and report documents, so part of the challenge of this project included migrating all thirty years of data to a database and associating data by site to location information in the GIS.

C-6 Nutrient Regulations

Section 303(d) of the U.S. Clean Water Act of 1977 (CWA) requires that Total Maximum Daily Loads (TMDLs) are developed for each water body that cannot meet water quality standards. Since BCR cannot consistently meet the standards set for chl-a of 10 ug/L and TP of 32 ug/L, it should have developed TMDLs decades ago that included nonpoint source (NPS) quantification. Other reservoirs for which Clean Lake Studies were completed under Section 208 of the CWA during the same period already have developed TMDLs, including Dillon, Cherry Creek, and Chatfield reservoirs. How BCR escaped the requirement for so long is not understood, except if the thought was to continue to place all reduction requirements on WWTFs despite their relatively lower proportional load while ignoring NPS indefinitely. As discussed throughout the in Appendix D, this is not an option, because further WWTF reductions are not capable in themselves of reaching BCR TP and chl-a standards consistently.

In addition to Reg. 74, nutrients in Colorado are also subject to the following other CDPHE WQCD State Regulations (all regulations are found at: http://www.colorado.gov/cs/Satellite/CDPHE-Main/CBON/1251595703337).

Regulation 31: The Basic Standards and Methodologies for Surface Water describe how Reg. 38 standards are designed and updated to improve the quality of state surface waters. It also describes how site-specific narrative standards and individual discharger variances are permitted. It includes an anti-degradation rule and review process to ensure that such allowances do not further impair specific stream reaches. Section 31.17 establishes interim numerical standards for TP, total nitrogen (TN), and chl-a.

Regulation 38: South Platte Water Quality Numeric Standards and Methods determines 303(d) non-attainments based on stream classifications for aquatic life type cold or warm, recreation, water supply, and agriculture. Currently, BCR must meet maximum standards of chl-a of 10 µg/L and TP of 32 µg/L to be delisted (See Section C-3). However, EPA would like the TP standard reduced to around 21 µg/L (EPA Disapproval Letter 6/17/2011, EPA Reg. 38 Scoping Comments 9/25/13). Opposing EPA's position on the BCR TP site-specific standard, the WQCD believes uncertainty in the effects of low flows caused by water rights diversions, temperature effects of drought, residence times, and internal loading do not allow EPA TP translations methods based on stratified, cooler reservoirs to apply to BCR. They prefer to study these effects first (WQCD December 2013 Hearing Exhibit 10: Draft Bear Creek Plan).

Rather than nutrients, perhaps the most problematic listings relates to Bear Creek and BCR temperature standards for cold water fish use classifications. Both a daily maximum temperature of 23.8 °C and a maximum weekly average temperature (MWAT) of 18.2 °C typically apply April through December for most BCR tributaries and Evergreen Lake. However, the site-specific BCR MWAT is 23.3 °C because it represents a predominantly warm water fishery, although the potential effects of aeration further warming the reservoir and its more urban location do not appear to have been taken into consideration in setting this standard. The stream is over-appropriated, so diversions also leave little cooler inflow during drought periods or late summers. Streamside impermeable road surfaces and concentrated development increase the temperature of what runoff is collected during brief summer showers. Many riparian areas have been thinned or removed, so stream shading is also limited. As water residence time increases in BCR during drought, overall reservoir temperature also increases, especially since aeration is maintained throughout the growing season to support dissolved oxygen (DO) levels. WWTF often receive the most criticisms, although they cannot control these other factors. Currently, BCWA and ETU work closely to try to understand temperature patterns, although no protective temperature control measures can be easily determined or implemented.

Regulation 43: On-site wastewater treatment system regulation went into effect on 6/30/2013. Each county was responsible for developing parallel, local regulations by April 2014. New features include soil profile analysis, effluent filters, appropriate technology, sales inspections, and formal permitting.

Regulation 61: Colorado discharge permit system implements federal NPDES requirements under the CWA under which all point dischargers in the watershed must comply with Reg. 62 Effluent Limitations, applicable Reg. 63 Pretreatment requirements, and federal reporting.

Regulation 64: Biosolids Regulation applies to both septage and WWTF sludge remaining from treatment processes, as well as, to point dischargers that directly land-apply wastewater.

Regulation 65: Regulations Controlling Discharges to Storm Sewers to prevent point source pollution.

Regulation 74: Bear Creek Watershed Control Regulation (5 CCR 1002-74) sets a total annual wasteload allocation for each wastewater discharger (Table 3). Phosphorus trading is specifically permitted. The regulation is reviewed every three years, but it has not been updated since 2005. The 2017 review will set a lower TP waste load allocation for each discharger and the watershed overall.

Regulation 85: The Nutrients Management Control Regulation went into effect on 9/30/2012. It provides numeric nutrient standards for new and existing point dischargers based on daily wastewater flows. It also permits nutrient trading. MS4s are required to conduct public education and stormwater pollution control programs. NPS are to implement BMPs. Based on a cost-benefit analysis conducted at the behest of cost-affected dischargers, facilities smaller than 2 MGD were provided a ten-year delay in application of effluent nutrient limits, including a further delay for lower priority watersheds. However, starting in 2013, all dischargers must sample effluent for nutrient concentrations at least bimonthly, and monthly if over 1MGD.

Regulation 93: Water Quality Limited Segments Requiring Total Maximum Daily Loads, Colorado's Monitoring and Evaluation List, 303(d) listed impaired segments (5CCR 1002-35). See Section 4.5.

COR 090000 MS-4 Standard Permit: In addition to wastewater permits, each municipal and county stormwater discharger must maintain a state MS4 permit, requiring pollution control planning, monitoring, and annual reporting (WQCD 2012).

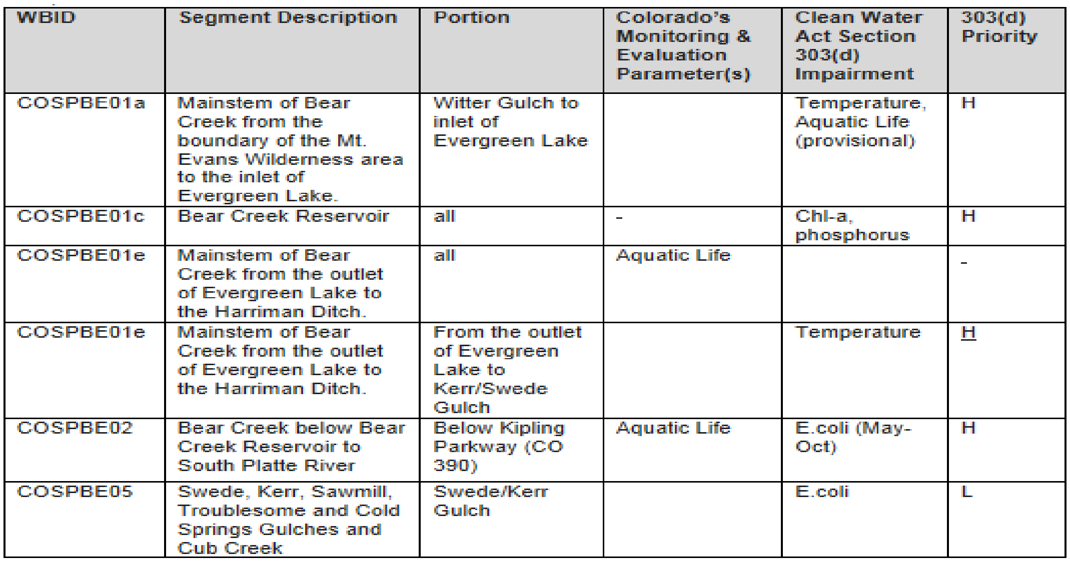
C-7 Impaired Stream Segments

In 2012, five segments in the Bear Creek Watershed were listed as EPA 303(d) listed impaired streams (See Table 4). Recently the CDPHE WQCC 2014 303(d) listing process was cancelled due to resource demands related to priority review of Section 401 Certifications to identify additional water supply projects (WQCC 2012). This places an additional monitoring burden on the BCWA, because some of the segments were only listed in 2012 after exhibiting a single exceedance. The BCWA also discovered a contaminant plume at the headwaters of Bear Creek downstream from Summit Lake, which is not shown in the table, that appears to be related to Summit Lake visitor latrine pits and vaults (BCWA Technical Memo 2012.02, 12/9/12).

Segment COSPBE02, which was listed for e-coli in Table 4, is not included in the Bear Creek Watershed, but the Barr-Milton Watershed as explained in Section 4.1. However, in 2012, a downstream entity, GroundWork Denver, received a grant from the WQCD NPS program to develop a watershed plan to address this 303(d) listing. BCWA became involved as a technical consultant and because some related sampling overlapped into the Bear Creek Watershed. Through this cooperation, it was determined that BCR was not a significant source of e-coli, though they should work further on joint stewardship.

GroundWork Denver was determined to possess useful ties to National Park Service and Denver Nature Areas grant and support programs and extensive experience in community organizing. This knowledge and experience could prove useful to BCWA as it further extends its own community outreach and seeks to develop stronger federal and City of Denver department ties. GroundWork Denver has also expressed interest in continuing a BCWA geocache sign project upstream to the downstream portion of Bear Creek to its confluence with the South Platte. This example demonstrates the strategic importance of systematically developing stronger cooperative ties between BCWA and its downstream neighbors over time.

Table C-2. Bear Creek Watershed EPA Section 303(d) Listed Impaired Segments



WBID	Segment Description	Portion	Colorado's Monitoring & Evaluation Parameter(s)	Clean Water Act Section 303(d) Impairment	303(d) Priority
COSPBE01a	Mainstem of Bear Creek from the boundary of the Mt. Evans Wilderness area to the inlet of Evergreen Lake.	Witter Gulch to inlet of Evergreen Lake		Temperature, Aquatic Life (provisional)	H
COSPBE01c	Bear Creek Reservoir	all	-	Chl-a, phosphorus	H
COSPBE01e	Mainstem of Bear Creek from the outlet of Evergreen Lake to the Harriman Ditch.	all	Aquatic Life		-
COSPBE01e	Mainstem of Bear Creek from the outlet of Evergreen Lake to the Harriman Ditch.	From the outlet of Evergreen Lake to Kerr/Swede Gulch		Temperature	H
COSPBE02	Bear Creek below Bear Creek Reservoir to South Platte River	Below Kipling Parkway (CO 390)	Aquatic Life	E.coli (May-Oct)	H
COSPBE05	Swede, Kerr, Sawmill, Troublesome and Cold Springs Gulches and Cub Creek	Swede/Kerr Gulch		E.coli	L

C-8 BCWA Policies and Technical Memos

BCWA has designed a number of policies to document its management strategies. With the increasing focus on adaptive management since the ACM DSS process was initiated, the number of BCWA policies increased from nine to 24. Now, whenever an important topic is discussed in a BCWA board or TRS meeting, the BCWA manager drafts a related policy before the next BCWA TRS meeting to discuss and improve through technical review. At the following BCWA board meeting, the policy is then formally adopted or rejected. To date, no policy has been rejected, though several have required significant improvements before approval. The policies have become an effective means to help new members understand BCWA positions and practices. BCWA policies also allow all BCWA members to discuss topics more effectively outside of BCWA with their own management boards and constituents. This encourages alignment among different entities and more focused, productive discussion on areas of disagreement. A list of BCWA policies is found in Appendix A. Exhibit 22.

Another important adaptive management tool employed by BCWA is the development of technical memos. Any time water quality monitoring exceedances occur, illicit dumping, or other problems in the watershed, BCWA carefully documents the event through pictures, data, and details in a technical memo. Three example watershed issues described in technical memos include the Summit Lake Plume, Kerr Swede e-coli listing, and the Coyote Gulch stream restoration project (Section C-11).

C-9 Monitoring

Annually, BCWA develops a Quality Assurance Plan for the monitoring program and selects sites and frequency based on known discharge points and nonpoint water quality exceedances. Staff from BCLP and EMD typically assists the BCWA manager to collect samples monthly and bi-monthly during the growing season (Figure C-10). Data is also collected from all point dischargers to calculate phosphorus waste load allocations for Reg. 74 per Section 4.3. In addition to water quality sampling, BCWA conducts routine pebble counts, macroinvertebrates surveys, and fish counts to further characterize stream health.

Both streams and on-stream reservoirs are monitored throughout the watershed. To the extent possible, each point discharge is bracketed with upstream and downstream sampling points to determine how its discharge may be directly affecting stream nutrient loading. Chl-a is measured in both BCR and Evergreen Lake, and rough estimates of periphyton cover is recorded at each stream sampling location. This helps determine both primary production and areas where nutrients may be of particular concern.

Figure C-10. Bear Creek Reservoir Monitoring at Bear Creek Reservoir

Due to the length, quality, and the comprehensive nature of the BCWA monitoring program, it has been used by the WQCD and other programs for mountain headwaters data analysis. One of the reasons BCWA was selected for this research project was also to determine if further analysis and incorporation of less traditional techniques like SNA and the ACM DSS collaborative process might expand the utility of this excellent dataset for specific nutrient management options development purposes.

C-10 BCR and Evergreen Lake Aeration Systems

In addition to clarity, HABs compete for oxygen with fish and the lower food chain of invertebrates, worms, and insects that supports fish. Therefore, BCR must be aerated from June through September to ensure that DO levels remain elevated into an acceptable range of 4-8 mg/L. Both Evergreen and BCR have installed aeration systems consisting of relatively fine bubble metal or ceramic dome diffusers. Fine bubble diffusers are more efficient in destratifying reservoirs, which is assumed to reduce anoxic conditions in bottom sediments to reduce TP releases. More importantly, though, aeration supports DO levels throughout BCR above levels that could affect fish health. The current BCR system was installed in 2002. In 2010, an aeration study was performed to reduce aeration to 40 HP to reduce costs one third (BCWA 2010 TM: BCR Aeration Log). The lower pump speed still allowed for adequate oxygen transfer because BCR is deep enough at most aeration locations to maximize oxygen transfer efficiency above 50 percent (ASI Clean Water Aeration brochure provided 10/1/2013). In the past, summer sampling had been conducted at five sites throughout the reservoir; however, because of such complete reservoir mixing from continuous aeration throughout the growing season, this was shown to be duplicative and no longer needed. The September 2013 flood displaced and damaged most of the aerators, so FEMA funds are being sought for replacement.

C-11 Coyote Gulch Restoration and Nutrient Reduction Credits

According to Reg. 74, BCWA may develop a nutrient trading program, allowing TP waste load allocation reductions beyond required levels of one discharger to offset exceedances of another. Typically, this is used by smaller, seasonal discharger with low discharge volumes for which further treatment may be excessively burdensome. With this in mind, in 2004 BCWA contributed to restoration of Coyote Gulch to reduce bank incising and sediment transport from upstream catchment areas under development. Data has been collected for over five years since completion of the project indicating the level of nutrient reduction credits that might be claimed. On January 12, 2012, BCWA adopted Total Phosphorus Trading Program Guidelines consistent with Regulation 74 for both point source-to-point source trading and nonpoint source-to-point source trading through an *Association Trade Pool*. Coyote Gulch may be used as the first opportunity to exercise the pool, if the CDPHE WQCD approves. See Appendix D, Exhibit D-2 for more discussion on trade execution opportunities and benefits.

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APPENDIX D. ISSUES ANALYSIS

EXHIBIT D-1: WASTEWATER EFFLUENT DISCHARGES ANALYSIS SHEET

Bear Creek Watershed Issues Analysis

Nutrient Issue: *Water Reclamation Facilities TP Contributions*

Analyst: MT Herzog
Date: August 1, 2014

Description: Wastewater dischargers in the Bear Creek Watershed must meet phosphorus wasteload allocations (WLAs) per WQCC Control Reg 74 (2005). Currently, water reclamation facilities (WRFs) in the watershed average a P contribution of less than 20 percent of their original WLAs. For decades, this has been the only focus of TP reduction in the watershed, although stormwater runoff from developed areas, streamside roads and unpaved private drives, and streambank erosion each produce more TP. OWTS are estimated to produce more TP, since almost as many residents in the watershed use OWTS as WRFs sewer service, but OWTS are not designed to reduce TP. WRFs remove TP and also provide return flows to streams after recycling most of the water withdrawn. Studies indicate that reducing TP discharges below current levels averaging 0.2 mg/L can cost up to $1000 per pound reduction (Jiang et al. 2005). Further TP reductions in wastewater effluent without additional watershed-wide nonpoint source controls typically could not provide sufficient long term water quality benefits to downstream water bodies to justify costs (Son 2013).

Data Sources

- EPA ECHO search
- EPA DMR P Loading Tool
- DWR Water R. Diversions
- CDPHE WQCD Regs
- BCWA Water Quality

Significance of Current TP Contributions: TP contributions from WRFs have been incorrectly calculated, without taking into account that all WRFs on Bear Creek are replacing most of the water they previously withdrew for water supply just upstream of their communities, which was not phosphate-free. The treated effluent is discharged just below the same community, so the TP pound contribution should be understood as only the difference between the pounds removed and the pounds returned. As WRFs continue to optimize their operations, this difference can become negligible. For example, since a 2013 WRF overhaul, the Town of Morrison may be returning treated effluent containing no more TP on average than found in the streamflow, which they extract for water supply. Their effluent has the added advantage of being discharged downstream of Harriman, Ward, and Warrior water rights diversions, which are permitted to completely dewater Bear Creek during periods of summer low flows and extended droughts. This demonstrates the importance of WRFs in maintaining stream and riparian health. Morrison WRF returns may also decrease periods of stagnation caused by extended water residence times in BCR, which increase temperature and phytoplankton production when enough flushing inflows do not flow through BCR. Morrison WRF consults directly with the Colorado School of Mines on an ongoing basis to continue to optimize its Enhanced Biological Phosphorus Removal (EBPR) process for further TP reductions over time.

Map: WRFs on Bear Creek return treated effluent to replace water withdrawn for water supply.

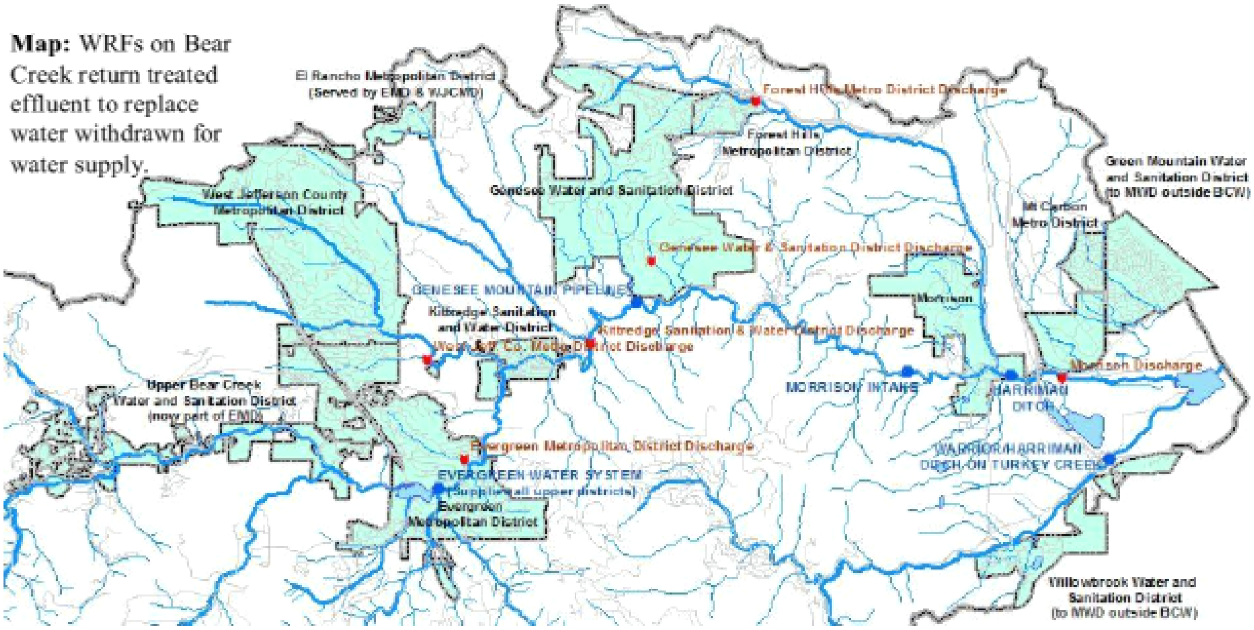
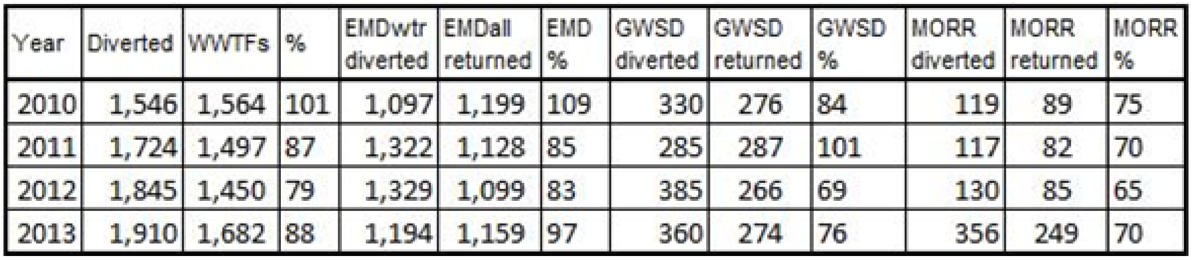
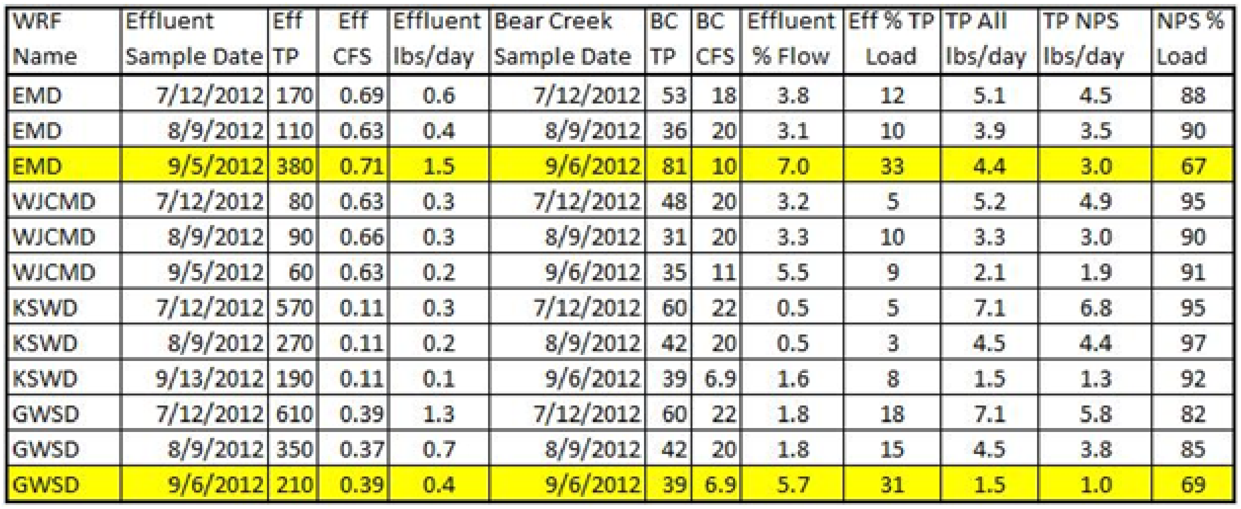


Table 1: Districts that withdraw water from Bear Creek for water supply return most as treated wastewater effluent. This is based on rough diversion records, and districts may further augment returns to limit withdrawals; some customers are on sewer but not water service, which further increases returns compared to withdrawals.



Year	Diverted	WWTFs	%	EMDwtr diverted	EMDall returned	EMD %	GWSD diverted	GWSD returned	GWSD %	MORR diverted	MORR returned	MORR %
2010	1,546	1,564	101	1,097	1,199	109	330	276	84	119	89	75
2011	1,724	1,497	87	1,322	1,128	85	285	287	101	117	82	70
2012	1,845	1,450	79	1,329	1,099	83	385	266	69	130	85	65
2013	1,910	1,682	88	1,194	1,159	97	360	274	76	356	249	70

Table 2: During drought and late summer when flow in Bear Creek reach a minimum, discharges from WRFs becom a substantial portion of the TP load, because instream TP may be 30-60 µg/L while effluent TP levels may range fror 60 to 600 µg/L. Even though flows from WRFs never reach more than about fiver percent of stream flow upstream o Harriman Ditch, they may represent up to 30 percent of the TP in extremely dry periods through higher TP concentrations in the effluent. If you consider that the average TP entering BCR is roughly 43 µg/L and treated effluent contains about 60-600 µg/L TP, effluent can increase TP during low flows in discharge reaches up to 10 percent or more, but that is not enough to change the character of the reservoir on its own. Other contributing source nutrient cycling, and reservoir sediments add a greater percentage.



WRF Name	Effluent Sample Date	Eff TP	Eff CFS	Effluent lbs/day	Bear Creek Sample Date	BC TP	BC CFS	Effluent % Flow	Eff % TP Load	TP All lbs/day	TP NPS lbs/day	NPS % Load
EMD	7/12/2012	170	0.69	0.6	7/12/2012	53	18	3.8	12	5.1	4.5	88
EMD	8/9/2012	110	0.63	0.4	8/9/2012	36	20	3.1	10	3.9	3.5	90
EMD	9/5/2012	380	0.71	1.5	9/6/2012	81	10	7.0	33	4.4	3.0	67
WJCMD	7/12/2012	80	0.63	0.3	7/12/2012	48	20	3.2	5	5.2	4.9	95
WJCMD	8/9/2012	90	0.66	0.3	8/9/2012	31	20	3.3	10	3.3	3.0	90
WJCMD	9/5/2012	60	0.63	0.2	9/6/2012	35	11	5.5	9	2.1	1.9	91
KSWD	7/12/2012	570	0.11	0.3	7/12/2012	60	22	0.5	5	7.1	6.8	95
KSWD	8/9/2012	270	0.11	0.2	8/9/2012	42	20	0.5	3	4.5	4.4	97
KSWD	9/13/2012	190	0.11	0.1	9/6/2012	39	6.9	1.6	8	1.5	1.3	92
GWSD	7/12/2012	610	0.39	1.3	7/12/2012	60	22	1.8	18	7.1	5.8	82
GWSD	8/9/2012	350	0.37	0.7	8/9/2012	42	20	1.8	15	4.5	3.8	85
GWSD	9/6/2012	210	0.39	0.4	9/6/2012	39	6.9	5.7	31	1.5	1.0	69

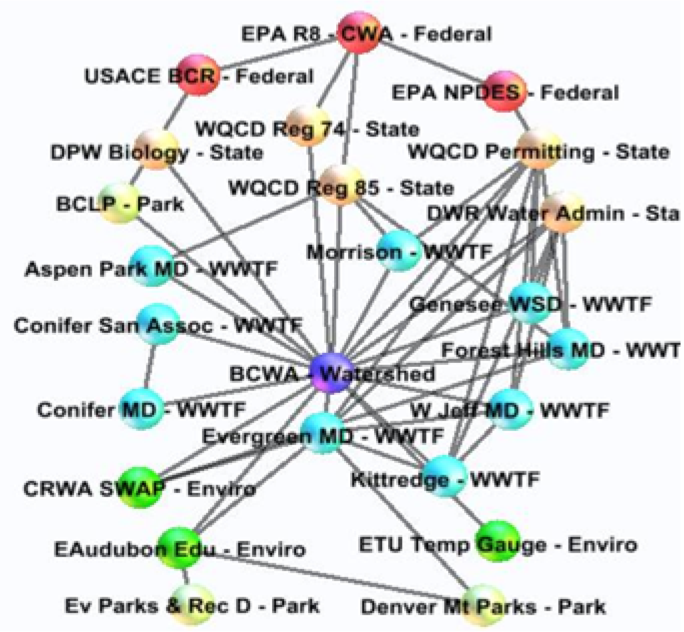
ASSUMPTIONS

1. Effluent is not lost in transit between the effluent discharge point and the downstream station
2. No cumulative downstream impacts for point discharges collectively has yet been determined
3. There is no nutrient retention or release from river-bed sediments
4. Loads from WRFs spot samples and stream flow samples are representative of average daily flows and discharges
5. There is no nutrient attenuation by periphyton within Bear Creek or other vegetative or geochemical processes
6. Natural variation in nutrient loads with stream flow and catchment rainfall has not been considered.

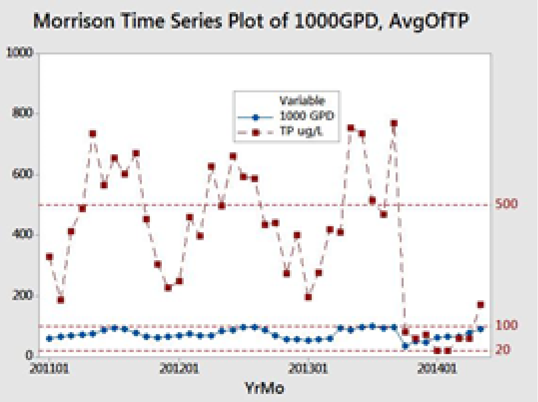
SNA Diagram 1: Sociogram of WWTFs (most are WRFs which replace stream flow used). EPA Clean Water Act (1977) led to state Reg 74 for BCR TP reduction and Reg 85 to reduce both TP and TN. EPA National Pollution Discharge Elimination Program (NPDES) led to State Permitting, which requires DMR monitoring and reporting.

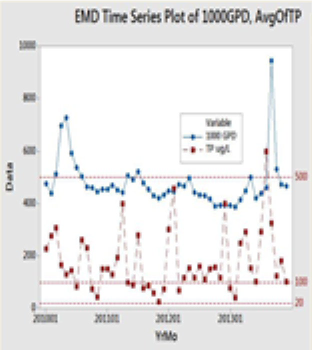
Potential Options: WRFs tend to upgrade facilities regularly on a maintenance schedule to reduce energy and chemical costs, as well as, enhance treatment performance. BCWA serves as a forum to exchange BMPs.

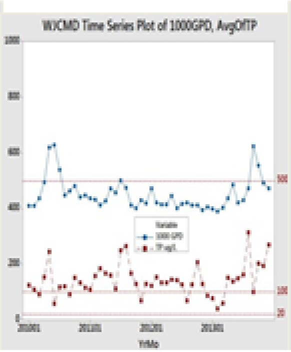
Further Reduce TP discharges during extremely low flows: By using additional chemicals to increase phosphates precipitation or other measures, WRFs should attempt to further decrease TP discharges during periods of drought.

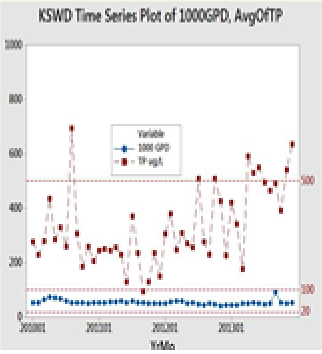


Dilute Flows During Drought through Conjunctive Use: BCLP is located where fractured bedrock mountain aquifers meet the alluvial Denver aquifers in the eastern high plains. Groundwater tends to mound here in particular, so even if other areas of the Denver Aquifers are overused, BCLP is underutilized with few high capacity wells in the area. Conjunctive use modeling may help demonstrate that water rights administration and legislation could be altered to allow water to be pumped into Bear Creek in the park just below major Turkey and Bear Creek withdrawals out of basin to prevent BCR and downstream reservoirs from stagnating, while better supplying more downstream diverters and riparian needs in times of drought. A pipeline has already been installed by DWR to supply water to downstream states from the Republican River, so this would not be without precedent. Only this time, the effort would directly serve water quality, downstream urban Denver and other area floodplain parks, wildlife and vegetation, and many more South Platte appropriators.









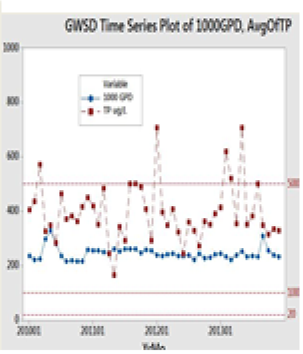


EXHIBIT D-2: SMALL WASTEWATER EFFLUENT DISCHARGES ANALYSIS SHEET

Bear Creek Watershed Issues Analysis
Nutrient Issue: *Small Dischargers Have Difficulty Meeting TP Standards*

Analyst: MT Herzog
Date: August 1, 2014

Description: Small dischargers must maintain an EPA NPDES discharge permit if they discharge more than 2,000 gpd or directly discharge to a stream. The typical "package plant" used in these applications was not designed in the past decade to meet low TP discharges now required to remain below 1 mg/L consistently. Currently, there is one restaurant, a hotel, three camps, three shopping malls, and schools that are permitted.

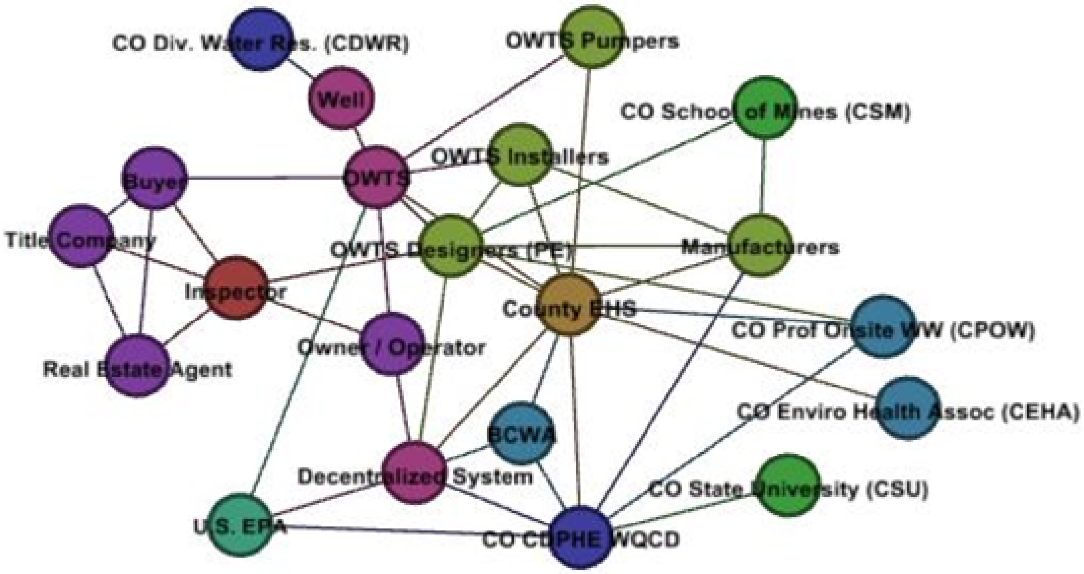
Decentralized Systems are not Developed: Since maintaining an NPDES permit at the state level requires more costly monitoring and reporting, developers do not choose to developed decentralized systems even if they would provide economies of scale and better protect groundwater and surface water that individual OWTS for each unit.
In other states, like Georgia, central planning is required based on certain criteria to prevent exurban areas from choosing OWTS over a single, decentralized system. Counties should be encouraged to address this issue and grants should be sought to pilot decentralized systems advantages.

Data Sources
- EPA ECHO search
- EPA DMR P Loading Tool
- CPOW training
- JVA design engineer
- Insight Engineering design
- Treatment Tech maintenance
- Policy 19. P Trading Eligibility
- Policy 26. P2P Trade Admin

Map 1: Location of Small Dischargers and WWTFs in the Bear Creek Watershed from BCWA Map Series-18, RNC

P Trading: In the past, BCWA members were involved in several point-to-point source phosphorus trades. Forest Hills Metro District traded with West Jefferson County Metro District to meet its annual waste load allocation and its maximum TP concentration limit of 1.0 mg/L. JCPS also traded with itself, providing waste load allocations from Conifer High School – which remained consistently below its annual waste load allocation limit – with its Mount Evans Outdoor Lab School – that could not meet its waste load allocation limit. BCWA and several members and external partners completed the Coyote Gulch stream restoration project discussed in Section 4.5.3, and demonstrated nutrient reductions through five years of monitoring.

SNA Diagram 1: Sociogram of Small Dischargers (Decentralized Systems) is essentially composed of similar organizations as for OWTS, except that the engineering firms, installers, and service providers are somewhat larger and focus a branch of their company in this specific niche or also in WWTFs, whereas OWTS providers usually only provide services for individual OWTS.



P Trading (continued): However, BCWA has not yet been able to exercise 2:1 trades against this project because it must first be formally added to the trade pool in Reg. 74. Reg. 74 has not been updated since 2005, though it was supposed to be updated every three years. Such regulatory uncertainty can produce watershed management challenges, such as, if BCWA had depended on trading for partial project cost recovery. In 2014, BCWA began developing innovative new nutrient trading policies to allow small dischargers to more easily use TP trading to meet new Reg. 85 TP effluent concentration exceedances. However, there is some concern that implementation of a competing trading program in Reg. 85 in future years may require further evidence that each trade produces a watershed benefit. This would be difficult, since the actual TP waste load being traded is extremely small and not at the same location as the offsetting reduction in point or nonpoint nutrient sources. Since EPA launched a Water Quality Trading Policy in 2003 (EPA 2003b), nutrient trading has become popular nationwide. Among several benefits, trading accelerates funding and incentives for watershed restoration projects. It fosters expanded partnerships and community cooperation that builds general resilience over time (Section 2.1.3). Trading provides flexibility for the scenarios discussed in which alternative options for small dischargers might not be developed in time or within cost constraints to reach regulatory compliance. Nutrient trading could also shift the burden of expensive WWTF upgrades to much more cost-effective non-point source control alternatives. For example, a large stable or group of horse properties might receive NRCS funding from their local conservation district, JCD, to reduce horse manure and pasture erosion, offsetting direct costs. The nutrient reductions could be traded 2:1 upstream to a WWTF to prevent it from having to reduce discharges below a current feasible range of perhaps 0.2 mg/L TP, as regulations become stricter in the next decade. In this way, economic benefits to the community are optimized by shifting nutrient control to the least cost alternative. It also incentivizes NPS control that would otherwise be difficult to enforce, even if it were most cost effective, because it requires changes in practices and investments of private landowners. In some cases, trading may even encourage entrepreneurs to build a wetlands or water rights holders to lease water rights, if the profit from nutrient trading offsets their costs. By highlighting their efforts, trading programs also encourage business participation for perceived public support. If BCWA set a high enough price on trade pool credits created by restoration projects like Coyote Gulch to gain a profit above the high cost of multi-year project monitoring, maintenance, and assessment and administrative costs, it could use nutrient trading proceeds to increase restoration throughout the watershed. Even though trading includes the transaction costs discussed, it can still provide a net benefit to both parties. Another important reason for BCWA to trade is that trade fees can provide a stable cash flow for multiple years that can be used in more forward-looking restoration and program planning.

EXHIBIT D-3: ONSITE WASTEWATER TREATMENT SYSTEMS (OWTS) ANALYSIS SHEET

Bear Creek Watershed Issues Analysis

Nutrient Issue: *Onsite Wastewater Systems TP Contribution Uncertain*

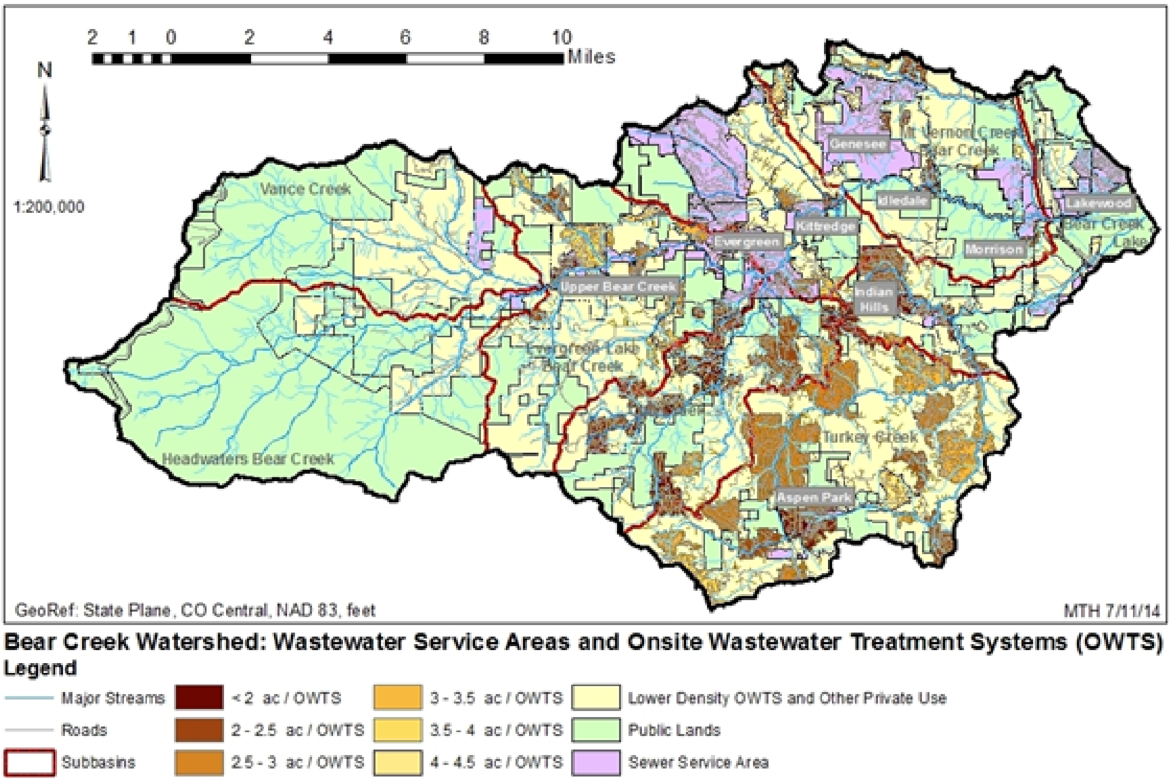
Analyst: MT Herzog
Date: August 14, 2014

Data Sources
- CPOW Statewide Association
- New! WQCC Regulation 43
- New! CCC OWTS Regulations
- New! Jeffco OWTS Regulations

Description: Onsite wastewater treatment systems (OWTS, a.k.a septic systems and individual sewage disposal systems (ISDS)) consist of a tank for settling solids and a soil treatment area (SAT) through which to percolate liquid waste. A biomat typically develops under the SAT which reduces harmful bacteria and phosphorus before it reaches the groundwater when an OWTS is operating as designed under optimal circumstances. However, soils and geology in mountain areas are not necessarily conducive to optimal performance and some systems are decades old, so the design may not meet current standards.

New State and County Regulations in 2013: In 2013, the state WQCC passed new regulations governing OWTS. Counties were required to adopt new standards based on minimum permissible criteria by mid-2014. Many counties, including those in the Bear Creek Watershed, chose to require point-of-sale inspections, so that over time more OWTS failing or in need or repair could be discovered and corrected to reduce water quality effects.

Figure 1: Approximate Locations of Areas of More Closely Spaced OWTS (primarily in the southern, drier portion)



Bear Creek Watershed: Wastewater Service Areas and Onsite Wastewater Treatment Systems (OWTS)

Notes

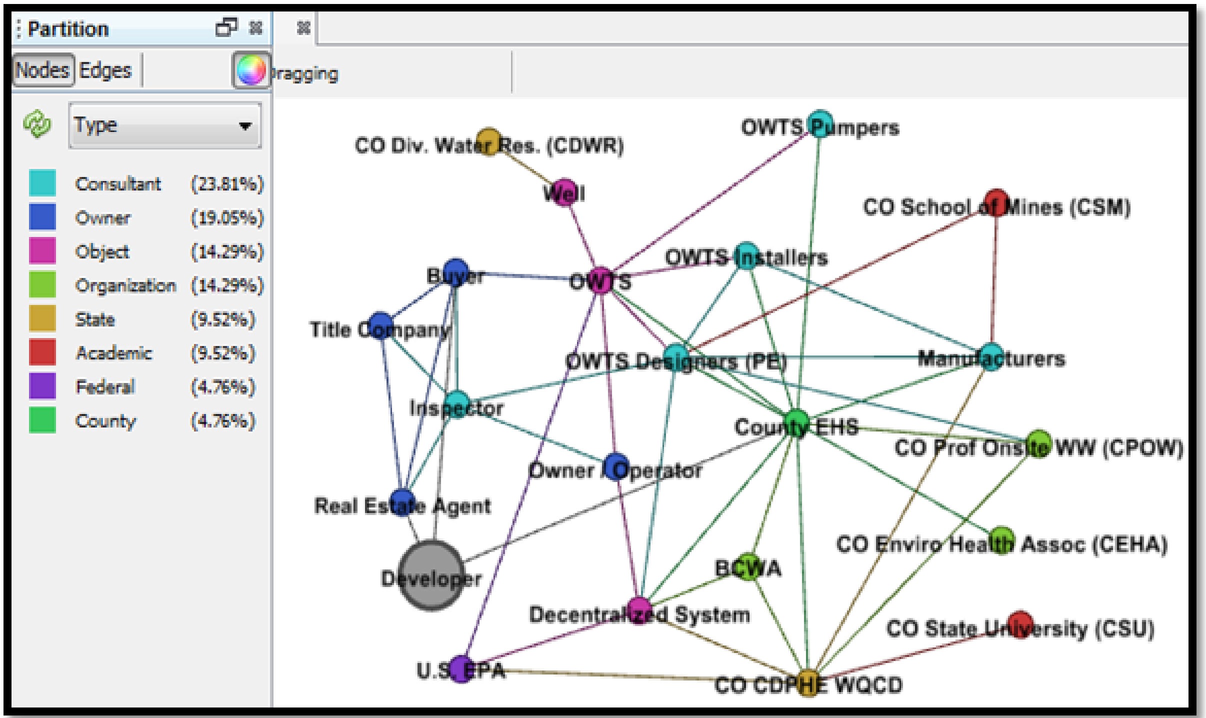
OWTS were approximately located by built parcel (Jeffco) or building location (Clear Creek County) using county provided data.
Higher density OWTS areas shown were typically less than 500 feet apart. Wastewater service providers verified approximate service area extents, which may include small areas of OWTS. Public lands shown may include OWTS or latrines in recreational areas for public use.

Owner Education: From CPOW conferences and NAWT inspector training, it was revealed that many failing systems are caused by neglect and misuse. Some residents do not even know they own an OWTS, unless it fails. Common issues involve doing multiple loads of laundry or taking multiple showers or running a day care that cause inflows to exceed the capacity of the septic tanks and SAT to receive the load. Garbage disposals and other sources of unprocessed foods are particular difficult for anaerobic processes in the septic tank to break down, leading to more rapid filling. Older water softeners have a tendency to continuously cycle, adding additional unplanned loads.

Residents undergoing chemotherapy or on long-term antibiotic treatment can also affect septic tank performance. Unless designers, installers, and cleaners post information and discuss operation with residential owners / operators, many of these common issues will not be corrected, so more OWTS will continue to fail in spite of proper design.

SNA: OWTS Regulatory, Installation, and Service Framework

Developers, real estate agents and title companies often drive new installation practices, so educating them about BMPs and long-term community advantages of decentralized systems is important.



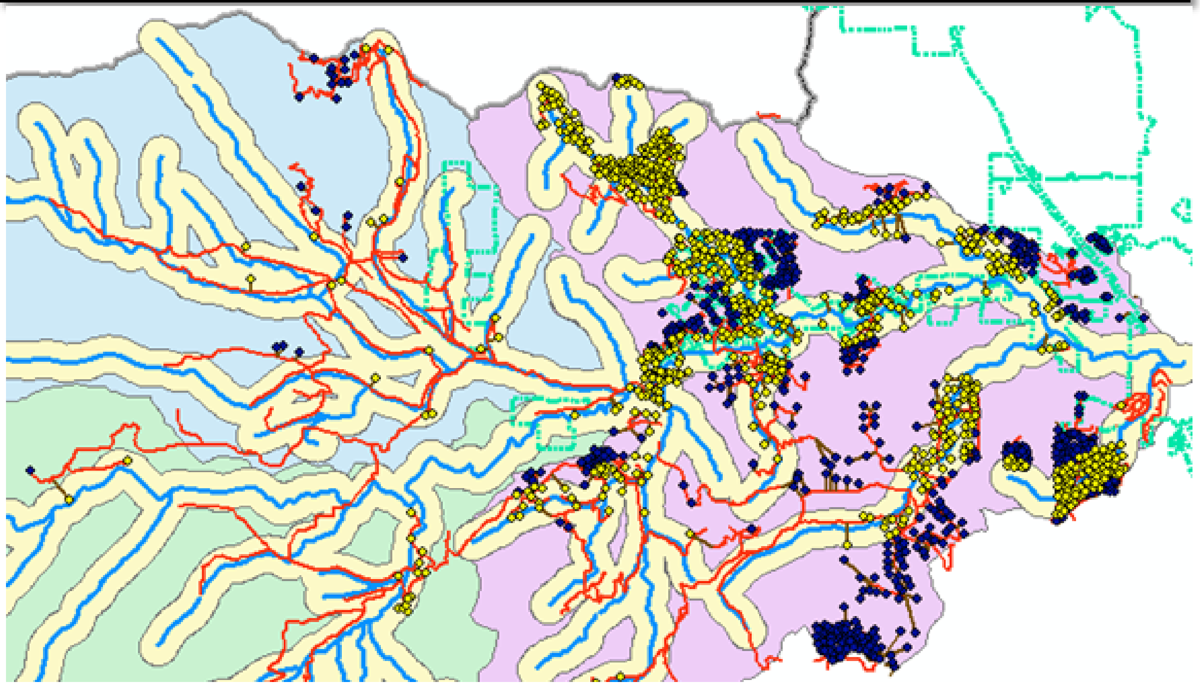


Figure 2. Rough Locations of OWTS above EMD Intake of Source Water Protection Concern
(yellow points approximate OWTS locations are within 1000-ft stream buffer of higher priority)

EXHIBIT D-4: HORSE PROPERTIES AND OTHER LARGE ANIMALS ANALYSIS SHEET

Bear Creek Watershed Issues Analysis
Nutrient Issue: *Denuded Horse Properties and Related Manure Issues*

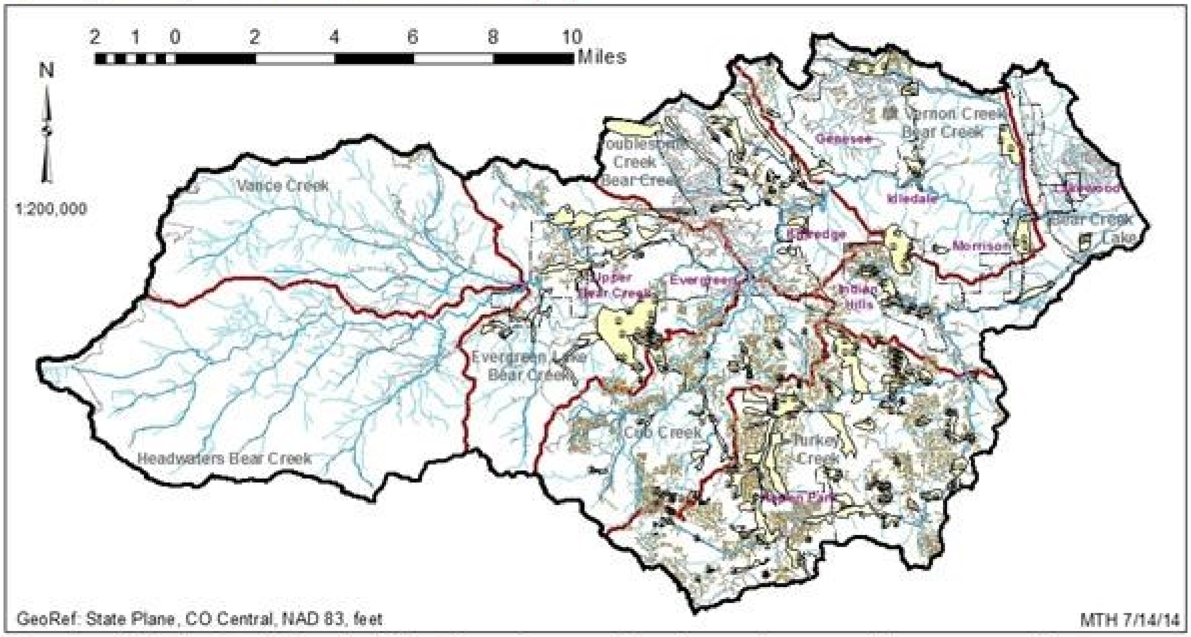
Analyst: MT Herzog
Date: August 19, 2014

Description: From 2012 county aerial maps, more than 230 horse properties were located throughout the Bear Creek Watershed. In addition to fencing, stables, and horse tracks, it was often easy to delineate horse areas because they tended to be completely denuded of vegetation through horse grazing and compaction. In a similar way to OWTS, horse properties near tributary streams, particularly adjacent to perennial streams, are of concern. Horse pastures tended not to include good buffering adjacent to streams leading to more nutrients from streambank erosion and less nutrient, manure, and particulate filtering from adjacent lands. Grasslands produce several times higher runoff and nutrient loads than forested lands, and denuded, exposed soils are much worse. There have also been reports that heavy elk activity in certain areas may produced localized nutrient issues that may be addressed by hazing and or fencing. Excessive Canadian geese flocks could also lead to potential reservoir TP enrichment.

Data Sources
- NRCS Small Acreage Program
- Jefferson Conservation District
- Jeffco Horse Regulations
- BCWA Horse Policy
- BMPs for Horse Management

Nutrient Contribution Estimates: Manure and horse properties in the Bear Creek Watershed are estimated to produce between 300 and 600 pounds of phosphorus annually in manure and denuded area particulate runoff. Streambank erosion caused by riparian vegetation destruction and direct watering from the stream may add more. The small acreage program of the NRCS and Jefferson Conservation District may assist horse owners to improve.

Map 1: Apparent pastures and meadows and horse properties



Bear Creek Watershed: Rough delineation of unpaved roads, pastures, and horse properties

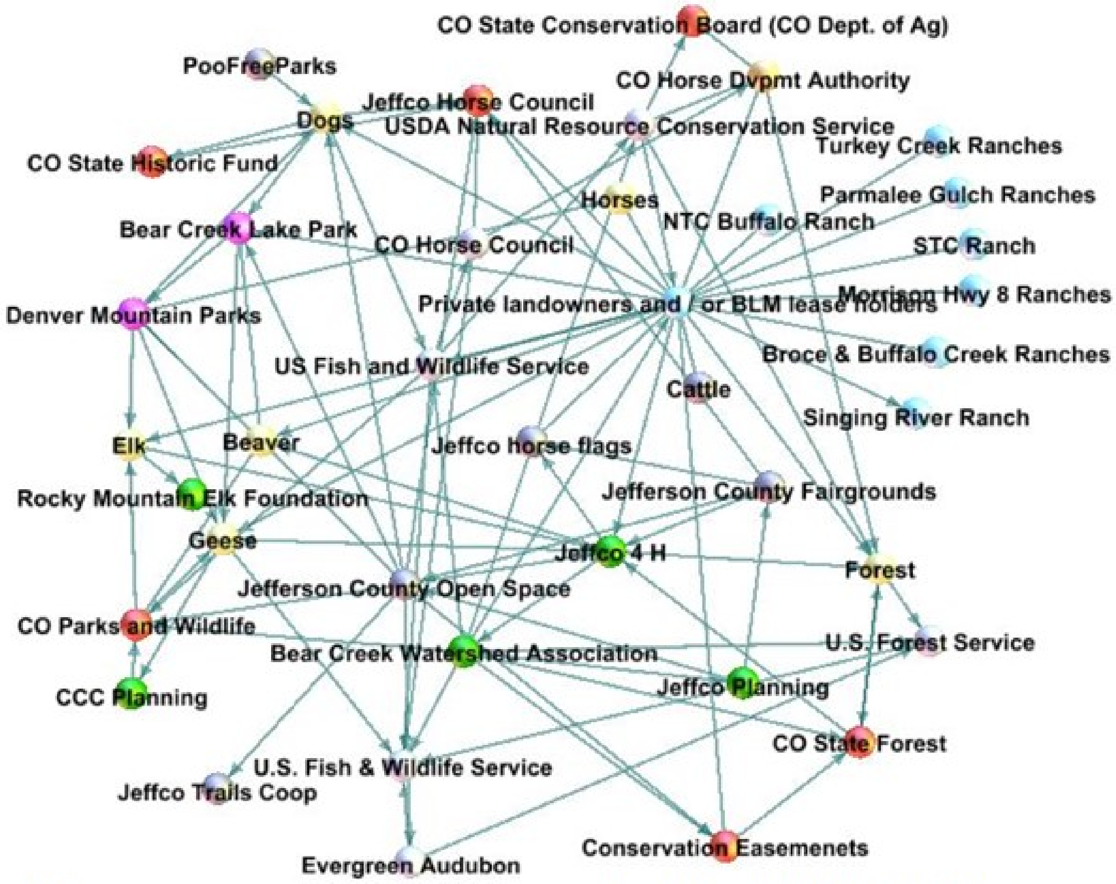
Legend

* Horse Property
— Major Streams
▭ Subbasins
▭ Meadow or Pasture
— Main Roads
— Unpaved Roads

Notes

A partial delineation of horse properties, meadows and unpaved roads / private drives throughout the Bear Creek Watershed were approximately located using Jeffco 2012 aerial photos.

SNA Diagram 1: SNA demonstrate that BCWA may be able to work with popular area 4-H and Westernairs equestrian groups that instruct children in horsemanship to reach parents who own horses about BMPs. The Colorado and Jefferson County Horse Councils and horse property relators may also be able to reach the target audience with policy information, if properly approached. Individual large ranches and stables such as Geneva Glen Camp, which is an inactive BCWA member, may have a large impact due to their larger size and number of horses, so these properties could be targeted first, especially those within the BCWA 200-foot streamside priority management tier (BCWA Policy 10. Management Tiers). Eliciting support from NRCS/JCD and the State Horse Development Authority could provide specific project funding, while developing important relationships for continued, long-term improvement. This example demonstrates how SNA more systematically delineated relationships and types of transactions that can be leveraged to make progress when nutrient management becomes stalled on a priority issue.



Potential Options:

BCLP has recorded over 30,000 horse visits from the two resident stables and other park visitors who bring their own. BCLP has a manure composting facility that keeps the stables relatively clean, but horse riders do not pick up after themselves when riding along the streamside trails, so more volunteer trail manager reminders could be helpful. Clear Creek County and Jefferson County 4-H clubs will meet with BCWA in Fall 2014 to help develop education and perhaps improve access to horse bags to contain manure while out riding for later disposal.

Both geese and elk can be hazed in areas where their concentration poses a specific problem.

Figure 1. Potential Buffalo Creek Pasture Management Area Delineated in Purple

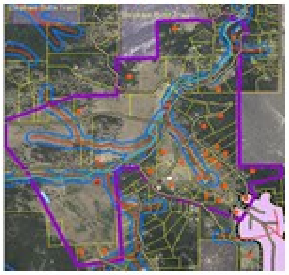


EXHIBIT D-5: PUBLIC LATRINES AND RECREATIONAL OVERUSE ANALYSIS SHEET

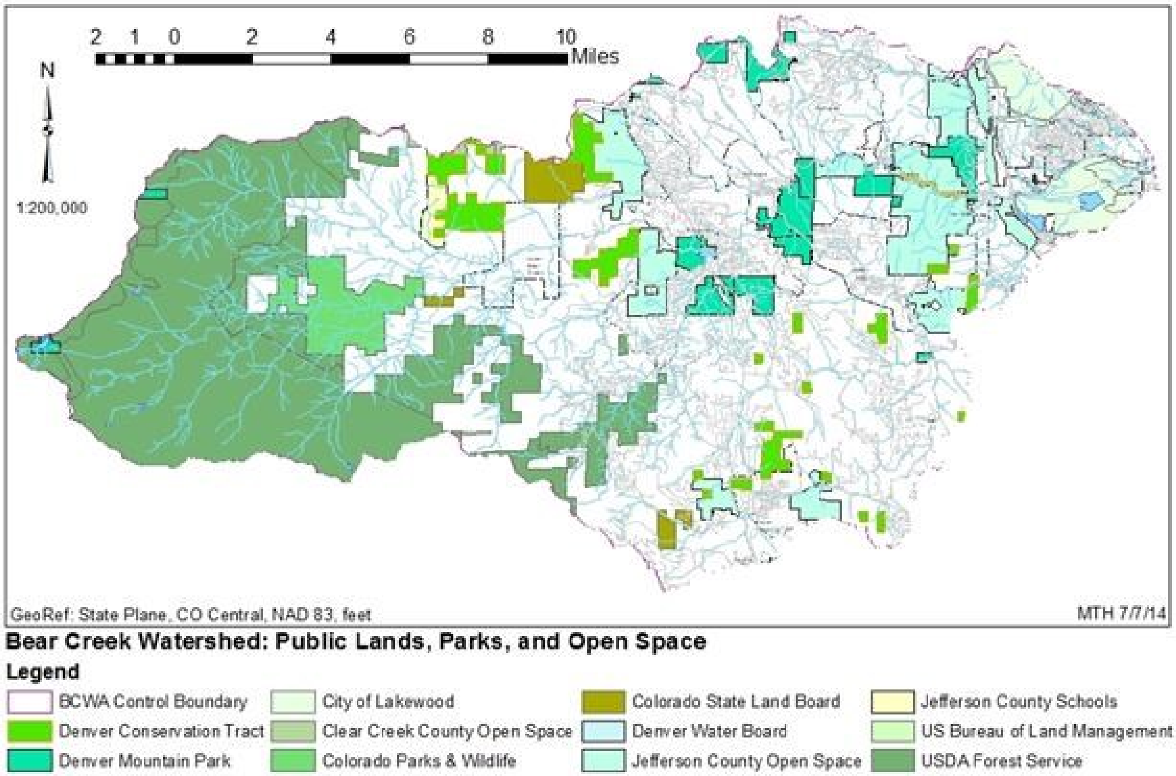
Bear Creek Watershed Issues Analysis
Nutrient Issue: *Public Latrines and Recreational Overuse*

Analyst: MT Herzog
Date: August 1, 2014

Description: Public latrines are found on more than thirty public properties throughout the Bear Creek Watershed owned by cities, counties, state parks, schools, and federal landowners. Public latrines are composting toilets that typically do not work well in Colorado, septic systems, or vault toilets. Summit Lake, for example, has experienced over 100,000 visitors per year since Mayor Speer built a road to the top of Mt. Evans in 1927. Until pit toilets were replaced with vaults, materials were left on site, which appears to have resulted in enriched TP in addition to potential sources from agricultural soil deposition and limited range for wildlife in the area.

Data Sources
- Denver Mountain Parks
- Jefferson County Open Space
- Clear Creek County Open Space
- CO Parks and Wildlife Areas
- U.S. Forest Service Lands
- City of Lakewood Mountain Parks

Figure 1. Public Lands in the Bear Creek Watershed



Notes

Data was obtained from Jefferson County Open Space, Denver Mountain Parks, and the Colorado Ownership, Management and Protection (CoMap) dataset produced by Colorado State University (http://nrel.colostate.edu/projects/comap/).
Denver Conservation Tracts do not typically permit public access or include facilities, but rather serve for wildlands protection and unobstructed city viewing purposes.

Recreational Overuse: The Bear Creek Watershed offers some of the most desirable recreational areas in relatively close proximity to the Denver Metro Area of over three million people. Public lands demonstrate overuse through thinning riparian areas, social trails, excessive erosion, parking, trash, pets, and other sources of pollution and degradation. The Evergreen Audubon has developed a program in responsible recreation that BCWA could expand. By involving more community members in issues analysis through stream surveys and improvement projects, like revegetation, as well as, teaching in schools, the situation could be improved.

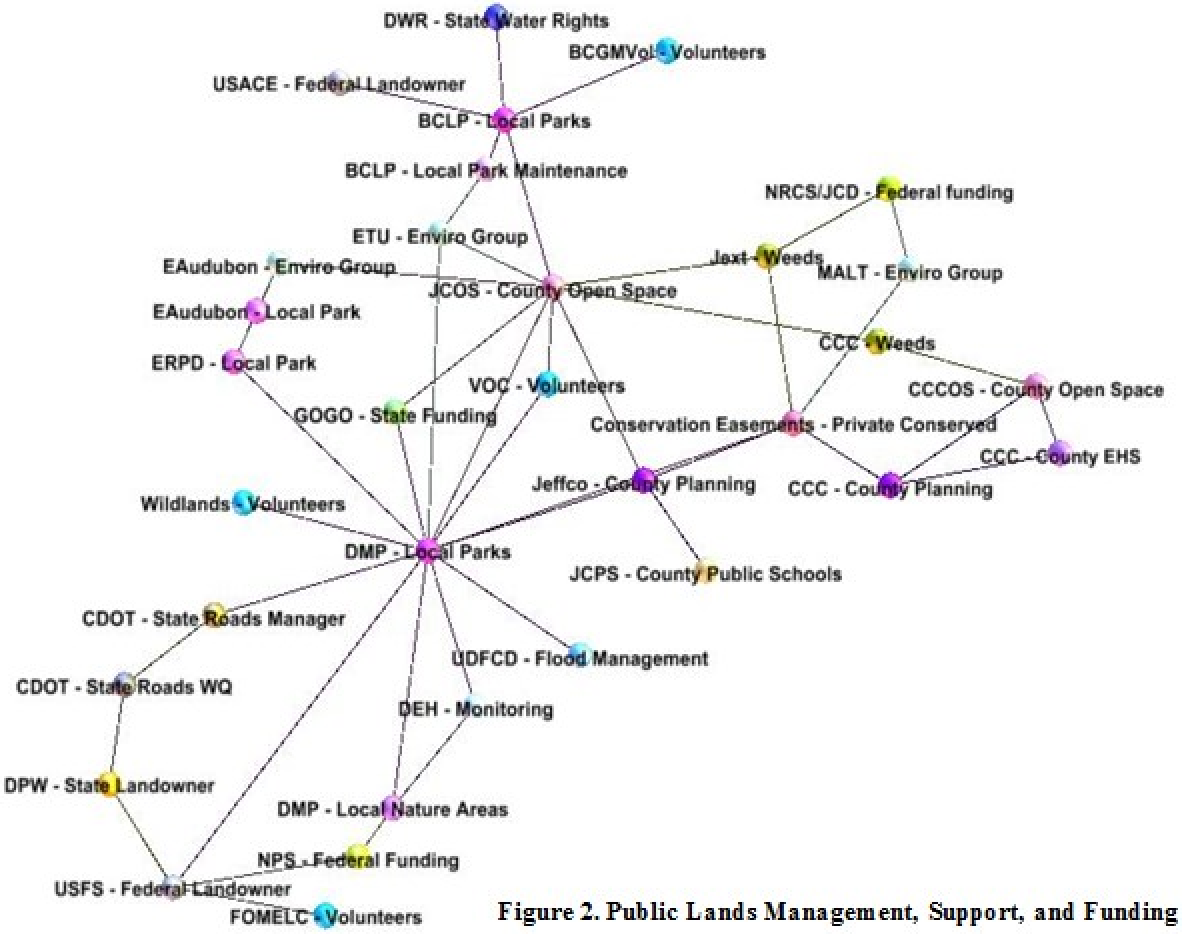


Figure 2. Public Lands Management, Support, and Funding

Figure 3. Approximately six miles of sewer line would be required to connect BCLP to Morrison WWTF

EXHIBIT D-6: STORMWATER AND ROAD NETWORKS ANALYSIS SHEET

Bear Creek Watershed Issues Analysis

Nutrient Issue: *Stormwater Runoff and Sediments are a Source of Phosphorus*

Analyst: MT Herzog
Date: August 12, 2014

Data Sources
- CSU Climatology Center
- DWR Real Time Streamflow
- WQCD Sediment Regulations
- MS4 Stormwater Discharges

Description: Although Colorado is considered semi-arid with relatively lower annual flow across the state, mountain headwaters receive more precipitation that is often more intense than in the plains.

Road Networks: In the lower half of the watershed, almost every road is named after the drainage alongside. Roads have fragmented habitat and encroached on the narrow mountain valley floodplains. Streams have been straightened and armored in many reaches, increasing the erosive potential of the water and exacerbating nutrient contributions from streambank erosion and nearby road embankments. Unvegetated areas contribute especially high loads. Recreational overuse can lead to social trails straight downslope from roads and parking areas, too. Although Phosphorus is not always readily available from particulate forms, over time about five percent to thirty percent can become available to support algae growth.

Table 1. Event Mean Concentrations of Constituents in mg/L (DrCog 1993)
The Metro Vision (DrCog 1993) Regional Water Quality Analysis developed response factors for different urban land uses to begin to plan nutrient control. Currently, at the request of the WQCD, the Colorado Stormwater Coalition has paid a team of CSU and consulting experts to update these factors in 2014 to include in new state storm water regulations.

Constituent	Natural Grassland	Commercial	Residential	Industrial
Total Phosphorus	0.4	0.42	0.65	0.43
Dissolved Phosphorus	0.1	0.15	0.22	0.20
Total Nitrogen	3.4	3.3	3.4	2.7

Map 1: Bear Creek Watershed: Rough delineation of paved and unpaved roads

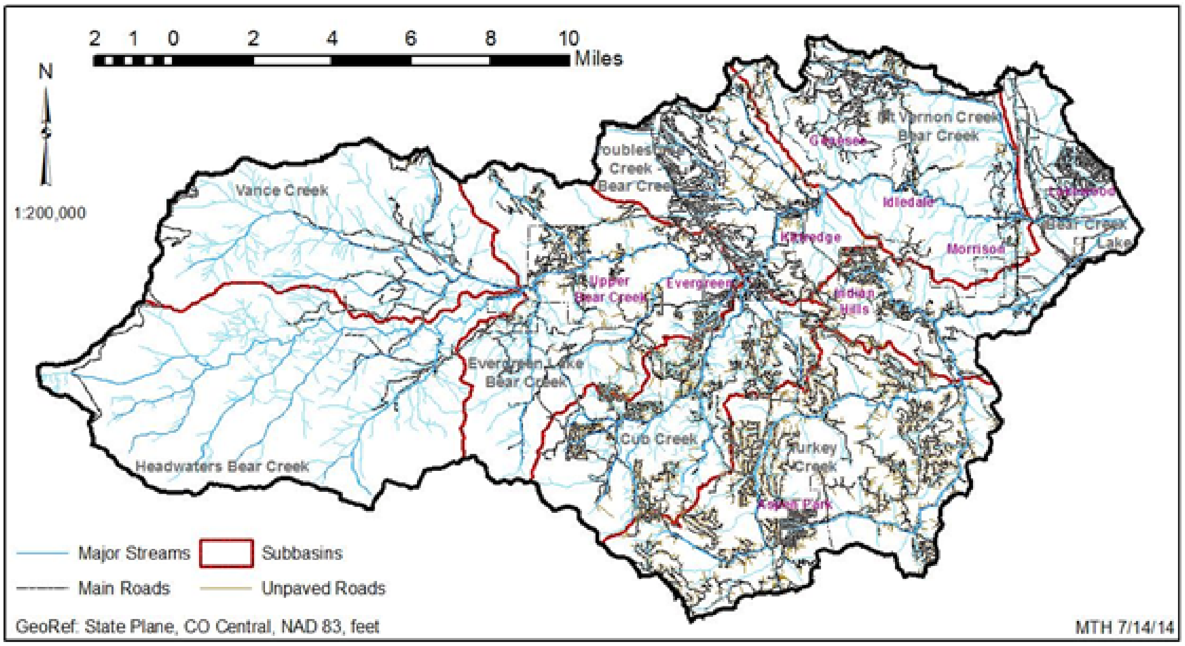


EXHIBIT D-7: WATER RIGHTS DIVERSIONS ANALYSIS SHEET

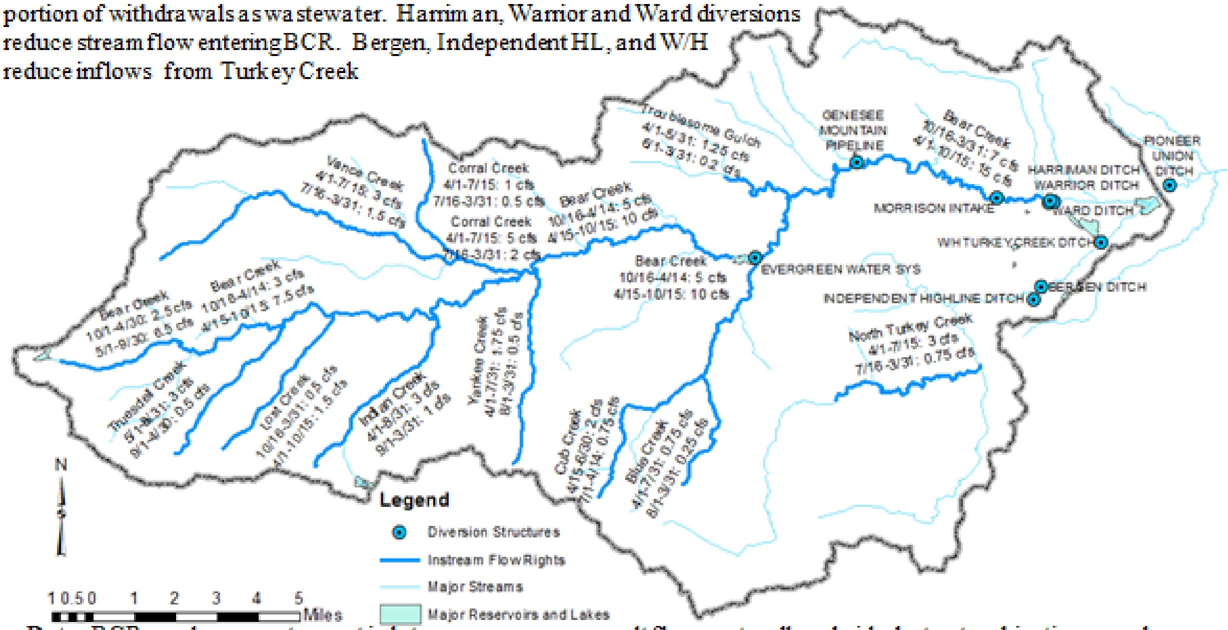
Bear Creek Watershed Issues Analysis
Nutrient Issue: *Water Rights Diversions Reduce Flow Through BCR*

Analyst: MT Herzog
Date: June 10, 2014

Description: Chl-a levels, an indication of cyanobacteria blooms, peak most often in August and September when diversions are high and snowmelt inflows have subsided. With less cool incoming mountain streamflows, reservoir temperatures increase and waters calm, creating improved conditions for maximum production. Internal P loading also peaks under these conditions, increasing supply for growth.

Data Sources
- CWCB/DWR CDSS Structures (Diversions)
- Streamflow Stations
- Real Time Gauged Data
- Instream Flow Rights
- BCWA Water Quality

Map: 1994 instream flow rights protect habitat and fish from new diversions, but not older ones that have an earlier priority date. Genesee, Evergreen, and Morrison return a portion of withdrawals as wastewater. Harriman, Warrior and Ward diversions reduce stream flow entering BCR. Bergen, Independent HL, and W/H reduce inflows from Turkey Creek

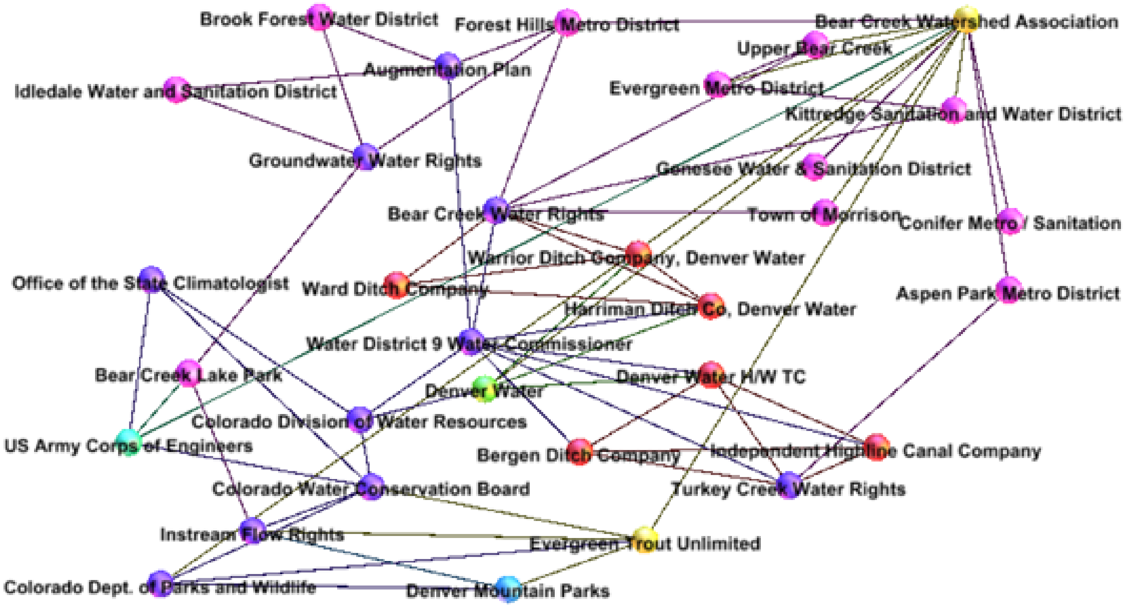


Data: BCR can become stagnant in late summer as snowmelt flows naturally subside, but eutrophication may be exacerbated by higher diversions for irrigation and higher outdoor residential water supply use in summer. In 2008, BCWA conducted a study which indicated that in the 2002 drought, Bear Creek ran dry for over a month and remained below 1 cfs for nearly two additional months. In a wet year, they recorded no flows below 2.5 cfs.

	Major Bear Creek Withdrawals in AF				Major Turkey Creek Withdrawals in AF						
Year	Total Out of Bear Creek	HARRIMAN DITCH	WARD DITCH	WARRIOR DITCH	Total Out of Turkey Creek	BERGEN DITCH	INDEPEND. HIGHLINE DITCH	WARRIOR/ HARRIMAN DITCH TC	Flow into BCR	Total Taken Prior	Percent Reaching BCR
2001	7,861	5,341	2,519		1,198	810	388		17,353	9,059	66%
2002	6,118	3,567	876	1,676	239		197	42	3,437	6,357	35%
2003	22,317	19,621	2,696		1,429	1,052	377		23,693	23,746	50%
2004	10,053	7,280	2,772		1,702	1,408	294		28,891	11,755	71%
2005	6,660	4,907	1,753		423	250	173		35,147	7,083	83%
2006	5,191	3,228	1,963		217	53	164		9,128	5,408	63%
2007	7,306	4,744	2,562		2,123	1,733	288	103	55,432	9,429	85%
2008	7,896	5,711	2,185		929	685	244		16,526	8,825	65%
2009	9,638	5,497	2,130	2,011	1,494	1,372	123		27,245	11,132	71%
2010	8,113	3,750	1,993	2,370	579	363	216		32,493	8,692	79%
2011	11,738	7,175	2,143	2,420	1,192	971	221		11,558	12,930	47%
2012	8,036	4,619	1,398	2,019	907	658	249		7,321	8,943	45%
2013	9,845	5,909	1,988	1,948	1,305	858	216	230	43,414	11,150	80%

Data: Districts withdraw water from Bear Creek for water supply and return most as treated wastewater effluent. This is based on rough diversion records, and districts may further augment returns to limit withdrawals and since some customers are on sewer but not water service. Not all water rights are measured and recorded, so junior rights are assumed to respect calls from senior rights to not take water or fully augment any water taken. This reduces the impact of these flows compared to flows that were not returned in the previous table. If you consider that the average TP in Bear Creek is roughly 43 µg/L and treated effluent is about 200-600 µg/L, it can increase TP during low flows in discharge reaches up to 10 percent or more, but that is not enough to change the character of the reservoir on its own. Other contributing sources, nutrient cycling, and reservoir sediments add a greater percentage.

Year	Diverted	WWTFs	%	EMDwtr diverted	EMDall returned	EMD %	GWSD diverted	GWSD returned	GWSD %	MORR diverted	MORR returned	MORR %
2010	1,546	1,564	101	1,097	1,199	109	330	276	84	119	89	75
2011	1,724	1,497	87	1,322	1,128	85	285	287	101	117	82	70
2012	1,845	1,450	79	1,329	1,099	83	385	266	69	130	85	65
2013	1,910	1,682	88	1,194	1,159	97	360	274	76	356	249	70



SNA: Sociogram of important relationships in water rights administration. CWCB manages instream flow rights (see map) determined by CDPW analysis of minimum flows needed for fish survival. DWR administers water rights through the District 9 Water Commissioner, who verifies all calls are being met.

Potential Options: Water Rights are very difficult to address because there is high likelihood of causing injury to downstream senior water rights through almost any change in quantity or point of diversion.

Harriman Ditch point of Diversion change below BCR: If quality was higher, Denver Water conducted a 2011 study that considered a constructed wetland at the mouth of Turkey or Bear Creek to improve quality enough to take water below the reservoir instead of at Morrison.

USACE Water Quality Requirement: If modeling could clearly demonstrate that storing some water in the high snowmelt season to release slowly over the summer could be achieved, it might become a TMDL requirement. Other measure could include flushing weekly, pulsing flows, or testing other reservoir level management measures.

EXHIBIT D-8: WATER RESIDENCE TIME ANALYSIS SHEET

Bear Creek Watershed Issues Analysis

Nutrient Issue: *Does Longer Water Residence Times Increase HABs in BCR?*

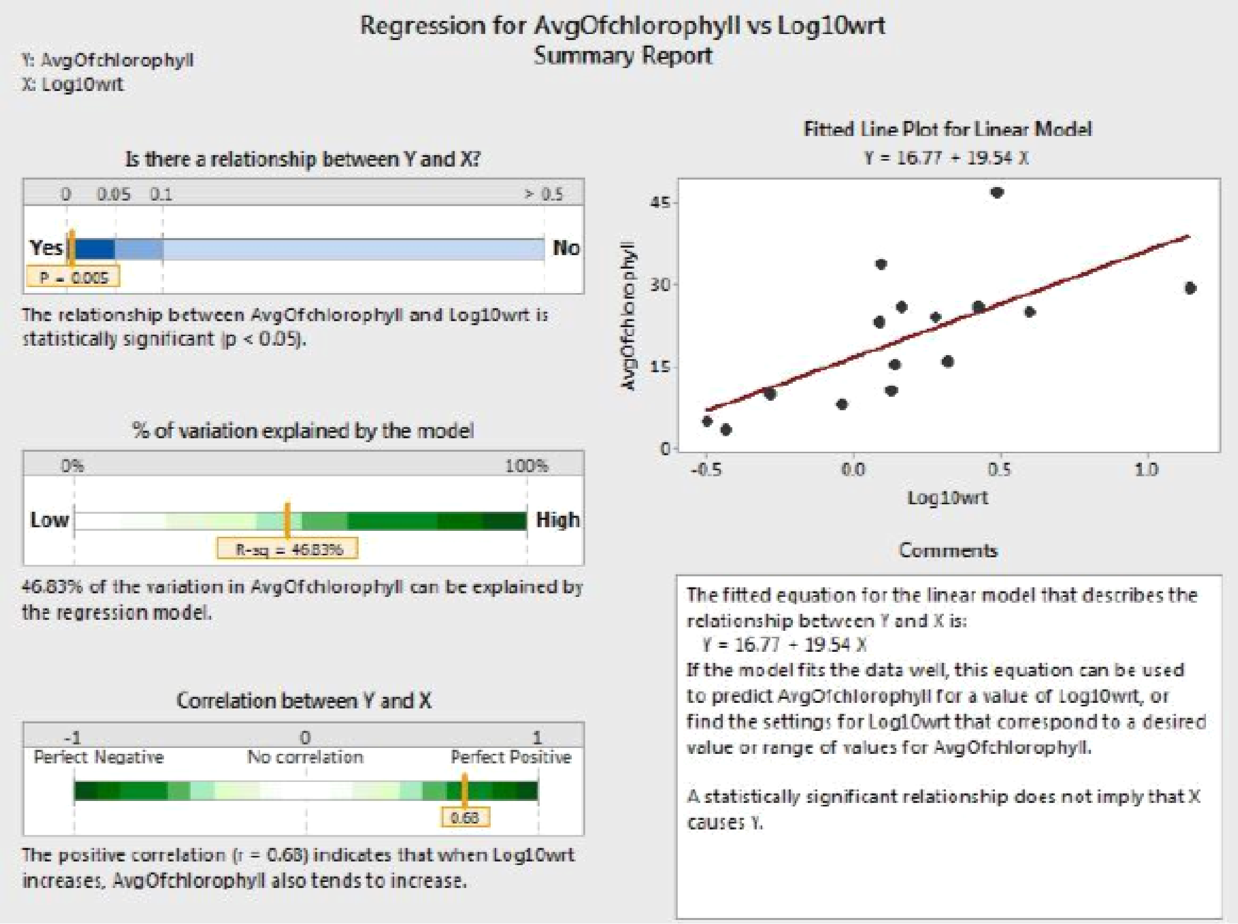
Analyst: MT Herzog
Date: June 10, 2014

Description: Cyanobacteria blooms often occur in August and September when snowmelt inflows subside, allowing BCR to heat and stagnate. However, WRT does not appear to be as much a factor as the seasonality of late August and September blooms.

Data Sources

- Streamflow Stations
- USACE provided inflows
- BCWA Water Quality

Data: BCR can become stagnant in late summer as snowmelt flows naturally subside, exacerbated by increased summer water rights diversion withdrawals (see water rights analysis), which tends to increase chl-a levels.



Regression for AvgOfchlorophyll vs Log10wrt
Summary Report

Y: AvgOfchlorophyll
X: Log10wrt

Is there a relationship between Y and X?

The relationship between AvgOfchlorophyll and Log10wrt is statistically significant ($p < 0.05$).

% of variation explained by the model

46.83% of the variation in AvgOfchlorophyll can be explained by the regression model.

Correlation between Y and X

The positive correlation ($r = 0.68$) indicates that when Log10wrt increases, AvgOfchlorophyll also tends to increase.

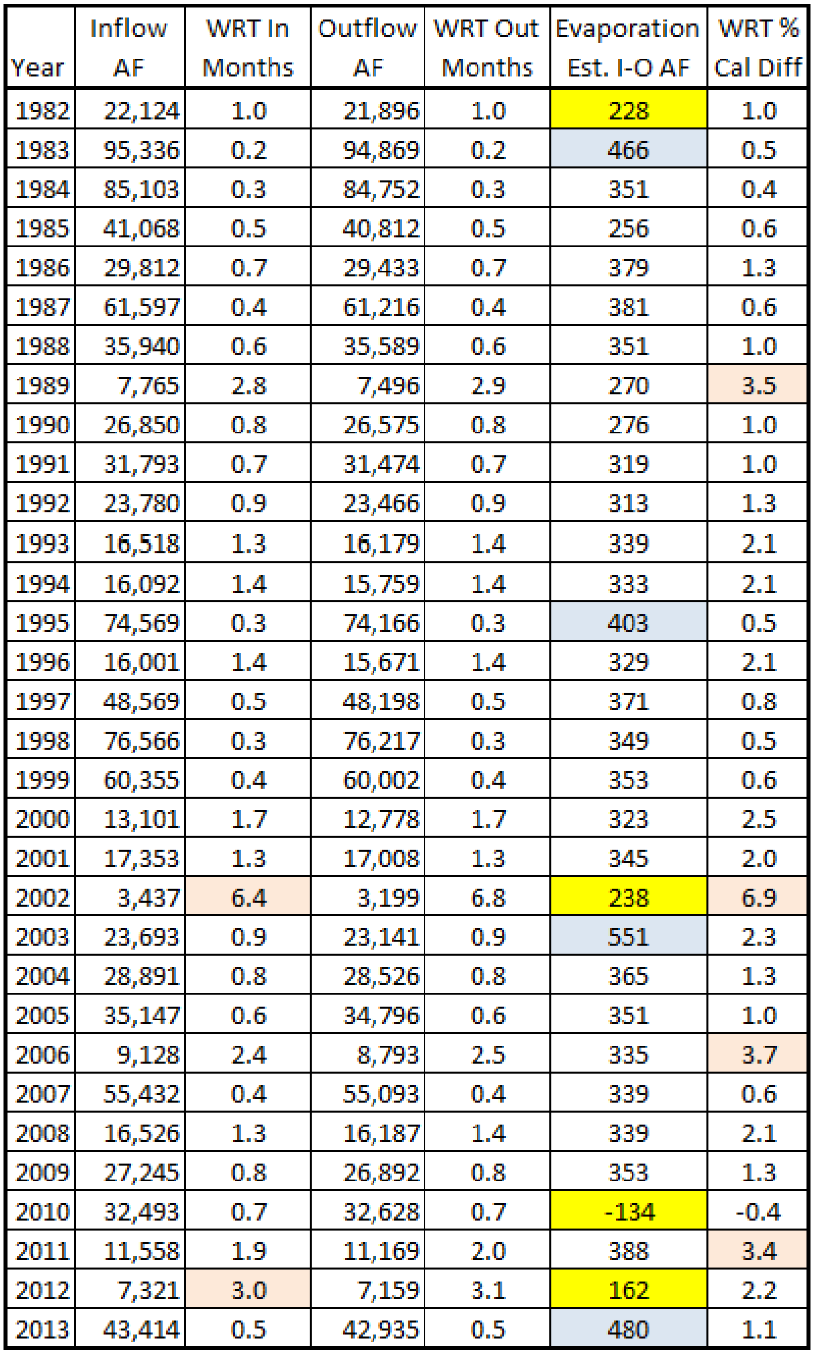
Fitted Line Plot for Linear Model
$Y = 16.77 + 19.54\ X$

Comments

The fitted equation for the linear model that describes the relationship between Y and X is:
$Y = 16.77 + 19.54\ X$
If the model fits the data well, this equation can be used to predict AvgOfchlorophyll for a value of Log10wrt, or find the settings for Log10wrt that correspond to a desired value or range of values for AvgOfchlorophyll.

A statistically significant relationship does not imply that X causes Y.

Table 2. Variation in Water Residence Time Since BCR Filled



Year	Inflow AF	WRT In Months	Outflow AF	WRT Out Months	Evaporation Est. I-O AF	WRT % Cal Diff
1982	22,124	1.0	21,896	1.0	228	1.0
1983	95,336	0.2	94,869	0.2	466	0.5
1984	85,103	0.3	84,752	0.3	351	0.4
1985	41,068	0.5	40,812	0.5	256	0.6
1986	29,812	0.7	29,433	0.7	379	1.3
1987	61,597	0.4	61,216	0.4	381	0.6
1988	35,940	0.6	35,589	0.6	351	1.0
1989	7,765	2.8	7,496	2.9	270	3.5
1990	26,850	0.8	26,575	0.8	276	1.0
1991	31,793	0.7	31,474	0.7	319	1.0
1992	23,780	0.9	23,466	0.9	313	1.3
1993	16,518	1.3	16,179	1.4	339	2.1
1994	16,092	1.4	15,759	1.4	333	2.1
1995	74,569	0.3	74,166	0.3	403	0.5
1996	16,001	1.4	15,671	1.4	329	2.1
1997	48,569	0.5	48,198	0.5	371	0.8
1998	76,566	0.3	76,217	0.3	349	0.5
1999	60,355	0.4	60,002	0.4	353	0.6
2000	13,101	1.7	12,778	1.7	323	2.5
2001	17,353	1.3	17,008	1.3	345	2.0
2002	3,437	6.4	3,199	6.8	238	6.9
2003	23,693	0.9	23,141	0.9	551	2.3
2004	28,891	0.8	28,526	0.8	365	1.3
2005	35,147	0.6	34,796	0.6	351	1.0
2006	9,128	2.4	8,793	2.5	335	3.7
2007	55,432	0.4	55,093	0.4	339	0.6
2008	16,526	1.3	16,187	1.4	339	2.1
2009	27,245	0.8	26,892	0.8	353	1.3
2010	32,493	0.7	32,628	0.7	-134	-0.4
2011	11,558	1.9	11,169	2.0	388	3.4
2012	7,321	3.0	7,159	3.1	162	2.2
2013	43,414	0.5	42,935	0.5	480	1.1

Potential Options: Water Residence Time is not easily adjusted because BCR is designed to maintained its permanent pool at 5558 ft MSL as a USACE operating procedure, except in times of flood, when pool levels are allowed to rise up to a few weeks to protect downstream urban areas from flooding.

USACE Water Quality Requirement: If modeling could clearly demonstrate that storing some water in the high snowmelt season to release slowly over the summer could be achieved, it might become a TMDL requirement. Other measure could include flushing weekly, pulsing flows, or testing other reservoir level management measures.

EXHIBIT D-9: CYANOBACTERIA BLOOMS ANALYSIS SHEET

Bear Creek Watershed Issues Analysis

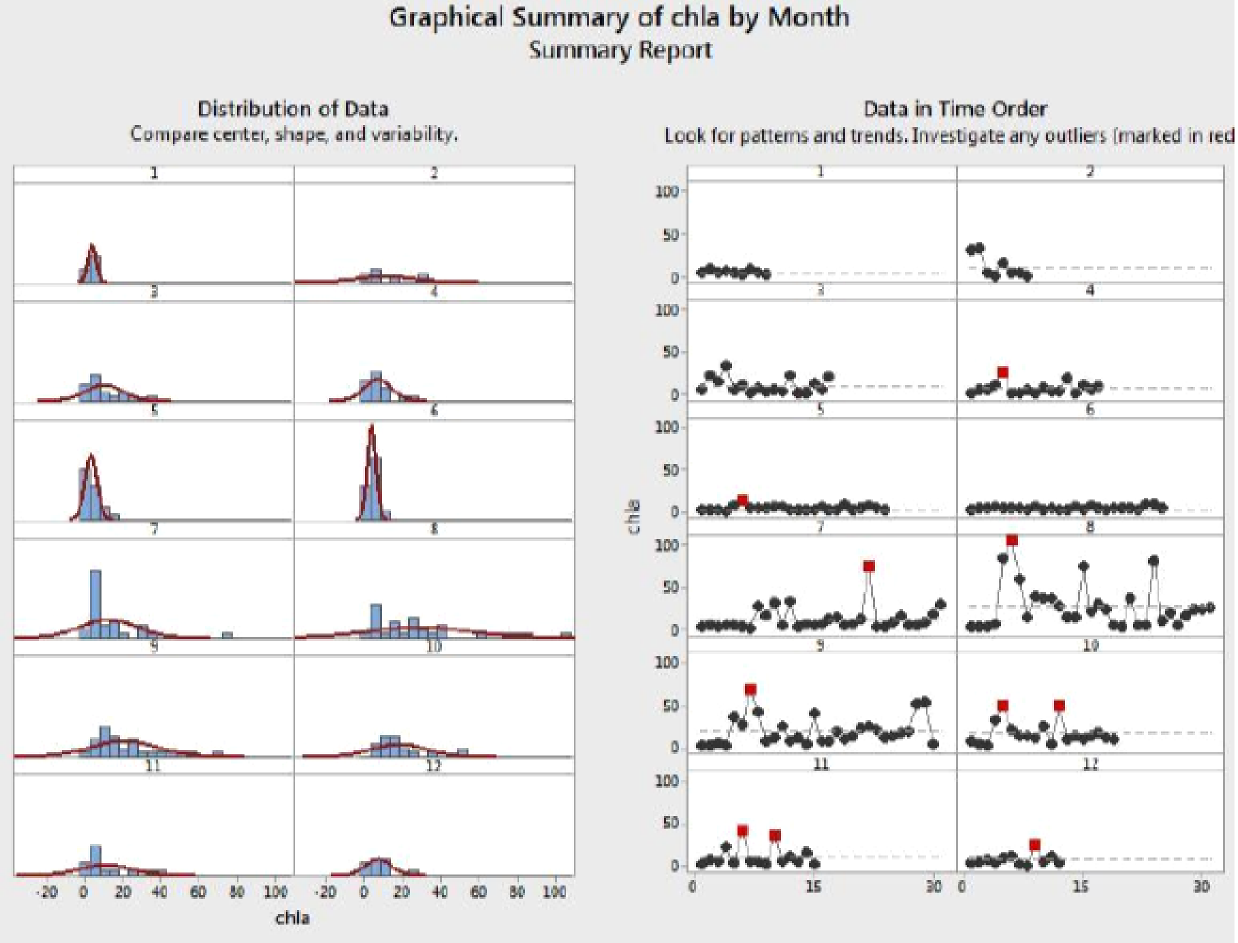
Nutrient Issue: *Seasonality in Chlorophyll-a Levels is Critical to Analysis*

Analyst: MT Herzog
Date: June 10, 2014

Description: Cyanobacteria blooms often occur in July through October depending on when higher snowmelt inflows subside and reservoir temperatures increase. However, there may be smaller peaks in winter under clean ice cover as ammonia builds up.

Data Sources
- Streamflow Stations
- USACE provided inflows
- BCWA Water Quality data

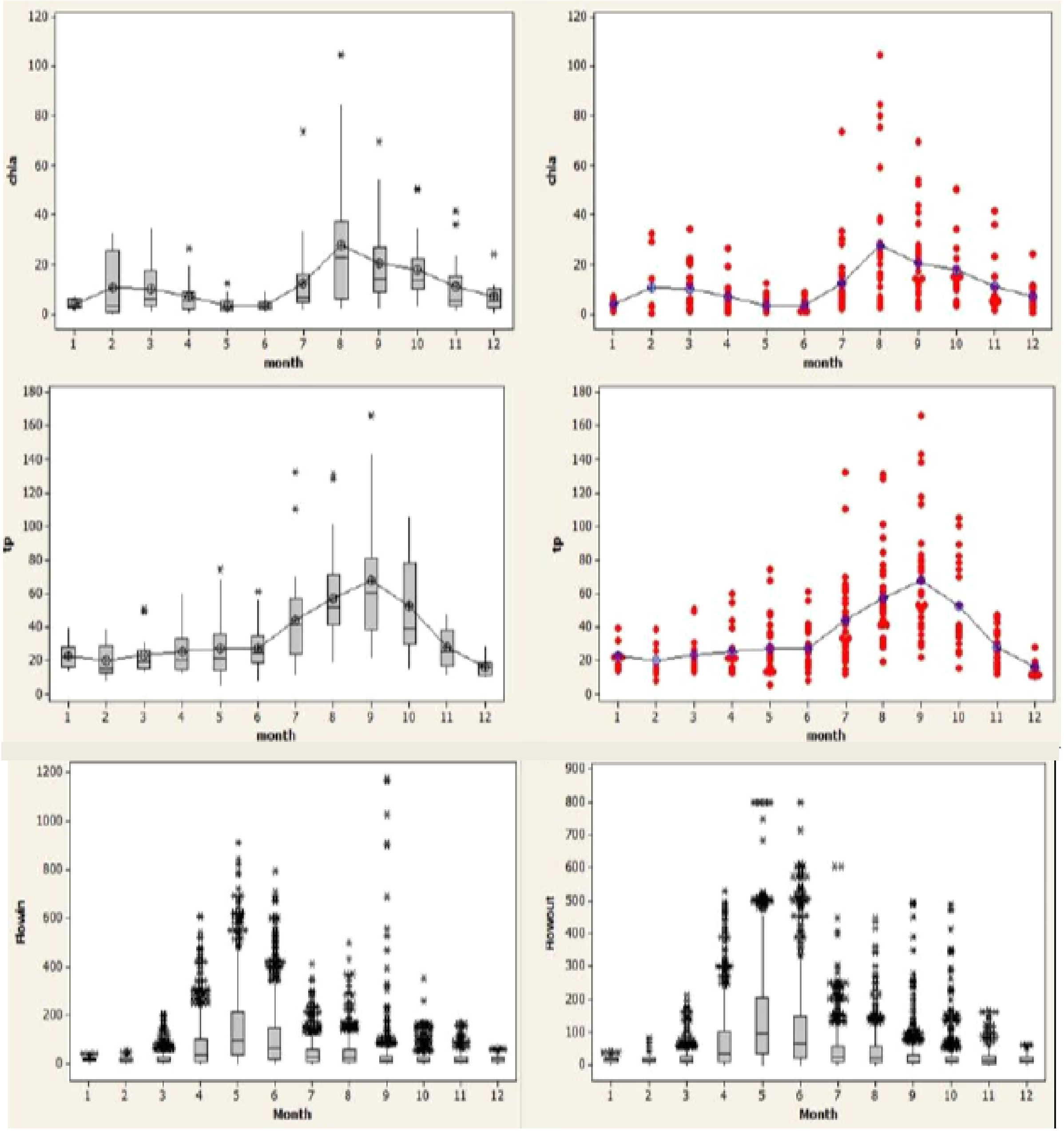
Data Analysis: Examining Chl-a monitoring data by month (1-12) by histograms to show variability and shape, and over time to show trends and cycles indicate that May and June consistentlyhave the lowest Chl-a levels in BCR, which coincides with highest inflows from mountain snowmelt. July through October exhibit the greatest variability. Both July and April tend to have more low readings, probably depending on if snowmelt starts earlier or later each year. Although Chl-a levels appear to peak rarely above 50 µg/L, August readings are more than double the 10 µg/LChls-a BCRstandard most years. Variability analysis is not considered because the state is only interested in consistent reductions in summer averages (July through September). Obviously, a low July reading can reduce the average while a high October peak, which is even more common, will be missed. Variability renders hypothesis testing and regression analysis insignificant.



Potential Options: Cyanobacteria blooms are best controlled by nutrient source control, control of fine sediments and organic matter inputs, and reservoir flushing. All of these preferred, long term controls will be difficult to achieve. Therefore, some potential temporary controls may be applied to reduce blooms

Figures 2a-c: Monthly fluctuations in chl-a, TP, and Flow in and out of BCR 1998-2013

Notice that peak chlorophyll levels precede peak TP levels and occur as soon as cool spring snowmelt inflow subsides. Even though solar radiation is highest in June, until water temperatures increase with less cool inflow anc flushing of fish excrement, urine, and other internal sources of high nutrient cycling, blooms do not occur.



Biomanipulation: In times of pending drought and low flows, fish removal and reestablishment of macrophytes in shallow areas might be achieved by storing water in Soda Lakes during highest spring runoff, when all water rights are being fulfilled. Then the reservoir would be drawn down in early summer as soon as flows subside to remove fish, targeting benthivorous and planktivorous species likely to be causing the most resuspension of sediments and reduction in large zooplankton needed to control phytoplankton. Just before refilling, a variety of native macrophytes would be planted to provide habitat for species diversity, zooplankton cover, and improved water clarity to allow a better balance of phytoplankton with more green algae and diatom species and less surface scum.

EXHIBIT D-10: INTERNAL P LOADING ANALYSIS SHEET

Bear Creek Watershed Issues Analysis

Nutrient Issue: *Summer Internal P Loading is Critical to Analysis*

Analyst: MT Herzog
Date: June 10, 2014

Data Sources

- Streamflow Stations
- USACE provided inflows
- BCWA Water Quality

Description: Total Phosphorus has been demonstrated to be a key factor in cyanobacteria blooms. However, BCR has TP in excess both in inflows and through internal P loading released from reservoir sediments and through biologically-mediated nutrient cycling. Therefore, unlike Chl-a, TP can exceed the 32 µg/L in any month, and even that level is much greater than would be low enough to limit blooms. WWTFs have already reduced TP contributions to about 1,000 pounds per year from a high above 5,000 pounds per year. With other sources producing more than 4,000 pounds and sometimes double that in some years, further WWTFs TP reductions beyond steadily decreasing TP contributions through optimization and plant upgrades over time would not be warranted until more nonpoint sources can begin to be similarly reduced.

Data Analysis: Examining TP monitoring data at site 40a in BCR by month (1-12) by histograms to show variability and shape, and over time to show trends and cycles indicate that only December values tend to be consistently low. In comparing results to the chl-a analysis, TP levels exhibit more variability throughout the year and do not decrease with flushing flows as dramatically. July through October TP levels are highest as with chl-a, but rather than a consistent cause and effect relationship as a P-limited natural lakes may exhibit, high TP readings in August are sustained or even increase through September and October, so they do not track peak chl-a levels, which tend to precede them. This may indicate that the release of TP from decomposing organic matter produced in the summer may continue into the fall.

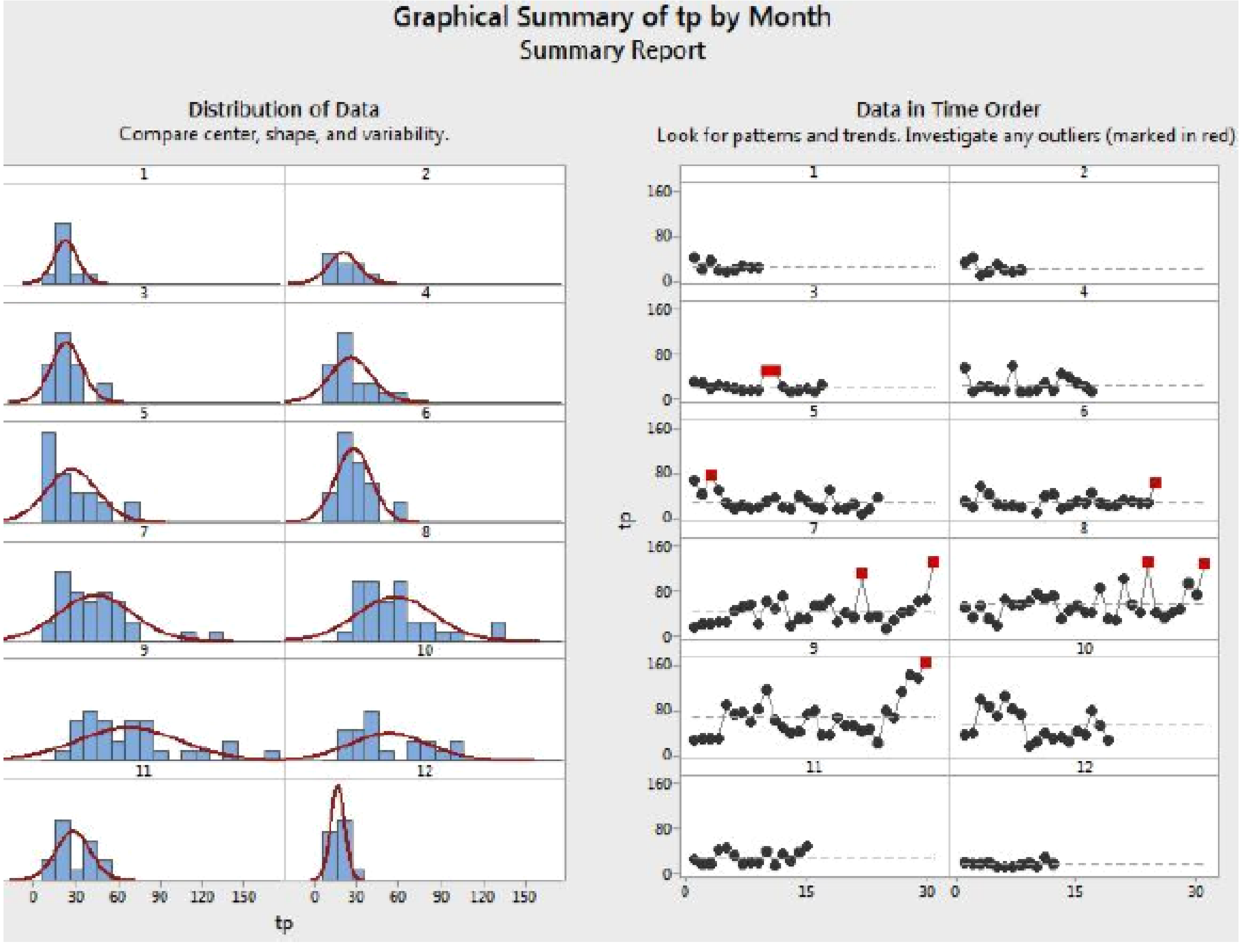
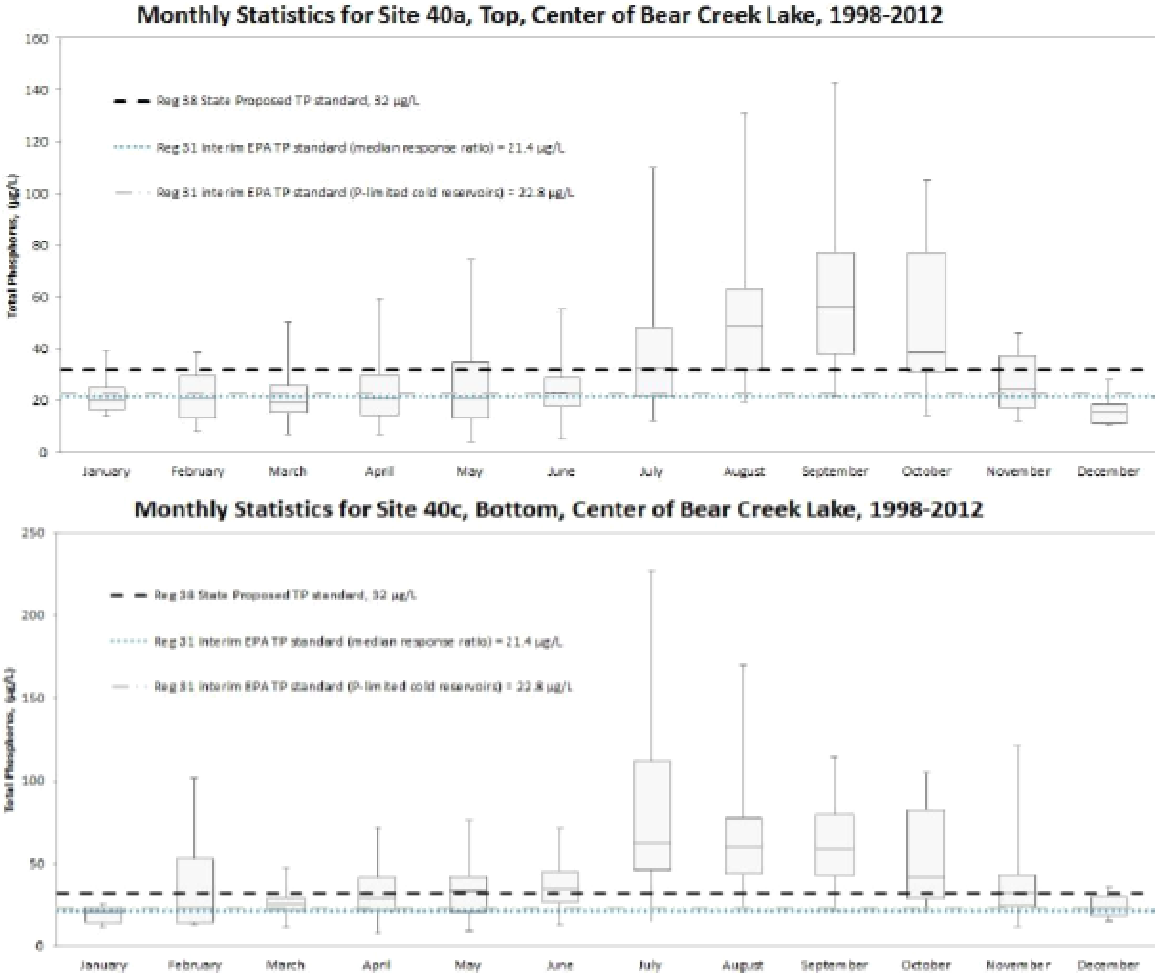


Figure 2a-b: Monthly Trends in Total Phosphorus Concentrations at Top (40a) andBottom (40c) of BCR
Although surface TP peaks in late summer, TP is generated in July from bottom sediments that supply this rise.



Potential Options: TP generated from nutrient cycling , resuspension, and desorption of TP from bottom sediments may be partially controlled in advance of full incoming TP control, though it can not be fully controlled until incoming TP is reduced by more than half of current levels.

Aeration Improvements: The September 2013 flood provided an opportunity to replace the devastated BCR aeration system. Instead of accepting FEMA funds to replace the existing system that was easily damaged and resuspends sediments without providing small enough fine bubbles for maximum transfer of oxygen to the water column, BCLP and BCWA are working together to design a custom system in house to avoid these issues. The improved aeration should reduce hypoxia in bottom sediments, so less TP is released in July to fuel August blooms.

Phosphorus Deactivation: Studies indicate that using repeated, small doses of alum, iron, calcium, or custom clay bound TP sorption materials such as lanthanide bound to bentonite clay particles (PhosLock), can successfully reduce internal P loading, depending on the characteristics of the reservoir. With aeration and its relatively shallow nature, BCR is polymictic, so it cannot maintain a stable thermocline for stratification, so waters completely mix throughout the year. TP deactivation has been used to shock reservoirs into at least a temporarily improved trophic state. Chemicals would need to be applied right after June snowmelt inflows subside for best results at controlling TP releases in July that most directly lead to blooms. By simultaneously applying a flocculate, cyanobacteria, which have been storing TP to max August growth, can be reduced from the water column during the deactivation process.

EXHIBIT D-11: MONITORING ANALYSIS SHEET

Bear Creek Watershed Issues Analysis
Nutrient Issue: *Monitoring Needs*

Analyst: MT Herzog
Date: August 1, 2014

Data Sources
- EPA ECHO search
- CDPHE WQCD Regs
- BCWA Water Quality

Description: Regulatory monitoring is conducted on a weekly to monthly basis at wastewater effluent discharges, on-stream reservoirs, and stream stations throughout the Bear Creek Watershed. Temperature, nutrients including TN, Total Inorganic Nitrogen, Ammonia, Nitrate-nitrogen, and TP and Total Dissolved Phosphorus, pH, specific conductivity, dissolved oxygen (DO), chlorophyll-a (reservoirs only), total suspended solids, and flow. Macroinvertebrates analysis and fish counts are conducted in the fall most years. Percent periphyton cover is recorded at stream stations on sampling dates. Sediment in on-stream reservoirs is usually also sampled yearly for texture, organic matter, and TP at a minimum. Additional studies are conduced as needed.

Use Continuous Flow Gauge Data: Instantaneous flow measurements conducted at a stream site on a single date of the month do not always coincide well with flow-weighted measurements based on continuously gauged daily averages. Not only do day-to-day flows change significantly, but there are also natural diurnal and seasonal fluctuations that grab samples cannot capture. Therefore, to the extent possible, continuous flow gauge data should be used for TP load calculations, which may require extrapolation to ungauged stations. Evaporation measurements calculated by USACE methods using continuous gauged data also correlate more closely with both regional empirical relationships and nearby Fox Hollow weather station results, which further demonstrates the validity of this approach.

Table 1. 2012 Daily Gauged Flow v. Monthly Flow Meter Values Extrapolated over the Month

Daily vs. Monthly Flow Averaging - Implications?					Actual Outflow Value Recorded, cf:			BCWA,i	USACE,da	DWR,da
		BCWA Monthly Sampling Flow Avg					1/13/2012	16	18.2	17.2
Month	USACE In	Total Inflow	Total Outflow	DWR gauge	USACE Outflow Estim:		2/10/2012	14.45	20.6	19.5
Jan	1118	1118.2	983.6	1046	1111		3/26/2012	12.75	12.4	11.4
Feb	1394	907.5	831.0	1303	1373		4/23/2012	5.5	4.4	1.5
Mar	1071	672.5	783.8	988	1072		5/21/2012	15.73	10.2	7.8
Apr	508	360.5	327.2	338	485		6/26/2012	1.4	3.4	0.9
May	450	726.6	967.0	296	425		7/9/2012	0.2	3.1	0.5
Jun	179	240.3	83.3	105	204		7/23/2012	0.2	7.2	4.5
Jul	551	671.9	12.3	292	405		8/6/2012	0.4	16.9	13.0
Aug	532	356.9	27.7	551	711		8/27/2012	0.5	4.8	3.1
Sep	379	109.2	136.8	346	269		9/10/2012	2.2	5.7	3.9
Oct	615	435.8	30.7	327	460		9/25/2012	2.4	6.0	5.4
Nov	246	435.8	11.9	378	422		10/22/2012	0.5	7.3	4.8
Dec	276	435.8	12.3	189	221		11/26/2012	0.2	0.0	0.0
Annual	**7318**	**6471**	**4207**	**6161**	**7159**	AF / yr	12/14/2012	0.2	5.1	4.6

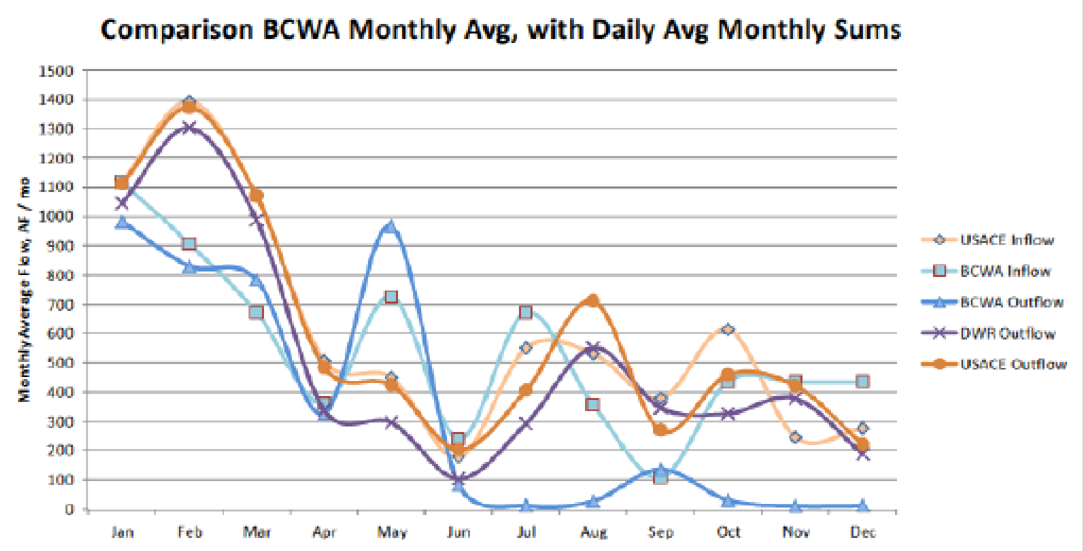


Table 2: Analysis of Instantaneous Monthly, 5-day Instantaneous Estimates, and DWR and USACE continuous BCR inflow and outflow data used in Estimating BCR Evapotranspiration Rates in 2012

	2012 Estimated Monthly Flow (AF/month) At Stations Bear Creek Reservoir												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	AF/yr
Site 16a-Turkey Creek Inflow	79.9	109.3	202.2	156.5	274.8	99.9	239.4	59.9	28.9	19.1	25.0	21.5	1,316
Actual 5-day week average TCIn	95.1	164.4	181.8	178.3	222.0	46.7				92.9	92.1	96.1	1,169
Site 15a-Bear Creek Inflow	1038.3	798.2	470.3	204.1	451.8	140.4	432.5	296.9	80.3	416.8	109.5	113.1	4,552
Actual 5-day week average BCIn	919.2	944.8	871.5	356.7	373.8	100.7				407.0	144.4	149.7	4,268
Est from MOR-Div+WWTF, Mvmiss	746	655	616	117	275	100	239	60	29	301	46	602	3,786
Total Actual Inflow	1014.3	1109.2	1053.3	535.0	595.8	147.4	671.9	356.9	109.2	499.9	236.5	245.8	6,575
Total Inflow	1118.2	907.5	672.5	360.5	726.6	240.3	671.9	356.9	109.2	435.8	435.8	435.8	6,471
USACE Inflow	1121.1	1394.4	1071.1	507.8	450.2	178.5	551.4	531.6	378.8	614.9	246.0	275.7	7,322
Total Outflow	983.6	831.0	783.8	327.2	967.0	83.3	12.3	27.7	136.8	30.7	11.9	12.3	4,207
Total Actual Outflow	652.8	700.4	720.6	651.6	700.2	320.5	58.0	96.6	56.0	317.2	301.1	180.9	4,756
DWR Outflow	1046.3	1303.3	1003.1	443.8	387.1	147.0	350.3	648.1	402.3	439.3	378.3	188.9	6,738
USACE Outflow	1111.4	1373.3	1071.7	485.2	424.7	203.9	405.4	711.4	269.1	460.0	421.8	221.4	7,159
Fox Hollow BCR Est Evaporation	20.5	12.2	50.0	37.4	40.7	48.1	45.0	59.9	29.7	24.6	20.6	14.4	403
USACE Estimated Evaporation	10.0	14.2	20.3	21.2	36.8	46.3	62.5	43.6	42.3	26.5	14.6	9.1	347
BCWA BCR Estimated Evaporation	134.6	76.5	-111.3	33.3	-240.4	157.1	659.6	329.2	-27.7	405.1	423.9	423.5	2,264

Gauging Major Tributaries Recommended: At least one continuous gauge should be purchased to periodically or permanently located at fixed bridge or lined channel cross sections on Turkey Creek, Mt. Vernon Creek, Cub Creek, and Troublesome Creek. These four creeks contributed the most to flood and storm flows and each may contribute significant nutrient loads, as well. Water quality would need to concentrate on at least surrogate measurement taken repeatedly during storm events to attempt to gain information for the full event hydrograph.

Recording low flows: Continuous flow meters do not seem to as accurately measure flow before a specific minimum level. When flow meter readings do not agree with gauged flow records, additional metering should be done to determine the number of days and quantity affected. Measures of vegetation and habitat effects under extended Bear Creek dewatering through BCLP should be conducted on day in which the creek is dewatered by water rights diversions from Warrior/Harriman and Ward ditches on Bear Creek and / or Independent High Line Canal, Bergen Ditch, and the Warrior/Harriman Turkey Creek Canal on Turkey Creek.

Stream Surveys: Mixed researcher, high-education students, and community professionals and experienced volunteers could be involved in helping to map all erosion, invasive species, habitat, fragmentation, and misuse issues along Bear Creek from Evergreen Lake to Bear Creek Reservoir, and later along other stream reaches throughout the Bear Creek Watershed. LIDAR data, aerial photos, and remote sensing data can be used to corroborate findings. Detailed inspections of reported issues could lead to landscape scale projects. A Quality Assurance Plan and Standard Operating Procedures for each type of survey data to be collected would need to be developed and leaders trained to guide students and citizen scientists to carry out this work.

Table 3: Flow in AF / yr by Monthly Grab Sample Compared to USACE Continuous Gauged Outflow

BCWA Year	BCWA Flow Grab ac-ft/yr	USACE Flow TotOutAF	Flow Mthd Difference
2000	15,113	12,778	18%
2001	15,906	17,008	-6%
2002	2,317	3,199	-28%
2003	21,215	23,141	-8%
2004	33,706	28,526	18%
2005	31,605	34,796	-9%
2006	11,748	8,793	34%
2007	67,725	55,093	23%
2008	20,307	16,187	25%
2009	21,503	26,892	-20%
2010	29,462	32,628	-10%
2011	9,432	11,169	-16%
2012	5,868	7,159	-18%
2013	45,726	42,935	7%
Mean	23,688	22,879	Total Dif
	28,891	2004 median	1%

EXHIBIT D-12. SEPTEMBER 2013 FLOOD ANALYSIS SHEET

Bear Creek Watershed Issues Analysis

Nutrient Issue: *September 2013 Flood Issues and Water Quality Impacts*

Analyst: MT Herzog
Date: September 1, 2014

Data Sources

- FEMA Disaster Assistance
- CO Flood Recovery Website
- Jeffco Disaster Recovery
- Jeffco Floodplains
- CCC Flood Recovery
- CCC Floodplain Info
- CSU Ext Flood Resources

Description: Although there is typically more concern for droughts and wildfire in the watershed, in September 2013, the first major flood since BCR closed in 1977 led to a re-awareness of the water quality problems that floods may cause. BCR USACE flood control dam west of Denver is usually maintained at a permanent pool elevation of 5558 feet. However, in September 2013, flood waters rose nearly 50 feet, surface area increased from 106 to 448 acres, and storage volume increase from 1,891 to 14,366 AF. Two latrine vaults were submerged and both boat docks were destroyed. Much of the populated lower half of the watershed from Upper Bear Creek through Evergreen, Kittredge, Idledale, and Morrison required significant FEMA funding to repair damages to roads, culverts, streambanks, and structures along Bear Creek and its tributaries. However, this damage was caused by just five days of elevated flows of 900 to 1,200 cfs, a magnitude that may only represent a return period of about 5.5 years at Morrison (an 18% probability of occurrence in any one year, Figure 1) according to the recently-updated FEMA Flood Insurance Study (2014). Even along state and county roads, some culverts and bridges remain undersized. Floodways are not always maintained to safely pass the probable 100-year event of 14,000 cfs at Morrison and of 4,000 to 6,000 cfs at the mouths of the four major tributaries (Table 1). The ACM DSS process sought to assist in planning future mitigation measures, while helping BCWA members to share what they learned with the community to prepare more directly for the inevitable floods to follow, which could be much worse.

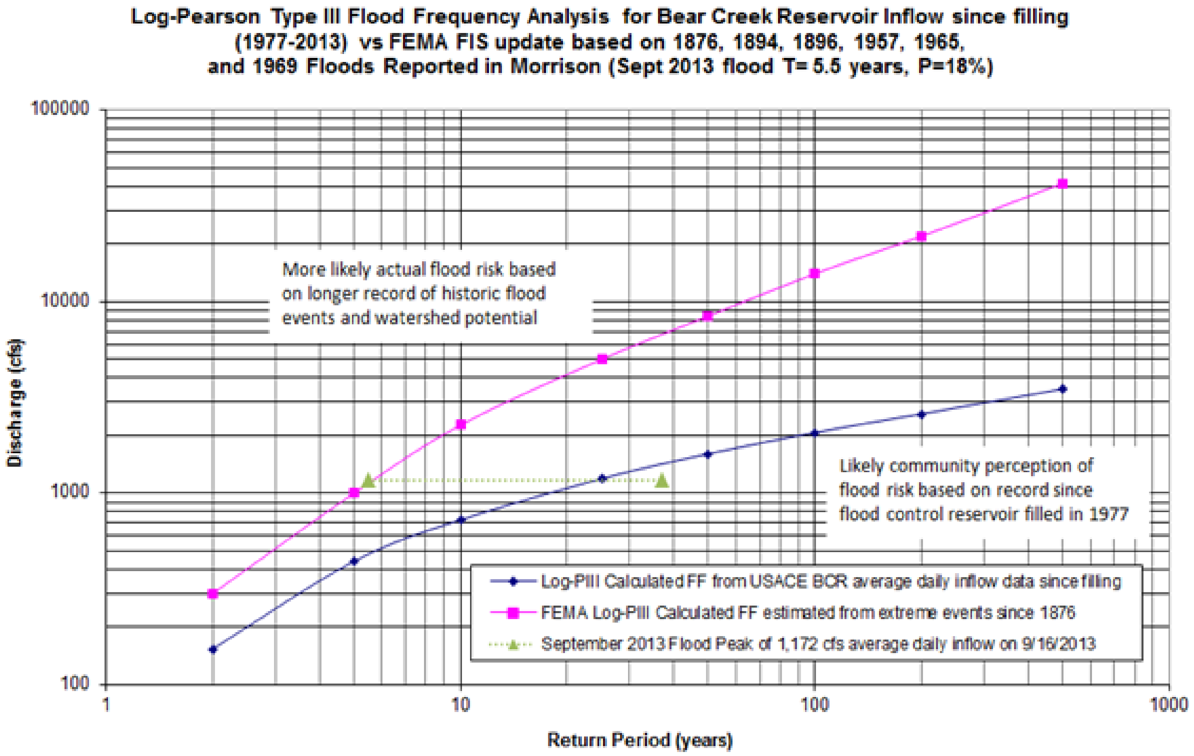
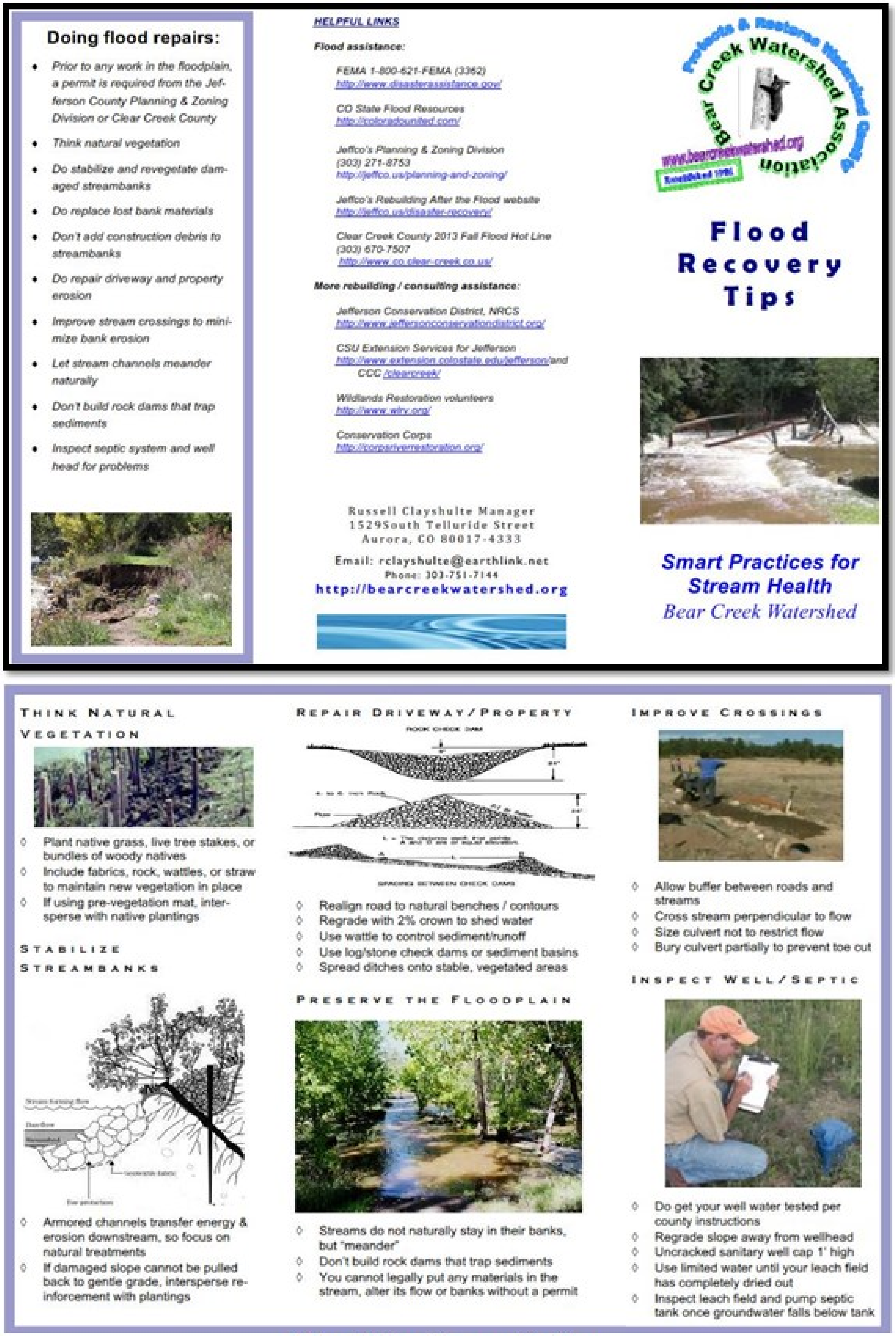


Figure 1. FEMA Estimated Flood Frequency vs. Community Perceived Flood Risk

Flood Recovery Tips Brochure and KLTV-8 Documentary: Based on the ACM principle to exploit unexpected events, a brochure was designed shortly after the flood to help the community rebuild with water quality and stream improvement tips (Figure 2). The brochure was provided at local flood recovery town hall meetings at which attendees were also asked to sign-up for the new BCWA quarterly newsletter to stay informed about water quality developments. A professional video was also created by the local television station in BCLP to discuss the effects on BCR and reflections from both the park manager and the BCWA water quality manager during rebuilding.



Doing flood repairs:

- *Prior to any work in the floodplain, a permit is required from the Jefferson County Planning & Zoning Division or Clear Creek County*
- *Think natural vegetation*
- *Do stabilize and revegetate damaged streambanks*
- *Do replace lost bank materials*
- *Don't add construction debris to streambanks*
- *Do repair driveway and property erosion*
- *Improve stream crossings to minimize bank erosion*
- *Let stream channels meander naturally*
- *Don't build rock dams that trap sediments*
- *Inspect septic system and well head for problems*

HELPFUL LINKS

Flood assistance:

FEMA 1-800-621-FEMA (3362)
http://www.disasterassistance.gov/

CO State Flood Resources
http://coloradounited.com/

Jeffco's Planning & Zoning Division
(303) 271-8753
http://jeffco.us/planning-and-zoning/

Jeffco's Rebuilding After the Flood website
http://jeffco.us/disaster-recovery/

Clear Creek County 2013 Fall Flood Hot Line
(303) 670-7507
http://www.co.clear-creek.co.us/

More rebuilding / consulting assistance:

Jefferson Conservation District, NRCS
http://www.jeffersonconservationdistrict.org/

CSU Extension Services for Jefferson
http://www.extension.colostate.edu/jefferson/*and*
CCC /clearcreek/

Wildlands Restoration volunteers
http://www.wlrv.org/

Conservation Corps
http://corpsriverrestoration.org/

Russell Clayshulte Manager
1529South Telluride Street
Aurora, CO 80017-4333

Email: rclayshulte@earthlink.net
Phone: 303-751-7144
http://bearcreekwatershed.org

Protects & Restores Watershed Quality
Bear Creek Watershed Association
www.bearcreekwatershed.org
Established 1996

Flood Recovery Tips

Smart Practices for Stream Health
Bear Creek Watershed

THINK NATURAL VEGETATION

- Plant native grass, live tree stakes, or bundles of woody natives
- Include fabrics, rock, wattles, or straw to maintain new vegetation in place
- If using pre-vegetation mat, intersperse with native plantings

STABILIZE STREAMBANKS

- Armored channels transfer energy & erosion downstream, so focus on natural treatments
- If damaged slope cannot be pulled back to gentle grade, intersperse reinforcement with plantings

REPAIR DRIVEWAY/PROPERTY

- Realign road to natural benches / contours
- Regrade with 2% crown to shed water
- Use wattle to control sediment/runoff
- Use log/stone check dams or sediment basins
- Spread ditches onto stable, vegetated areas

PRESERVE THE FLOODPLAIN

- Streams do not naturally stay in their banks, but "meander"
- Don't build rock dams that trap sediments
- You cannot legally put any materials in the stream, alter its flow or banks without a permit

IMPROVE CROSSINGS

- Allow buffer between roads and streams
- Cross stream perpendicular to flow
- Size culvert not to restrict flow
- Bury culvert partially to prevent toe cut

INSPECT WELL/SEPTIC

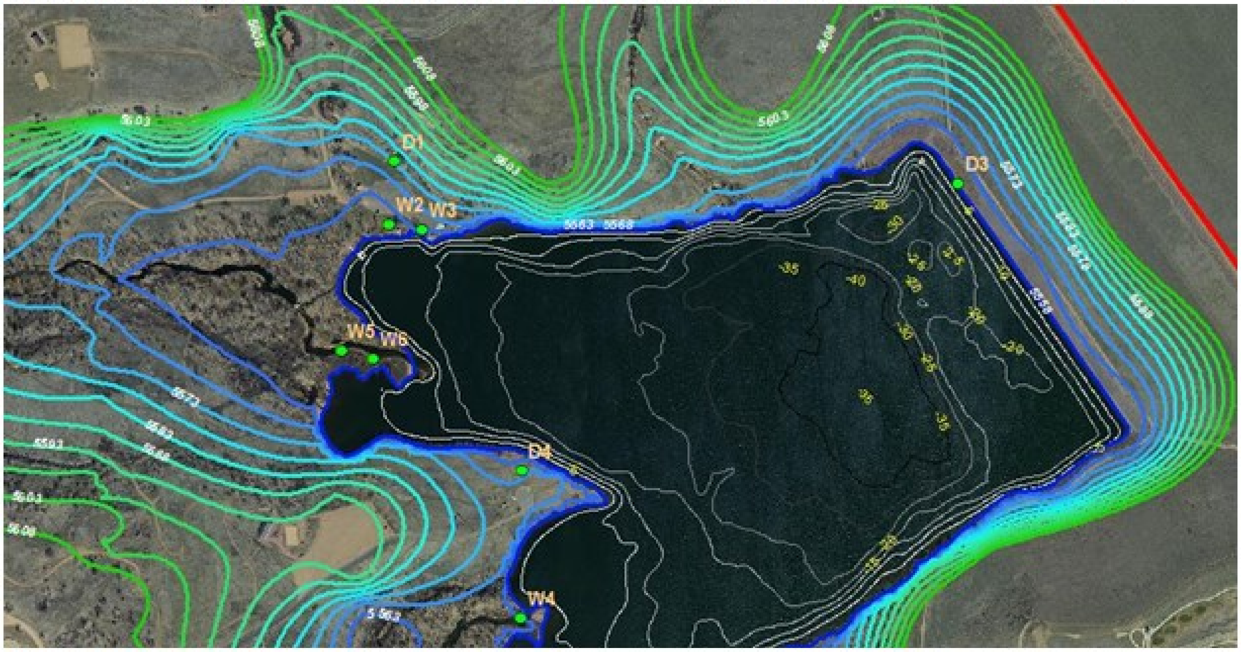
- Do get your well water tested per county instructions
- Regrade slope away from wellhead
- Uncracked sanitary well cap 1' high
- Use limited water until your leach field has completely dried out
- Inspect leach field and pump septic tank once groundwater falls below tank

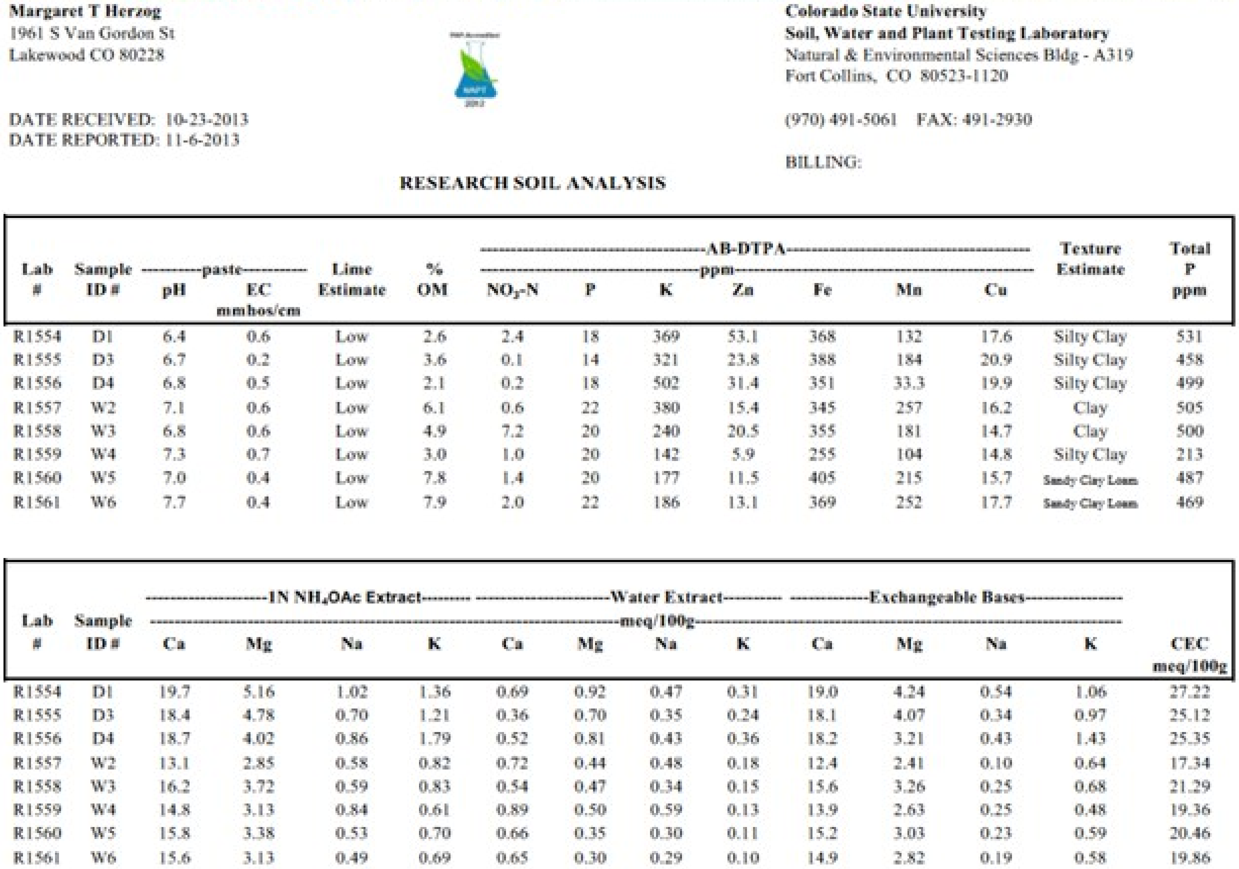
Figure 2. Flood Recover Brochure

Table 1. Bear Creek 2014 FEMA Firm Updated Flood Estimates

	Drainage Area mi^2	10-Year cfs	50-Year cfs	100-Year cfs	500-Year cfs
Bear Creek (at Lakewood) At South Sheridan Blvd (SH-95)	N/A	4,120	6,710	7,910	11,800
Bear Creek Below Mt. Carbon Dam	239	500	1,000	1,000	2,000
Bear Creek Below confluence with Mount Vernon Creek	174	2,270	8,410	14,000	41,400
Bear Creek At USGS Gage at Morrison	164	2,180	8,140	13,500	39,900
Bear Creek Below confluence with Sawmill gulch	158	1,930	6,750	10,800	30,500
Bear Creek Below confluence with Swede Gulch	146	1,710	5,850	9,500	25,000
Bear Creek Above confluence with Myers Gulch	139	1,600	5,350	8,500	22,500
Bear Creek Above confluence with Troublesome Creek	126	1,390	4,500	7,100	17,750
Bear Creek Above confluence with Buffalo Creek	96	950	2,780	4,200	9,500
Bear Creek At Western Jefferson County Line	85	800	2,250	3,250	7,050
Bear Creek Tributary No. 1 At mouth	0.59	145	385	510	980
Bear Creek Tributary No. 1 At upstream limit of detailed study	0.14	45	115	155	285
Bear Creek Tributary No. 2 At mouth	0.69	100	290	385	670
Bear Creek Tributary No. 3 At Dedisee Park Road	0.41	120	310	415	760
Bear Creek Tributary No. 5 At Morrison Road	1.18	260	580	670	1,250
Bear Creek Tributary No. 5 At Tributary confluence	0.69	150	320	380	660
Bear Creek Tributary No. 6 At mouth	1.53	650	920	1,040	1,333
Bear Creek Tributary No. 7 At mouth	0.64	170	375	465	690
Buffalo Creek At confluence with Sand draw	46.7	370	540	630	840
Cold Spring Gulch At mouth	5.07	655	1,630	2,070	4,025
Cold Spring Gulch 0.40 mile above mouth	4.49	590	1,485	1,885	3,575
Cold Spring Gulch 1.74 miles above mouth	1.99	285	750	960	1,900
Cub Creek At mouth	22.1	620	2,310	3,840	11,300
Cub Creek Above confluence with Little Cub Creek	19.2	570	2,120	3,520	10,400
Cub Creek Below Lans Gulch	17.9	540	2,030	3,370	9,950
Elk Creek At mouth	63.8	455	650	760	1,020
Little Cub Creek At mouth	2.83	300	885	1,180	2,000
Mount Vernon Creek At mouth	9.66	2,030	3,630	4,395	6,400
Meyers Gulch At mouth	1.31	145	450	605	1,200
North Turkey Creek At downstream limit of detailed study	18.22	N/A	N/A	1,410	3,000
North Turkey Creek At upstream limit of detailed study	3.78	N/A	N/A	225	410
Parmalee Gulch At mouth	5.96	875	2,320	2,675	3,500
Parmalee Gulch At confluence with Giant Gulch	4.39	680	1,810	2,100	2,800
Sawmill Gulch At mouth	2.28	730	1,565	1,930	3,000
Swede Gulch At mouth	1.45	250	620	845	1,600
Troublesome Creek At mouth	9.06	1,280	3,330	4,240	7,000
Troublesome Creek Above confluence with Bergen Creek	3.05	470	1,195	1,525	2,400
Turkey Creek At USGS Gage near Morrison	50.1	1,040	3,870	6,420	19,000
Turkey Creek Above confluence with Parmalee Gulch	44.1	960	3,570	5,920	17,500
Wilmot Creek At mouth	1.73	360	900	1,175	1,850
Wilmot Creek Above confluence with Tributary	0.56	100	285	380	650
Wilmot Creek Tributary At mouth	0.61	150	375	490	830
Wilmot Creek Tributary At upstream limit of detailed study	0.26	55	160	215	390

Exposed Flood Sediments Analysis Results: Exposed flood sediment obtained at the locations around the BCR permanent pool after the flood indicated that plant available TP determined using the AB-DTPA method ranged from 14-22 ppm, which represents a medium to high runoff potential according to Colorado Phosphorus Index Soil Test P Risk Factors. Total phosphorus content of samples ranged from 469 to 531 ppm (mg/kg) except for the only submerged sample taken on Turkey Creek of 213 ppm, which had also experienced less flooding. Extractable iron was more than 345 ppm and manganese exceeded 250 ppm for several of the silty, clay sediment samples.





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DATE RECEIVED: 10-23-2013
DATE REPORTED: 11-6-2013

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BILLING:

RESEARCH SOIL ANALYSIS

Lab #	Sample ID #	paste pH	paste EC mmhos/cm	Lime Estimate	% OM	AB-DTPA ppm NO$_3$-N	AB-DTPA ppm P	AB-DTPA ppm K	AB-DTPA ppm Zn	AB-DTPA ppm Fe	AB-DTPA ppm Mn	AB-DTPA ppm Cu	Texture Estimate	Total P ppm
R1554	D1	6.4	0.6	Low	2.6	2.4	18	369	53.1	368	132	17.6	Silty Clay	531
R1555	D3	6.7	0.2	Low	3.6	0.1	14	321	23.8	388	184	20.9	Silty Clay	458
R1556	D4	6.8	0.5	Low	2.1	0.2	18	502	31.4	351	33.3	19.9	Silty Clay	499
R1557	W2	7.1	0.6	Low	6.1	0.6	22	380	15.4	345	257	16.2	Clay	505
R1558	W3	6.8	0.6	Low	4.9	7.2	20	240	20.5	355	181	14.7	Clay	500
R1559	W4	7.3	0.7	Low	3.0	1.0	20	142	5.9	255	104	14.8	Silty Clay	213
R1560	W5	7.0	0.4	Low	7.8	1.4	20	177	11.5	405	215	15.7	Sandy Clay Loam	487
R1561	W6	7.7	0.4	Low	7.9	2.0	22	186	13.1	369	252	17.7	Sandy Clay Loam	469

Lab #	Sample ID #	1N NH$_4$OAc Extract meq/100g Ca	1N NH$_4$OAc Extract meq/100g Mg	1N NH$_4$OAc Extract meq/100g Na	1N NH$_4$OAc Extract meq/100g K	Water Extract meq/100g Ca	Water Extract meq/100g Mg	Water Extract meq/100g Na	Water Extract meq/100g K	Exchangeable Bases meq/100g Ca	Exchangeable Bases meq/100g Mg	Exchangeable Bases meq/100g Na	Exchangeable Bases meq/100g K	CEC meq/100g
R1554	D1	19.7	5.16	1.02	1.36	0.69	0.92	0.47	0.31	19.0	4.24	0.54	1.06	27.22
R1555	D3	18.4	4.78	0.70	1.21	0.36	0.70	0.35	0.24	18.1	4.07	0.34	0.97	25.12
R1556	D4	18.7	4.02	0.86	1.79	0.52	0.81	0.43	0.36	18.2	3.21	0.43	1.43	25.35
R1557	W2	13.1	2.85	0.58	0.82	0.72	0.44	0.48	0.18	12.4	2.41	0.10	0.64	17.34
R1558	W3	16.2	3.72	0.59	0.83	0.54	0.47	0.34	0.15	15.6	3.26	0.25	0.68	21.29
R1559	W4	14.8	3.13	0.84	0.61	0.89	0.50	0.59	0.13	13.9	2.63	0.25	0.48	19.36
R1560	W5	15.8	3.38	0.53	0.70	0.66	0.35	0.30	0.11	15.2	3.03	0.23	0.59	20.46
R1561	W6	15.6	3.13	0.49	0.69	0.65	0.30	0.29	0.10	14.9	2.82	0.19	0.58	19.86

SNA: A sociogram of flood-related agencies and local governments seeking aid was developed to understand relationships and plan for improved coordination in response to future events.

Label	**Name**
CWCB	Colorado Water Conservation Board
CDWR	Colorado Division of Water Resources
CGS	Colorado Geological Survey
CDEmgMgmt	Colorado Division of Emergency Managem
Climatologist	Colorado Office of the State Climatologist
UDFCD	Urban Drainage & Flood Control District
DOLA	Department of Local Affairs
NWS	National Weather Service
NOAA	National Oceanic Atmospheric Administrati
USACE	US Army Corps of Engineers
NRCS	Natural Resources Conservation Service
USGS	US Geological Survey
USBR	US Bureau of Reclamation
FEMA R8	Federal Emergency Management Agency
Jeffco	Jefferson County Planning
DMP	Denver Mountain Parks
USFS	USFS Mt Evan Wilderness
Morrison	Town of Morrison
Evergreen	Unincorporated Area of Evergreen
UBC	Upper Bear Creek
Kittredge	Kittredge
Idledale	Idledale
BCLP	Bear Creek Lake Park
Lakewood	City of Lakewood
Denver Water	Denver Water
CDPW	Colorado Dept. of Parks and Wildlife
JCOS	Jefferson County Open Space
ETU	Evergreen Trout Unlimited
EAudubon	Evergreen Audubon
BCWA	Bear Creek Watershed Association

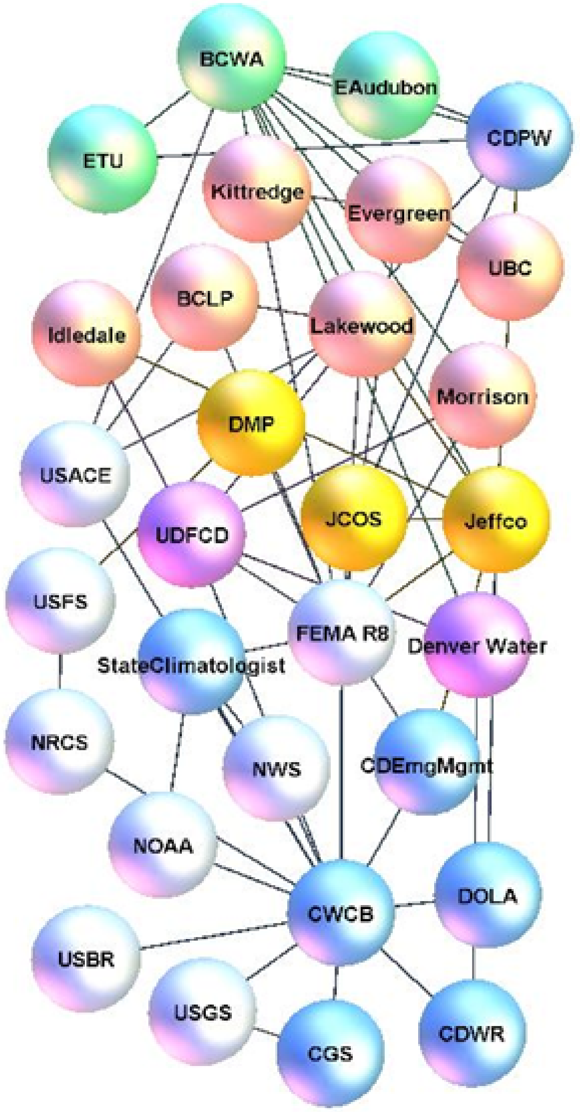
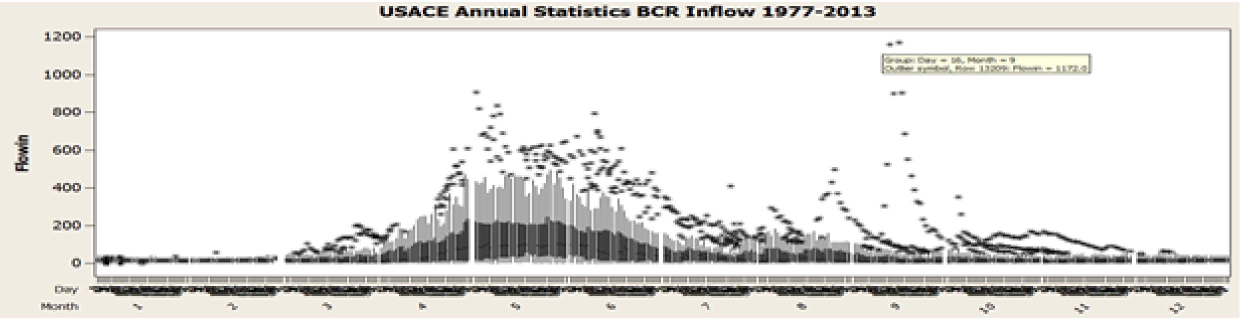


Figure 4. Flood Recovery Relationship between BCWA Members and State-Level Organizations



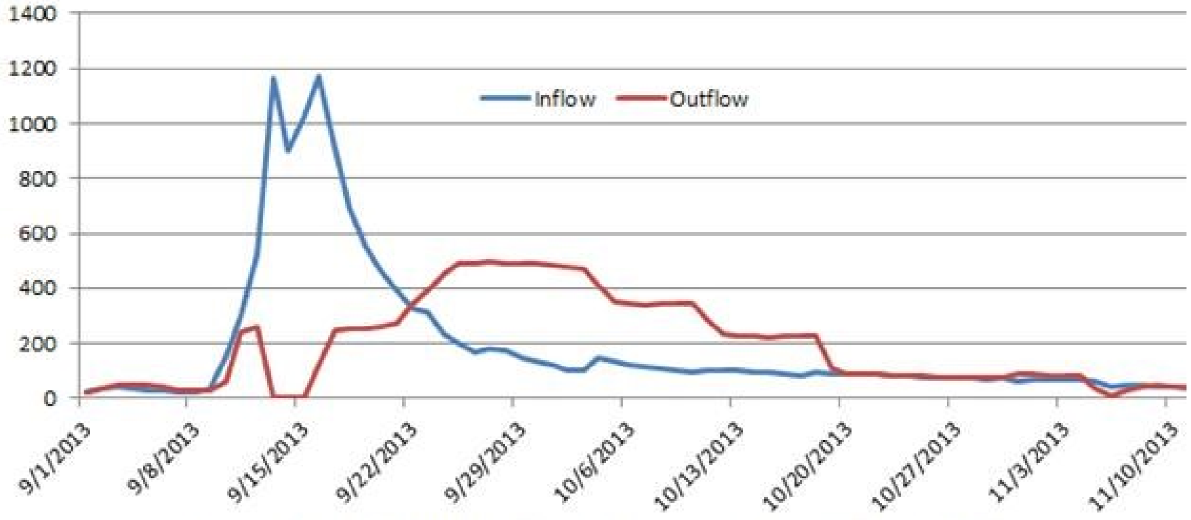


Figure 6. Sept. 2013 BCR Inflow and Outflow (cfs), Source Data: USACE

BCR Effects: Although flood waters reaches a pool elevation of 5608 ft. MSL, they only remained at that level for 2.3 days (Figure 6, Table 4). Data suggests that only a portion of fine sediments had time to settle and some were covered with coarser grained sands. Exposed sediment analysis (p. 3) does not seem to indicate that TP levels were higher in the transported sediment in the September 2013 flood than previously determined in existing bottom sediments by SePRO in 2012. In fact, 2013 pre-flood seasonal TP averages were already over 100 ug/L, so it is unlikely that the flood will cause an *ecological reset*, or worsen the internal loading problem that had already reached particularly elevated levels in both 2012 and 2013 growing seasons. A central BCR pool soil core taken in July 2014 at a 35 foot depth showed that organic matter had increased from 8% to 12% compared to exposed sediments.

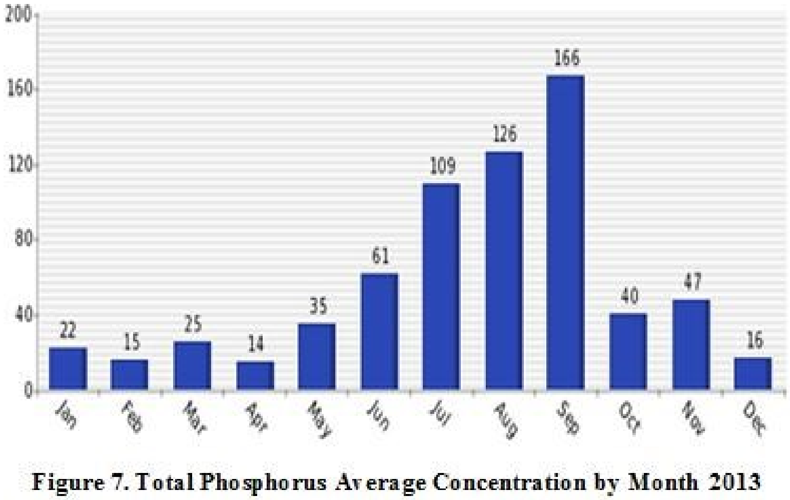


Figure 7. Total Phosphorus Average Concentration by Month 2013

Table 4. Flood Pool Changes

Elv ft MSL	Area Ac	Vol AF	Days
5558	104	1882	53.0
5563	124	2456	35.0
5568	150	3123	31.0
5573	177	3909	27.2
5578	206	4852	26.1
5583	238	5950	23.3
5588	277	7246	19.7
5593	326	8753	16.7
5598	374	10426	12.7
5603	418	12317	9.6
5608	469	14370	2.3

Flood Survey: Survey residents, businesses, and public landowners and government agencies affected by the flood to record lessons learned.

Further Reduce TP discharges during Flood Events: Conduct hydraulic analysis using new LiDAR data to better estimate where flood waters are likely to be most corrosive and cause the most streambank damage for mitigation.

EXHIBIT D-13: WILDFIRE HAZARD ANALYSIS SHEET

Bear Creek Watershed Issues Analysis

Nutrient Issue: *Wildfire Hazard, Nutrients, and Source Water Protection*

Analyst: MT Herzog
Date: August 18, 2014

Description: Wildfires have been shown to be a significant source of sediment, containing high levels of TP, in addition to carbon and nitrogen. Therefore, it is of primary concern from a source water protection standpoint. During study development, EMD received CWCB funding to partner with the Colorado Rural Water Association to develop a detailed Source Water Protection Plan for Evergreen Lake, which is the water supply for the community. During results presentation, participants noted how much the ACM DSS maps and plan input, which included links to a variety of studies conducted in the watershed over time, assisted in these efforts. In Phase II, there is now interest in develop a watershed-level plan for source water protection with particular emphasis on wildfire hazard mitigation.

Data Sources
- JW Phase II Fire Study
- Wildfire Watershed Protection Group
- FireWise Communities
- Jeffco Sheriff Wildfire
- CCC Wildfire P Plan
- Hayman Fire Case Study
- CSFS Wildfire Mitigation

In 2010, the U.S. Forest Service commissioned a Clear Creek/Bear Creek Phase 1 Watershed Assessment due to concern about expanses of bark beetle infestation and tree kill (USFS 2010). The more detailed Phase 2 Study was completed in early 2013 (JW Associates, LLC 2013). Critical information was developed concerning the risk to water supplies were wildfires to be followed by flooding, causing debris flows and increased sediment yields. The process also produced a wealth of GIS layers and spatial analysis results that were added to the ACM DSS. Component layers include wildfire hazard rankings based on forest conditions, ruggedness, road density, flooding or debris hazard flow ranking, soil erodibility to develop a Composite Hazard Ranking to superimpose on water supply. In Phase I, Vance Creek in the relatively undeveloped headwaters tributary north of the mainstem Bear Creek headwaters, as well as, the Evergreen Lake area were both relatively susceptible listing as Category 4 Moderate Hazard Risks, which could potentially affect the town's water supply.

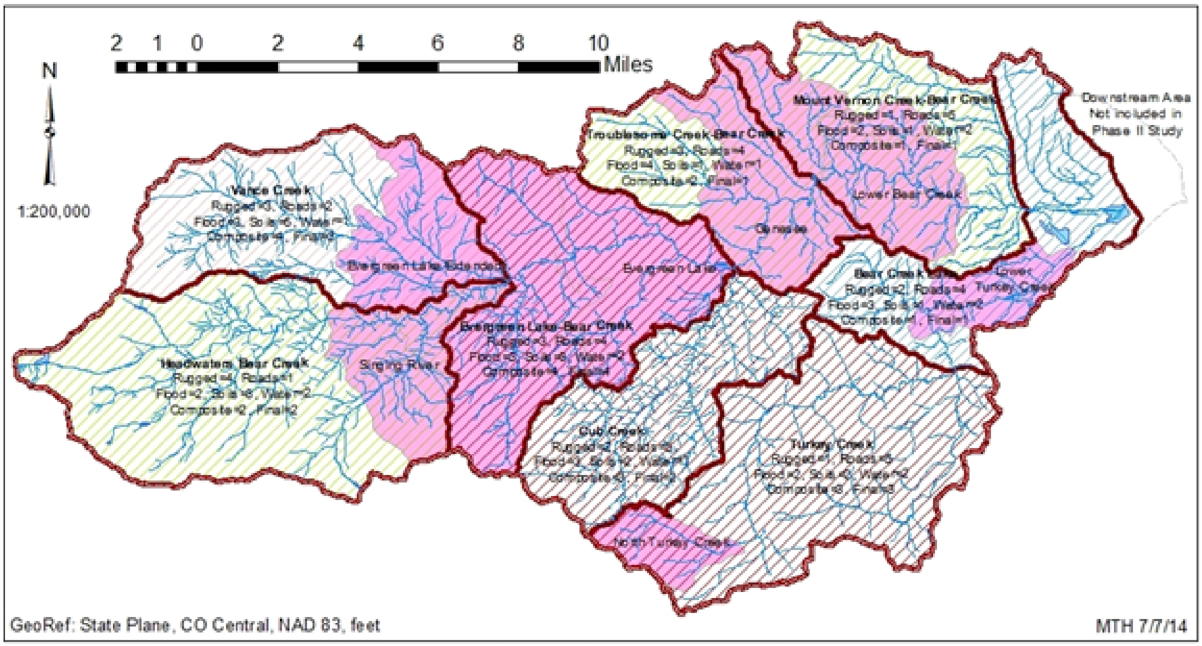


Figure 1. JW Associates Phase II Fire Study Results by Bear Creek Watershed Subbasin

Legend

▭ BCWA Control Boundary
▭ USGS HUC 12 Sub-basins
▨ Zones of Concern

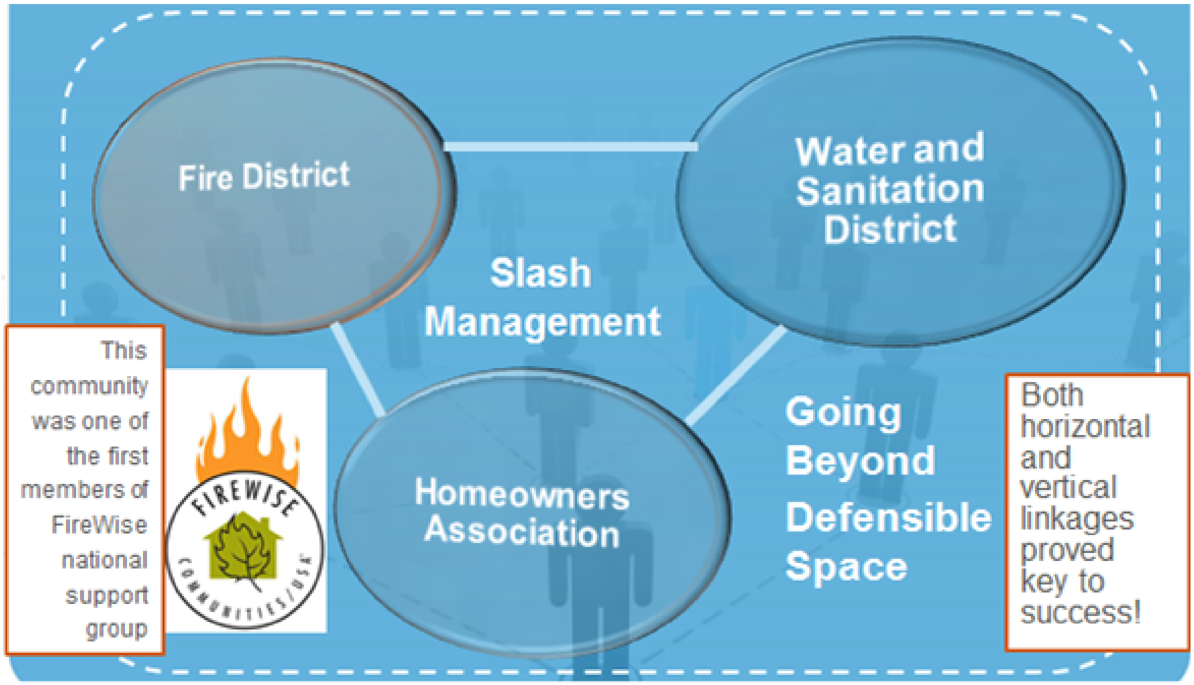
Wildfire Hazard Priority

▨ 1 ▨ 2 ▨ 4 ▨ 5

Notes

Analysis was complete by subbasins as shown.
The Final hazard priority for each subbasin was determined by combining component risk factors listed.
Zones of concern represent focus areas for mitigation.
Review the complete Phase I & Phase II
Clear / Bear Creek Wildfire Watershed Assessment
at: http://www.jw-associates.org/clearbearcreek.html.

SNA: JCD in partnership with the Natural Resources Conservation Service (NRCS), who provides most of its funding for projects on private lands, was found through study interviews and JCD meeting attendance to be clear cutting large swaths of trees on several large ranches. The triad below demonstrates through SNA how one community interviewed in the case study area developed an effective partnership among the homeowners association (HOA), which has its own fire coordinator, the local fire district, the water and sanitation district, and the national FireWise program to support whole community fire mitigation measures. Linking the three local level organizations (horizontal linkages) with the county and state fire protection agencies and the national community programs (vertical linkages) ensure that this community is one of the most advanced in fire mitigation. Collaborative innovations include HOA covenants that require approval and marking for all tree removal, chipping and hauling services, providing fire protection water connectors to downwind communities, and coordination among diverse groups. This model could serve as a template to improve fire protection community-by-community throughout the watershed or expand the scale watershed or county-wide to the extent feasible. By uncovering such best practices, the ACM DSS process provides an important pro-active orientation towards disaster management.



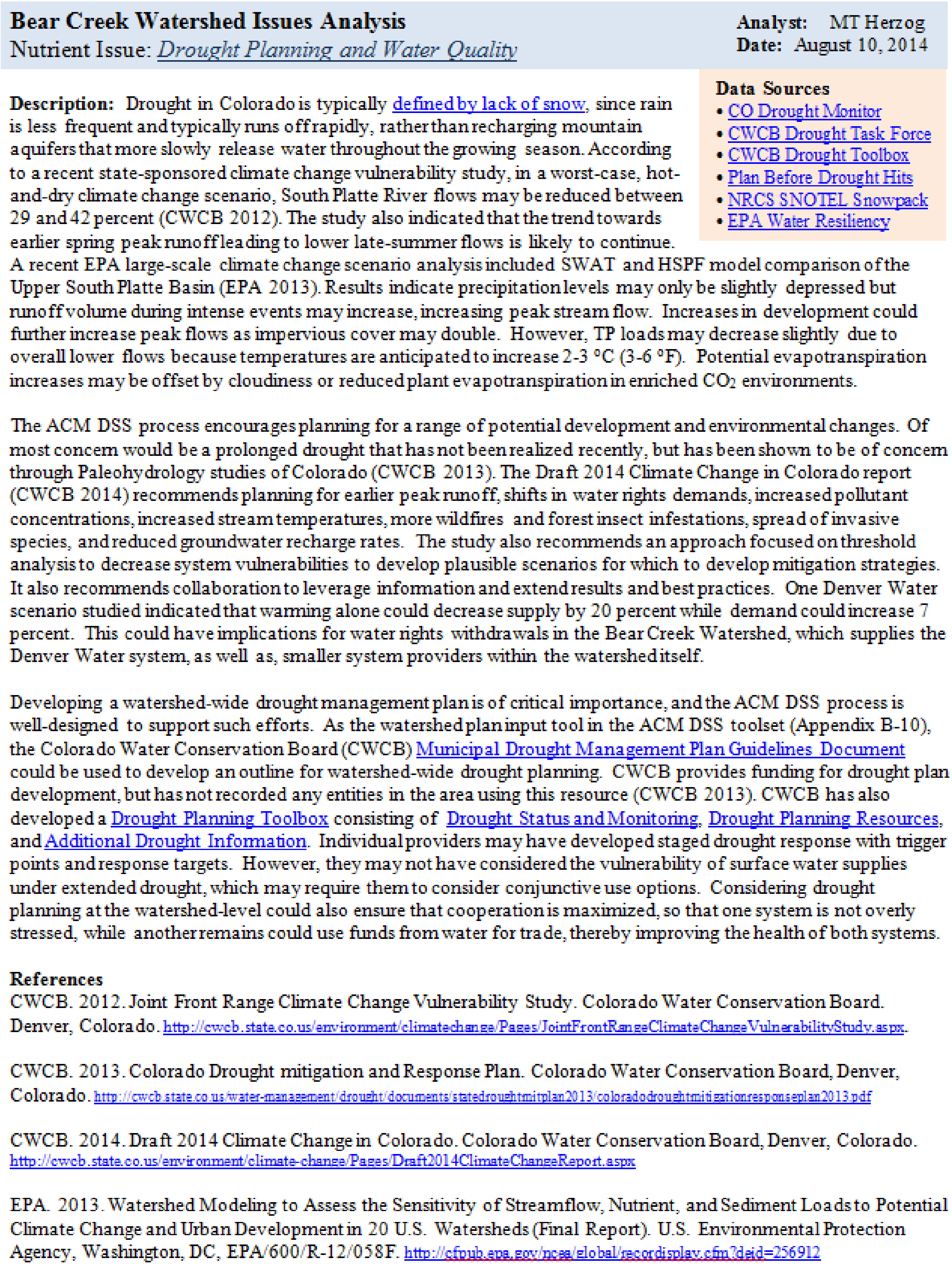
This community was one of the first members of FireWise national support group

Both horizontal and vertical linkages proved key to success!

Figure 2. Strongly Bonded Three-Member Community Partnership for Fire Hazard Mitigation

Potential Options: Pre-permit sedimentation basins. Develop formal memorandum of understanding with CUSP, the watershed to the south, which has helped other watersheds recover based on their experience with Hayman Fire. Develop a watershed-wide source water protection program that includes working with all fire districts and sheriff offices to develop a coordinated wildfire plan and more controlled burns. Map out all large areas where Jefferson Conservation District has worked with landowners to cut down areas that are too dense. Map out all controlled burn areas on public lands and other mitigation measures through FireWise neighborhoods and other efforts. Analyze community wildfire protection plans to determine what measures have not yet been implemented to prioritize. Work with counties to develop a regional slash management plan with more locations to drop off tree limbs and trunks.

EXHIBIT D-14: DROUGHT PLANNING ANALYSIS SHEET



Bear Creek Watershed Issues Analysis

Nutrient Issue: *Drought Planning and Water Quality*

Analyst: MT Herzog
Date: August 10, 2014

Data Sources
- CO Drought Monitor
- CWCB Drought Task Force
- CWCB Drought Toolbox
- Plan Before Drought Hits
- NRCS SNOTEL Snowpack
- EPA Water Resiliency

Description: Drought in Colorado is typically defined by lack of snow, since rain is less frequent and typically runs off rapidly, rather than recharging mountain aquifers that more slowly release water throughout the growing season. According to a recent state-sponsored climate change vulnerability study, in a worst-case, hot-and-dry climate change scenario, South Platte River flows may be reduced between 29 and 42 percent (CWCB 2012). The study also indicated that the trend towards earlier spring peak runoff leading to lower late-summer flows is likely to continue. A recent EPA large-scale climate change scenario analysis included SWAT and HSPF model comparison of the Upper South Platte Basin (EPA 2013). Results indicate precipitation levels may only be slightly depressed but runoff volume during intense events may increase, increasing peak stream flow. Increases in development could further increase peak flows as impervious cover may double. However, TP loads may decrease slightly due to overall lower flows because temperatures are anticipated to increase 2-3 °C (3-6 °F). Potential evapotranspiration increases may be offset by cloudiness or reduced plant evapotranspiration in enriched CO_2 environments.

The ACM DSS process encourages planning for a range of potential development and environmental changes. Of most concern would be a prolonged drought that has not been realized recently, but has been shown to be of concern through Paleohydrology studies of Colorado (CWCB 2013). The Draft 2014 Climate Change in Colorado report (CWCB 2014) recommends planning for earlier peak runoff, shifts in water rights demands, increased pollutant concentrations, increased stream temperatures, more wildfires and forest insect infestations, spread of invasive species, and reduced groundwater recharge rates. The study also recommends an approach focused on threshold analysis to decrease system vulnerabilities to develop plausible scenarios for which to develop mitigation strategies. It also recommends collaboration to leverage information and extend results and best practices. One Denver Water scenario studied indicated that warming alone could decrease supply by 20 percent while demand could increase 7 percent. This could have implications for water rights withdrawals in the Bear Creek Watershed, which supplies the Denver Water system, as well as, smaller system providers within the watershed itself.

Developing a watershed-wide drought management plan is of critical importance, and the ACM DSS process is well-designed to support such efforts. As the watershed plan input tool in the ACM DSS toolset (Appendix B-10), the Colorado Water Conservation Board (CWCB) Municipal Drought Management Plan Guidelines Document could be used to develop an outline for watershed-wide drought planning. CWCB provides funding for drought plan development, but has not recorded any entities in the area using this resource (CWCB 2013). CWCB has also developed a Drought Planning Toolbox consisting of Drought Status and Monitoring, Drought Planning Resources, and Additional Drought Information. Individual providers may have developed staged drought response with trigger points and response targets. However, they may not have considered the vulnerability of surface water supplies under extended drought, which may require them to consider conjunctive use options. Considering drought planning at the watershed-level could also ensure that cooperation is maximized, so that one system is not overly stressed, while another remains could use funds from water for trade, thereby improving the health of both systems.

References

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CWCB. 2013. Colorado Drought mitigation and Response Plan. Colorado Water Conservation Board, Denver, Colorado. http://cwcb.state.co.us/water-management/drought/documents/statedroughtmitplan2013/coloradodroughtmitigationresponseplan2013.pdf

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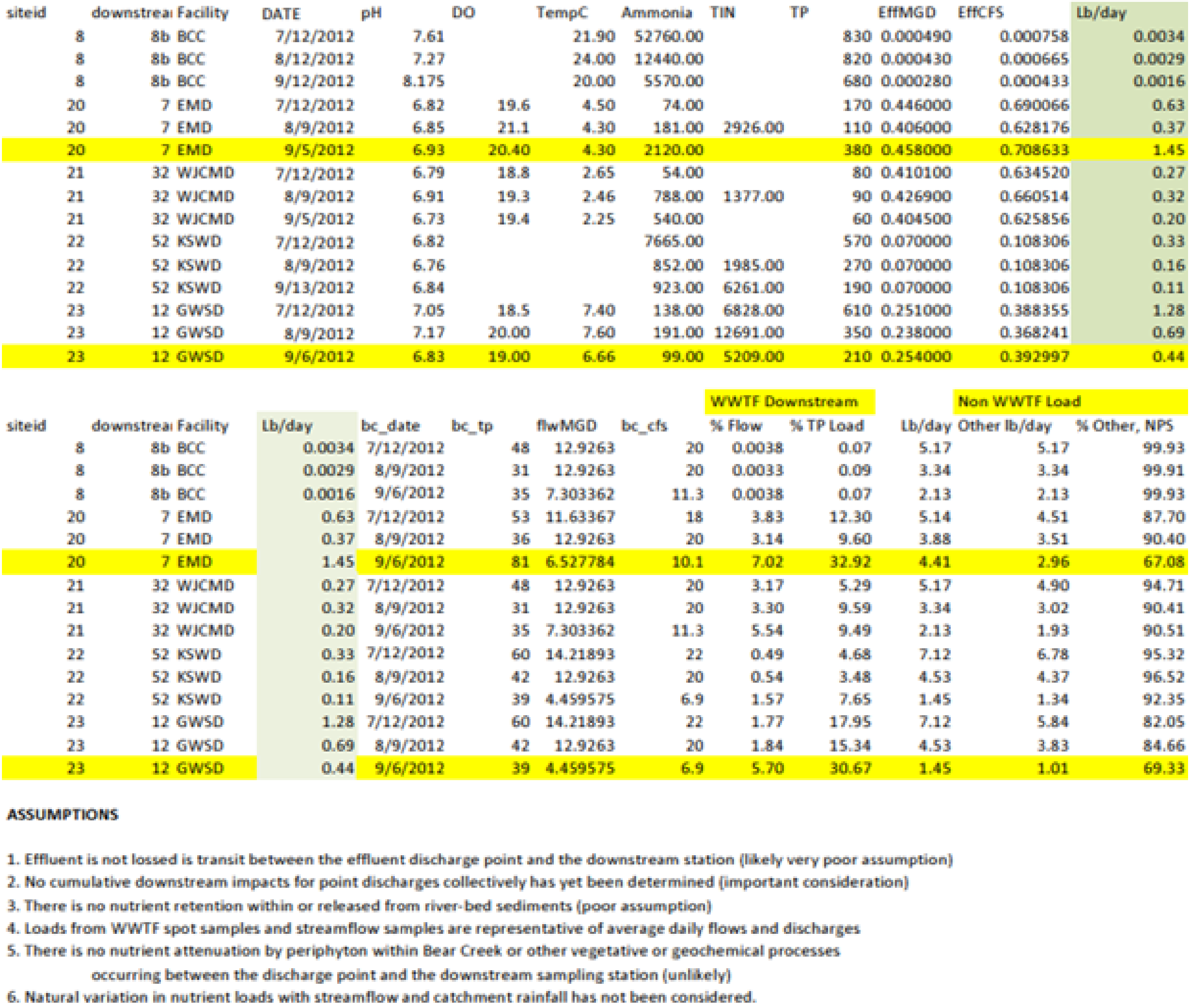
EPA. 2013. Watershed Modeling to Assess the Sensitivity of Streamflow, Nutrient, and Sediment Loads to Potential Climate Change and Urban Development in 20 U.S. Watersheds (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-12/058F. http://cfpub.epa.gov/ncea/global/recordisplay.cfm?deid=256912

Drought Analysis: During summer months, especially in low flow years, phosphorus loads are further reduced by the portion diverted out of the watershed before it reaches BCR. Turkey Creek can be dewatered by Bergen Ditch (600 to 1,700 AF/yr), the Independent Highline Canal (100-300 AF/yr), and the Warrior/Harriman D, if any water remains downstream of the other two diversion as it enters BCLP, but diversion records indicate that Turkey Creek streamflow was too low 2008-20012 for any more to be diverted. Harriman & Ward Ditches upstream of BCLP divert water from Bear Creek upstream of BCLP. Since 2009, addition withdrawals have been taken from Harriman ditch for the Warrior Ditch, increasing diversions from about 500 AF to about 750 AF/annually, while Ward Ditch withdraws an additional 200 to 300 AF in most years. In addition to not providing minimum streamflows that are provided in most reaches upstream of these diversions, the Bear Creek diversions also reduce dilution streamflow for Morrison WWTF that discharges in BCLP downstream. (See Appendix D, Exhibit D-7 Water Rights Analysis.)

Annual and seasonal low flows may cause elevated proportions to derive from WWTFs wastewater effluent (Table 1). For example, during summer low flow months of July through September 2012, each large WWTFs contributed up to about 30 percent of the TP load individually, and more collectively. Below the last diversion, when almost all water is removed in the summer, the Morrison WWTF could contribute more than 70 percent of the TP load before plant upgrades reduced loading in 2013 by more than half. This does not take into consideration the assimilative capacity of the stream. Unfortunately, although plant and periphyton growth might be expected to reduce some of the direct WWTF loading, stream sediments have been found in at least some cases to tend to release additional TP during summer through altered redox potentials under higher temperatures, more radiation, and greater biological activity. Therefore, P flux from stream sediments, in addition to sediment transport itself, alter loading continually.

Table 1. WWTF Effluent Discharges in Comparison to Worst Case Low Flow Scenario in 2012



siteid	downstrea	Facility	DATE	pH	DO	TempC	Ammonia	TIN	TP	EffMGD	EffCFS	Lb/day
8	8b	BCC	7/12/2012	7.61		21.90	52760.00		830	0.000490	0.000758	0.0034
8	8b	BCC	8/12/2012	7.27		24.00	12440.00		820	0.000430	0.000665	0.0029
8	8b	BCC	9/12/2012	8.175		20.00	5570.00		680	0.000280	0.000433	0.0016
20	7	EMD	7/12/2012	6.82	19.6	4.50	74.00		170	0.446000	0.690066	0.63
20	7	EMD	8/9/2012	6.85	21.1	4.30	181.00	2926.00	110	0.406000	0.628176	0.37
20	7	EMD	9/5/2012	6.93	20.40	4.30	2120.00		380	0.458000	0.708633	1.45
21	32	WJCMD	7/12/2012	6.79	18.8	2.65	54.00		80	0.410100	0.634520	0.27
21	32	WJCMD	8/9/2012	6.91	19.3	2.46	788.00	1377.00	90	0.426900	0.660514	0.32
21	32	WJCMD	9/5/2012	6.73	19.4	2.25	540.00		60	0.404500	0.625856	0.20
22	52	KSWD	7/12/2012	6.82			7665.00		570	0.070000	0.108306	0.33
22	52	KSWD	8/9/2012	6.76			852.00	1985.00	270	0.070000	0.108306	0.16
22	52	KSWD	9/13/2012	6.84			923.00	6261.00	190	0.070000	0.108306	0.11
23	12	GWSD	7/12/2012	7.05	18.5	7.40	138.00	6828.00	610	0.251000	0.388355	1.28
23	12	GWSD	8/9/2012	7.17	20.00	7.60	191.00	12691.00	350	0.238000	0.368241	0.69
23	12	GWSD	9/6/2012	6.83	19.00	6.66	99.00	5209.00	210	0.254000	0.392997	0.44

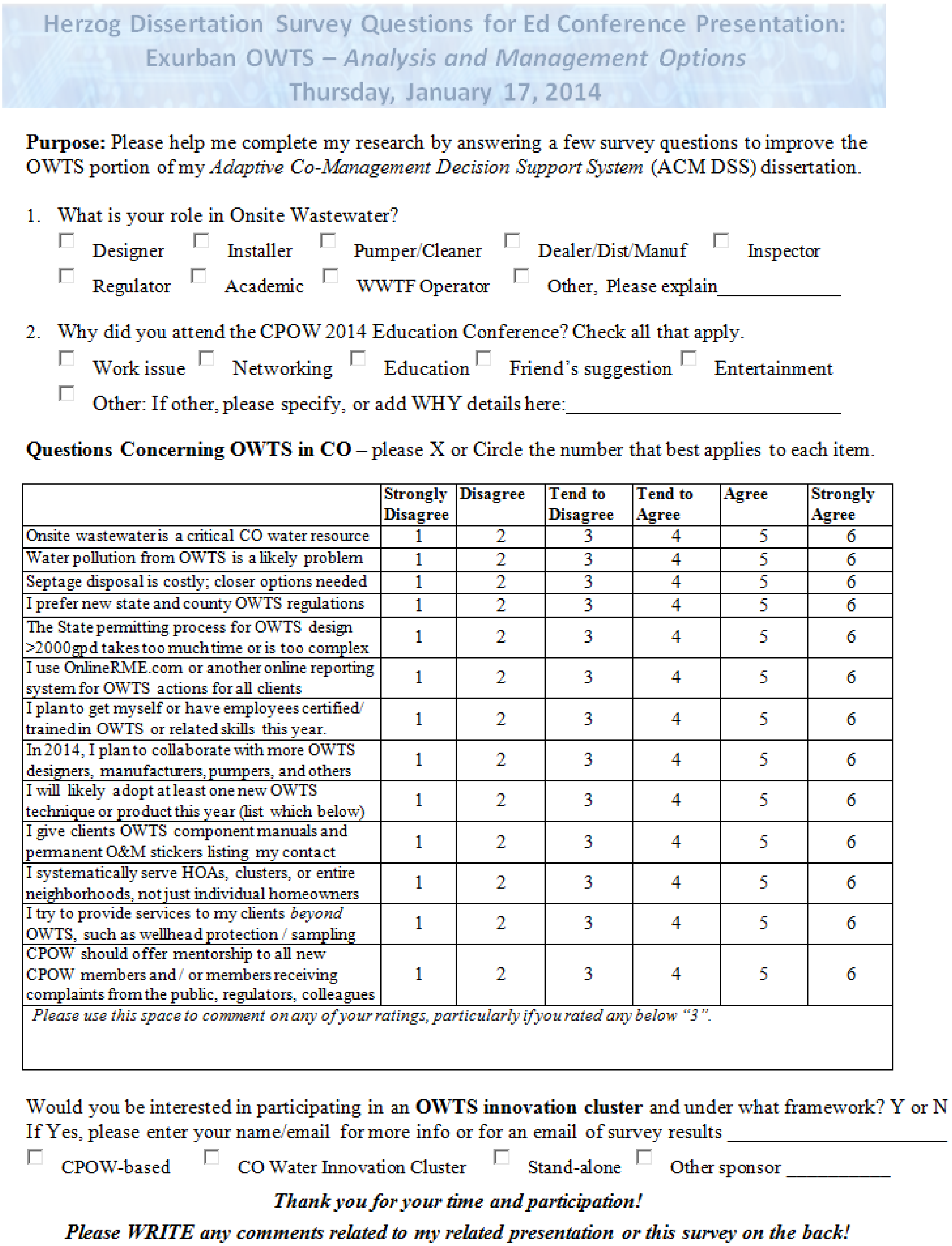
								WWTF Downstream			Non WWTF Load	
siteid	downstrea	Facility	Lb/day	bc_date	bc_tp	flwMGD	bc_cfs	% Flow	% TP Load	Lb/day	Other lb/day	% Other, NPS
8	8b	BCC	0.0034	7/12/2012	48	12.9263	20	0.0038	0.07	5.17	5.17	99.93
8	8b	BCC	0.0029	8/9/2012	31	12.9263	20	0.0033	0.09	3.34	3.34	99.91
8	8b	BCC	0.0016	9/6/2012	35	7.303362	11.3	0.0038	0.07	2.13	2.13	99.93
20	7	EMD	0.63	7/12/2012	53	11.63367	18	3.83	12.30	5.14	4.51	87.70
20	7	EMD	0.37	8/9/2012	36	12.9263	20	3.14	9.60	3.88	3.51	90.40
20	7	EMD	1.45	9/6/2012	81	6.527784	10.1	7.02	32.92	4.41	2.96	67.08
21	32	WJCMD	0.27	7/12/2012	48	12.9263	20	3.17	5.29	5.17	4.90	94.71
21	32	WJCMD	0.32	8/9/2012	31	12.9263	20	3.30	9.59	3.34	3.02	90.41
21	32	WJCMD	0.20	9/6/2012	35	7.303362	11.3	5.54	9.49	2.13	1.93	90.51
22	52	KSWD	0.33	7/12/2012	60	14.21893	22	0.49	4.68	7.12	6.78	95.32
22	52	KSWD	0.16	8/9/2012	42	12.9263	20	0.54	3.48	4.53	4.37	96.52
22	52	KSWD	0.11	9/6/2012	39	4.459575	6.9	1.57	7.65	1.45	1.34	92.35
23	12	GWSD	1.28	7/12/2012	60	14.21893	22	1.77	17.95	7.12	5.84	82.05
23	12	GWSD	0.69	8/9/2012	42	12.9263	20	1.84	15.34	4.53	3.83	84.66
23	12	GWSD	0.44	9/6/2012	39	4.459575	6.9	5.70	30.67	1.45	1.01	69.33

ASSUMPTIONS

1. Effluent is not lossed is transit between the effluent discharge point and the downstream station (likely very poor assumption)
2. No cumulative downstream impacts for point discharges collectively has yet been determined (important consideration)
3. There is no nutrient retention within or released from river-bed sediments (poor assumption)
4. Loads from WWTF spot samples and streamflow samples are representative of average daily flows and discharges
5. There is no nutrient attenuation by periphyton within Bear Creek or other vegetative or geochemical processes occurring between the discharge point and the downstream sampling station (unlikely)
6. Natural variation in nutrient loads with streamflow and catchment rainfall has not been considered.

APPENDIX E. CONFERENCE SURVEYS, SNA SUMMARY, COLLABORATIVE CAPACITY ASSESSMENT

EXHIBIT 1. 2014 CPOW ANNUAL CONFERENCE SURVEY RESULTS



Herzog Dissertation Survey Questions for Ed Conference Presentation:
Exurban OWTS – *Analysis and Management Options*
Thursday, January 17, 2014

Purpose: Please help me complete my research by answering a few survey questions to improve the OWTS portion of my *Adaptive Co-Management Decision Support System* (ACM DSS) dissertation.

1. What is your role in Onsite Wastewater?

☐ Designer ☐ Installer ☐ Pumper/Cleaner ☐ Dealer/Dist/Manuf ☐ Inspector
☐ Regulator ☐ Academic ☐ WWTF Operator ☐ Other, Please explain____________

2. Why did you attend the CPOW 2014 Education Conference? Check all that apply.

☐ Work issue ☐ Networking ☐ Education ☐ Friend's suggestion ☐ Entertainment
☐ Other: If other, please specify, or add WHY details here:________________________

Questions Concerning OWTS in CO – please X or Circle the number that best applies to each item.

	Strongly Disagree	**Disagree**	**Tend to Disagree**	**Tend to Agree**	**Agree**	**Strongly Agree**
Onsite wastewater is a critical CO water resource	1	2	3	4	5	6
Water pollution from OWTS is a likely problem	1	2	3	4	5	6
Septage disposal is costly; closer options needed	1	2	3	4	5	6
I prefer new state and county OWTS regulations	1	2	3	4	5	6
The State permitting process for OWTS design >2000gpd takes too much time or is too complex	1	2	3	4	5	6
I use OnlineRME.com or another online reporting system for OWTS actions for all clients	1	2	3	4	5	6
I plan to get myself or have employees certified/ trained in OWTS or related skills this year.	1	2	3	4	5	6
In 2014, I plan to collaborate with more OWTS designers, manufacturers, pumpers, and others	1	2	3	4	5	6
I will likely adopt at least one new OWTS technique or product this year (list which below)	1	2	3	4	5	6
I give clients OWTS component manuals and permanent O&M stickers listing my contact	1	2	3	4	5	6
I systematically serve HOAs, clusters, or entire neighborhoods, not just individual homeowners	1	2	3	4	5	6
I try to provide services to my clients *beyond* OWTS, such as wellhead protection / sampling	1	2	3	4	5	6
CPOW should offer mentorship to all new CPOW members and / or members receiving complaints from the public, regulators, colleagues	1	2	3	4	5	6
Please use this space to comment on any of your ratings, particularly if you rated any below "3".						

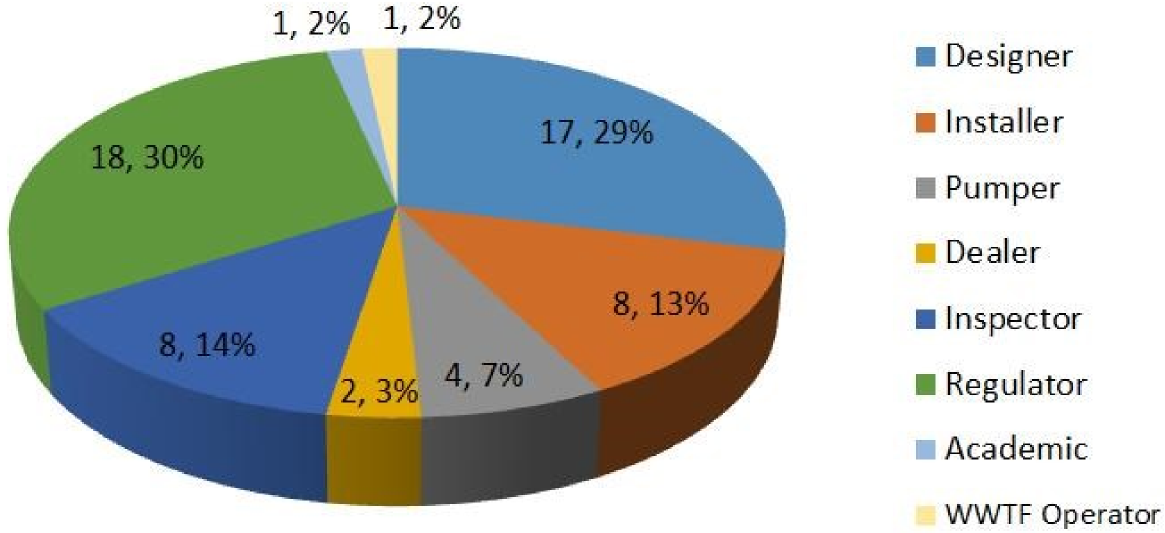
Would you be interested in participating in an **OWTS innovation cluster** and under what framework? Y or N
If Yes, please enter your name/email for more info or for an email of survey results ____________________

☐ CPOW-based ☐ CO Water Innovation Cluster ☐ Stand-alone ☐ Other sponsor __________

Thank you for your time and participation!

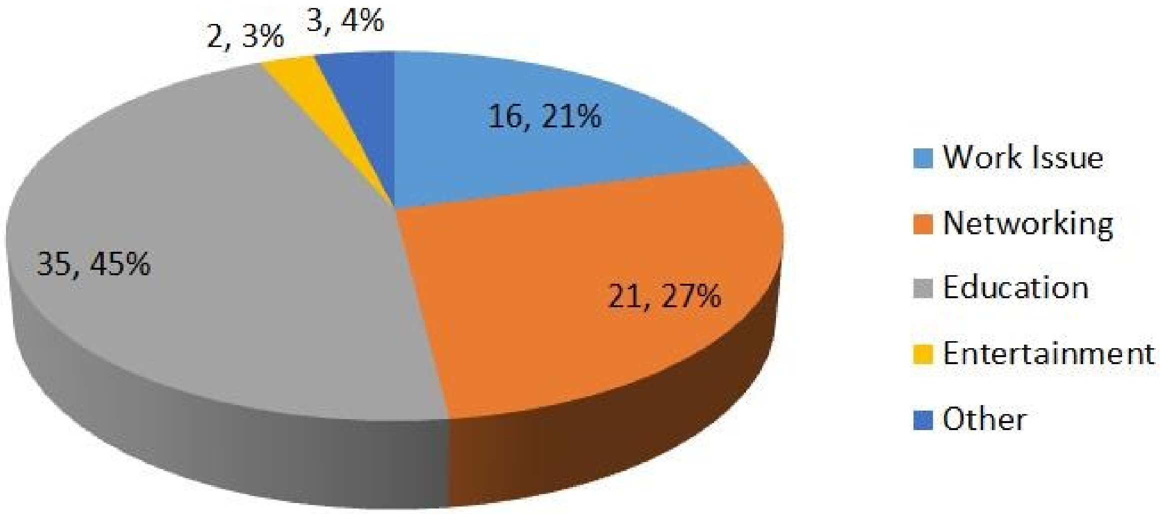
Please WRITE any comments related to my related presentation or this survey on the back!

CPOW 2014 Survey Respondents

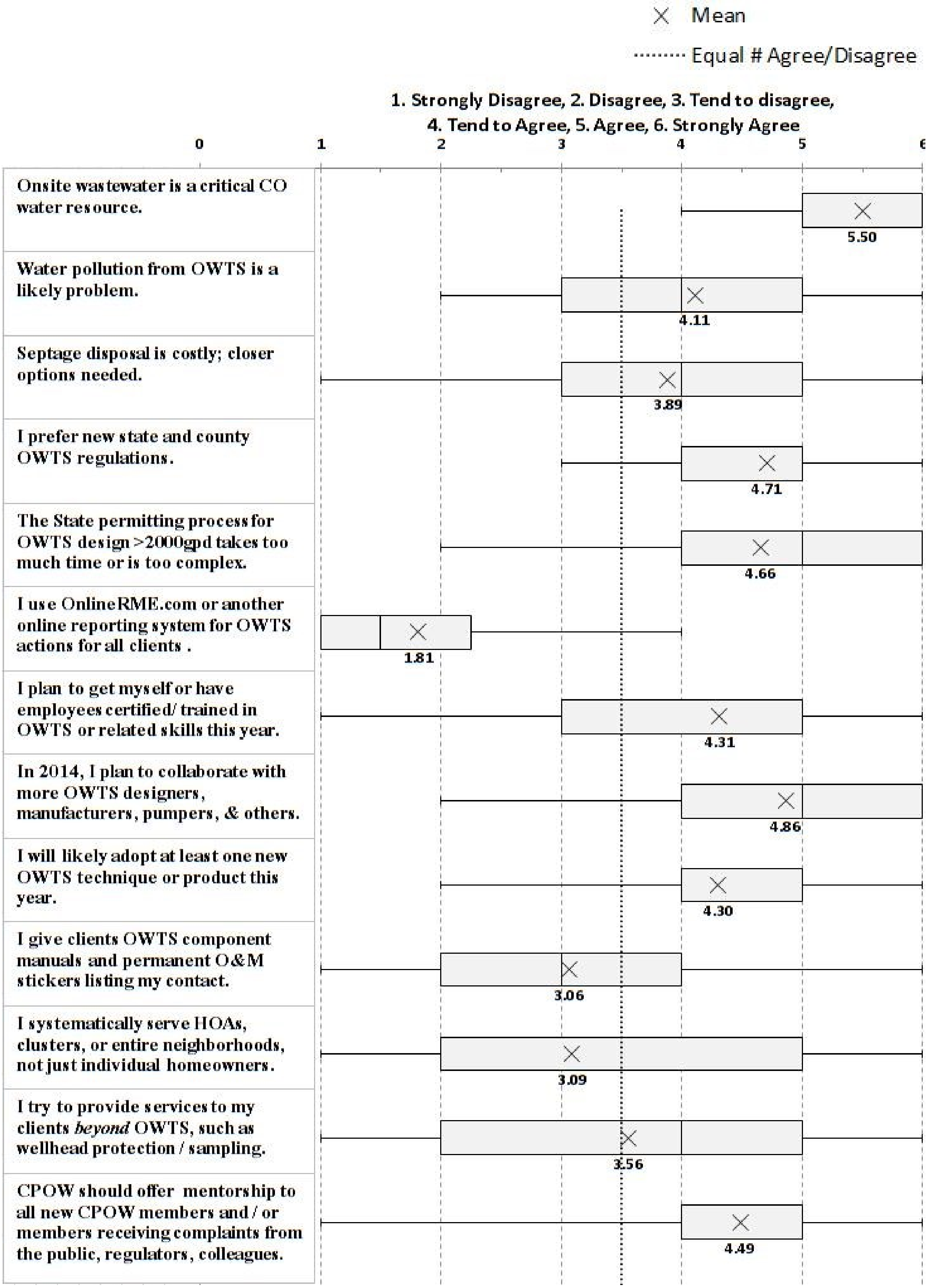


41 of about 80 attendees responding
Some respondents reported multiple roles in onsite wastewater

CPOW 2014 Reasons for Attending

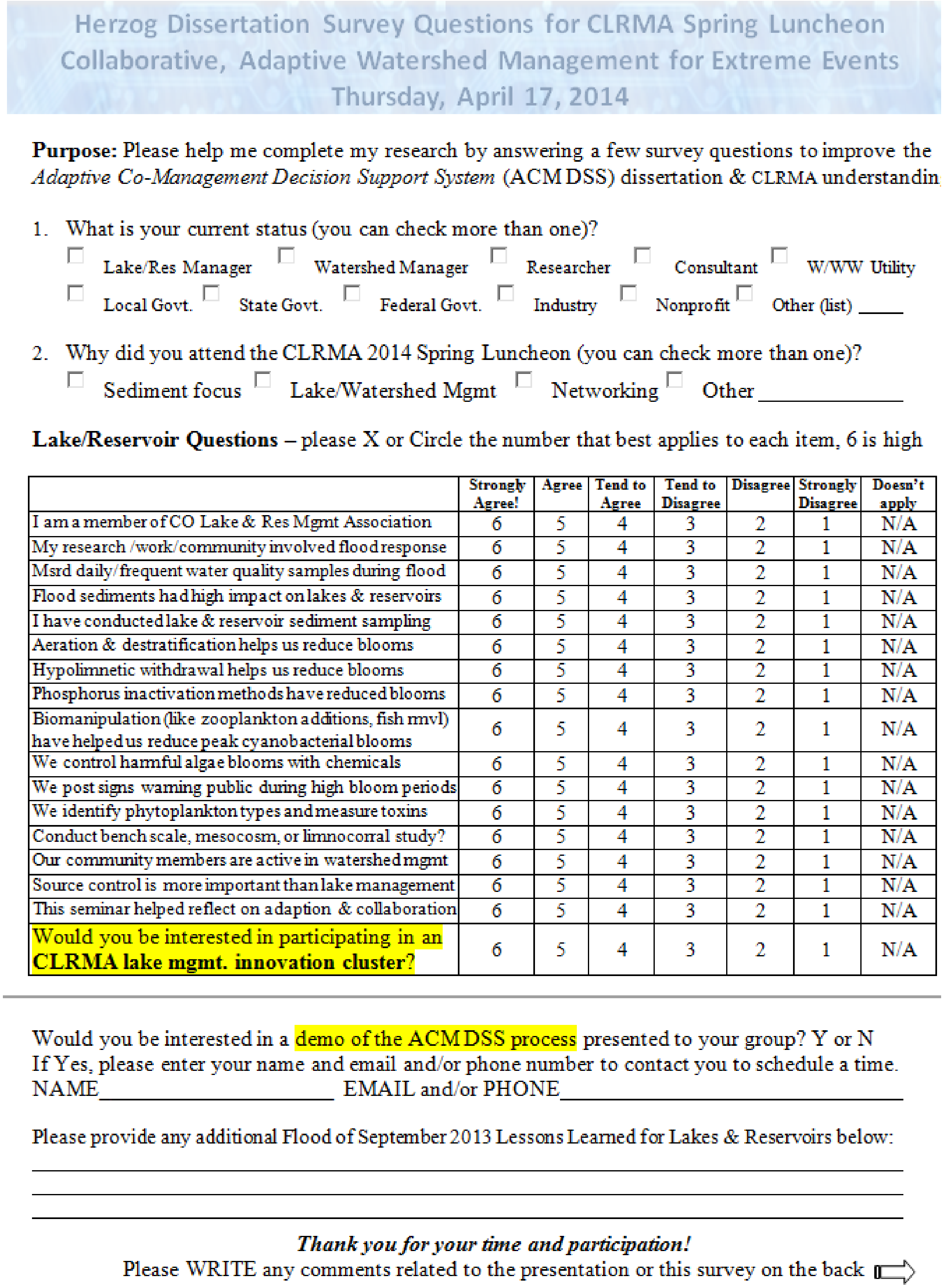


Some respondents reported multiple reasons for attending, Other reasons for attending included: NAWT recertification, to see additional technology advancements, and coming as a CPOW founder's tradition.



× Mean
········ Equal # Agree/Disagree
1. Strongly Disagree, 2. Disagree, 3. Tend to disagree,
4. Tend to Agree, 5. Agree, 6. Strongly Agree
0
1
2
3
4
5
Onsite wastewater is a critical CO water resource.
5.50
Water pollution from OWTS is a likely problem.
4.11
Septage disposal is costly; closer options needed.
3.89
I prefer new state and county OWTS regulations.
4.71
The State permitting process for OWTS design >2000gpd takes too much time or is too complex.
4.66
I use OnlineRME.com or another online reporting system for OWTS actions for all clients .
1.81
I plan to get myself or have employees certified/ trained in OWTS or related skills this year.
4.31
In 2014, I plan to collaborate with more OWTS designers, manufacturers, pumpers, & others.
4.86
I will likely adopt at least one new OWTS technique or product this year.
4.30
I give clients OWTS component manuals and permanent O&M stickers listing my contact.
3.06
I systematically serve HOAs, clusters, or entire neighborhoods, not just individual homeowners.
3.09
I try to provide services to my clients *beyond* OWTS, such as wellhead protection / sampling.
3.56
CPOW should offer mentorship to all new CPOW members and / or members receiving complaints from the public, regulators, colleagues.
4.49

EXHIBIT 2. 2014 CLRMA SPRING LUNCHEON SURVEY RESULTS



Herzog Dissertation Survey Questions for CLRMA Spring Luncheon
Collaborative, Adaptive Watershed Management for Extreme Events
Thursday, April 17, 2014

Purpose: Please help me complete my research by answering a few survey questions to improve the *Adaptive Co-Management Decision Support System* (ACM DSS) dissertation & CLRMA understandin

1. What is your current status (you can check more than one)?
   ☐ Lake/Res Manager ☐ Watershed Manager ☐ Researcher ☐ Consultant ☐ W/WW Utility
   ☐ Local Govt. ☐ State Govt. ☐ Federal Govt. ☐ Industry ☐ Nonprofit ☐ Other (list) _____

2. Why did you attend the CLRMA 2014 Spring Luncheon (you can check more than one)?
   ☐ Sediment focus ☐ Lake/Watershed Mgmt ☐ Networking ☐ Other ____________

Lake/Reservoir Questions – please X or Circle the number that best applies to each item, 6 is high

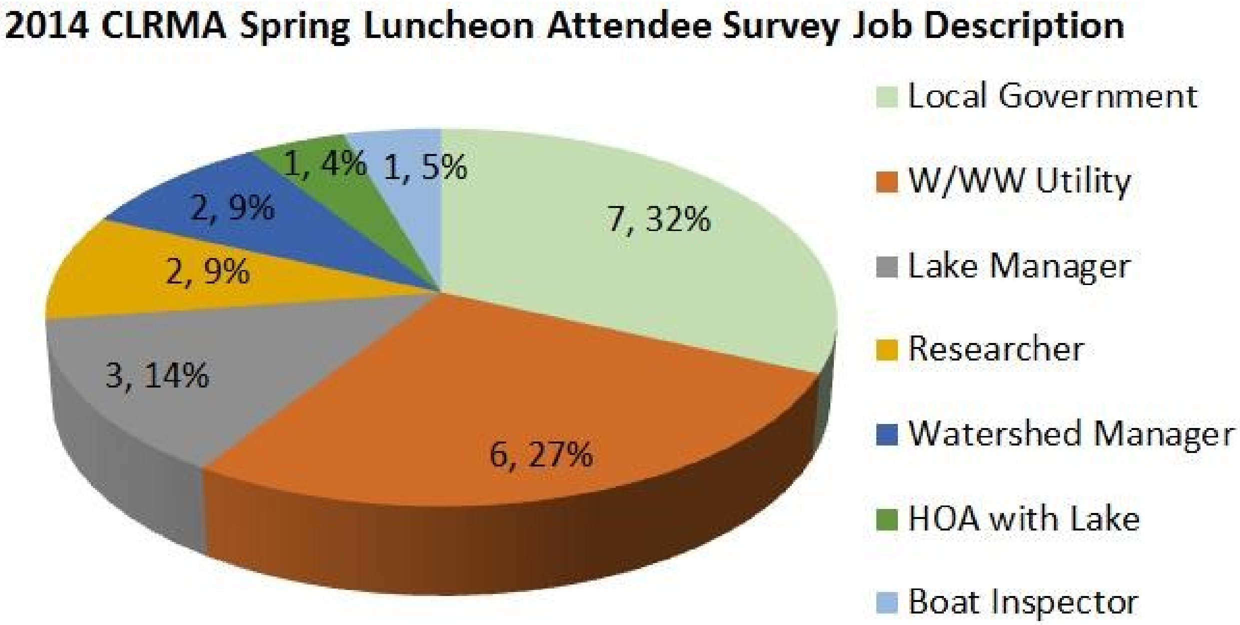
	Strongly Agree!	**Agree**	**Tend to Agree**	**Tend to Disagree**	**Disagree**	**Strongly Disagree**	**Doesn't apply**
I am a member of CO Lake & Res Mgmt Association	6	5	4	3	2	1	N/A
My research /work/community involved flood response	6	5	4	3	2	1	N/A
Msrd daily/frequent water quality samples during flood	6	5	4	3	2	1	N/A
Flood sediments had high impact on lakes & reservoirs	6	5	4	3	2	1	N/A
I have conducted lake & reservoir sediment sampling	6	5	4	3	2	1	N/A
Aeration & destratification helps us reduce blooms	6	5	4	3	2	1	N/A
Hypolimnetic withdrawal helps us reduce blooms	6	5	4	3	2	1	N/A
Phosphorus inactivation methods have reduced blooms	6	5	4	3	2	1	N/A
Biomanipulation (like zooplankton additions, fish rmvl) have helped us reduce peak cyanobacterial blooms	6	5	4	3	2	1	N/A
We control harmful algae blooms with chemicals	6	5	4	3	2	1	N/A
We post signs warning public during high bloom periods	6	5	4	3	2	1	N/A
We identify phytoplankton types and measure toxins	6	5	4	3	2	1	N/A
Conduct bench scale, mesocosm, or limnocorral study?	6	5	4	3	2	1	N/A
Our community members are active in watershed mgmt	6	5	4	3	2	1	N/A
Source control is more important than lake management	6	5	4	3	2	1	N/A
This seminar helped reflect on adaption & collaboration	6	5	4	3	2	1	N/A
Would you be interested in participating in an **CLRMA lake mgmt. innovation cluster**?	6	5	4	3	2	1	N/A

Would you be interested in a demo of the ACM DSS process presented to your group? Y or N
If Yes, please enter your name and email and/or phone number to contact you to schedule a time.
NAME_____________________ EMAIL and/or PHONE______________________________

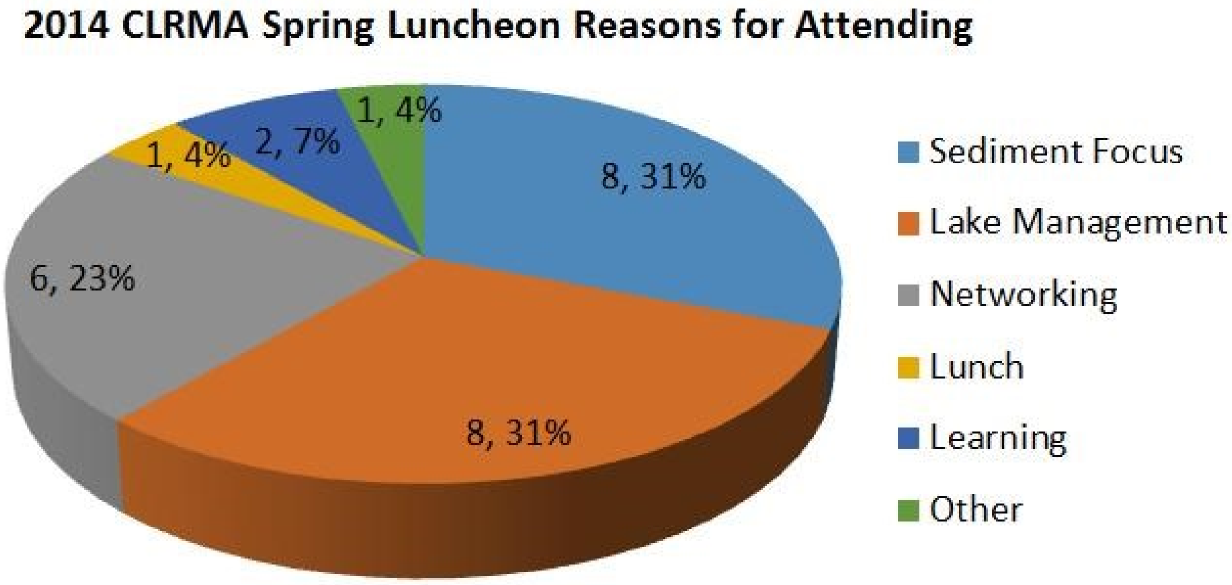
Please provide any additional Flood of September 2013 Lessons Learned for Lakes & Reservoirs below:

____
____
____

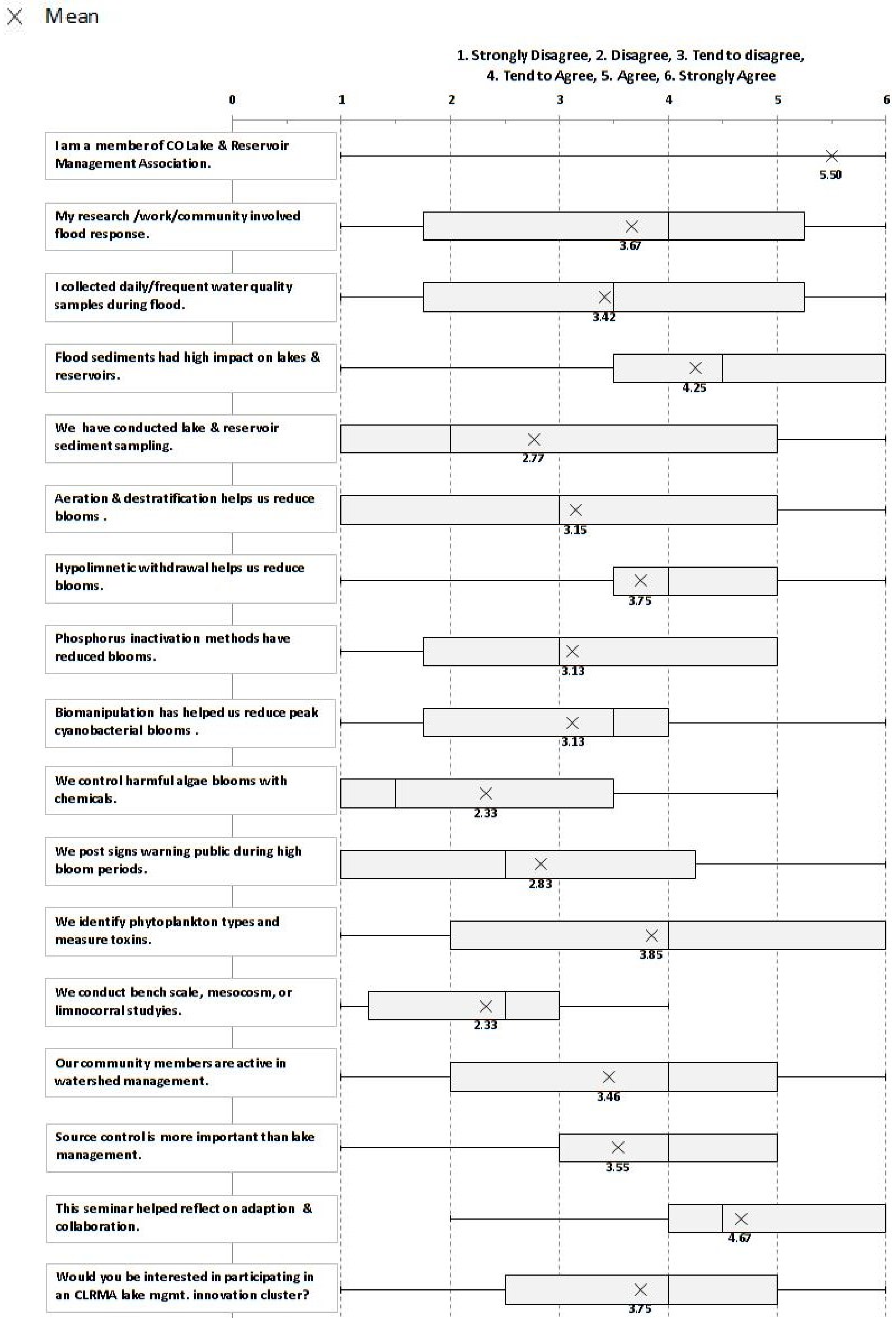
Thank you for your time and participation!
Please WRITE any comments related to the presentation or this survey on the back ⇨



14/40 attendees responding. Some respondenst indicated more than one role.



Some respondents reported multiple reasons for attending, Other reasons for attending included: NAWT recertification, to see additional technology advancements, and coming as a CPOW founder's tradition.


Mean
1. Strongly Disagree, 2. Disagree, 3. Tend to disagree, 4. Tend to Agree, 5. Agree, 6. Strongly Agree
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6
I am a member of CO Lake & Reservoir Management Association.
5.50
My research /work/community involved flood response.
3.67
I collected daily/frequent water quality samples during flood.
3.42
Flood sediments had high impact on lakes & reservoirs.
4.25
We have conducted lake & reservoir sediment sampling.
2.77
Aeration & destratification helps us reduce blooms .
3.15
Hypolimnetic withdrawal helps us reduce blooms.
3.75
Phosphorus inactivation methods have reduced blooms.
3.13
Biomanipulation has helped us reduce peak cyanobacterial blooms .
3.13
We control harmful algae blooms with chemicals.
2.33
We post signs warning public during high bloom periods.
2.83
We identify phytoplankton types and measure toxins.
3.85
We conduct bench scale, mesocosm, or limnocorral studyies.
2.33
Our community members are active in watershed management.
3.46
Source control is more important than lake management.
3.55
This seminar helped reflect on adaption & collaboration.
4.67
Would you be interested in participating in an CLRMA lake mgmt. innovation cluster?
3.75

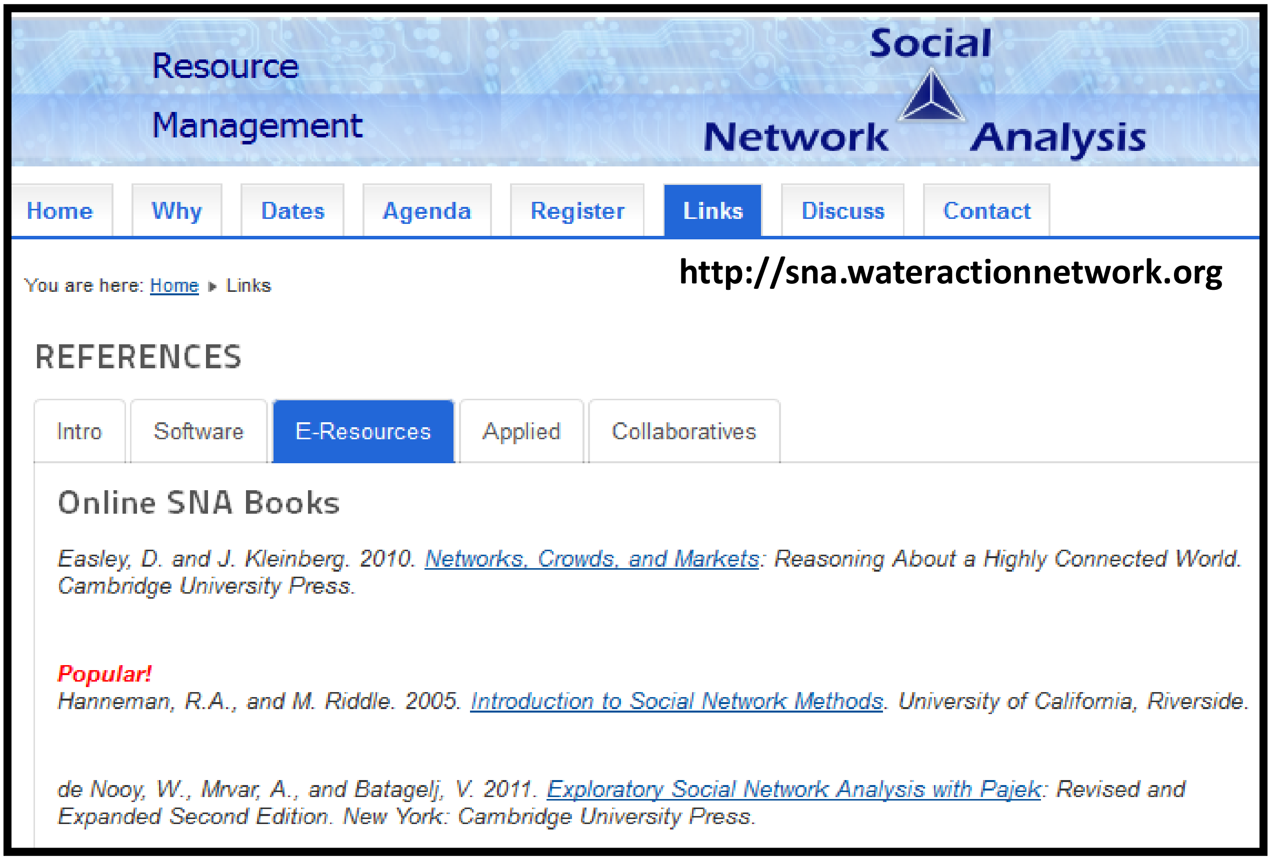
EXHIBIT 3. SOCIAL NETWORK ANALYSIS WORKSHOP SUMMARY

Project Title: Social Network Analysis Techniques for Water Resources Management Workshop

Project ID / Grant: 2014CO289B National Institutes for Water Resources (NIWR)

Formats and Audience: Two Evening Workshops for Area Professionals and CSU Students October 2013(8.14/10), Interactions of Society and the Environment Seminar Series (ISESS) three member panel on SNA applications February 2014 (5.29/6), Metropolitan Denver One World-One Water Center (OWOW) undergraduate seminar March 2014 (5.5/6), Full-Day CSU Conservation Leadership through Learning (CLTL) program workshop with afternoon SNA GEPHI software training April 2014 (6.6/10)

Findings: Multi-disciplinary undergraduate students expressed highest SNA workshop satisfaction, most participants found SNA concepts useful, though not all would likely use SNA software formally. Shorter, more technical seminars were preferred, especially if they included a discussion break with refreshments. SNA workshop may also be expanded into full semester course to provide more targeted resource focus.



You are here: Home ▸ Links

http://sna.wateractionnetwork.org

REFERENCES

Online SNA Books

Easley, D. and J. Kleinberg. 2010. Networks, Crowds, and Markets: Reasoning About a Highly Connected World. Cambridge University Press.

Popular!
Hanneman, R.A., and M. Riddle. 2005. Introduction to Social Network Methods. University of California, Riverside.

de Nooy, W., Mrvar, A., and Batagelj, V. 2011. Exploratory Social Network Analysis with Pajek: Revised and Expanded Second Edition. New York: Cambridge University Press.

Figure 1. Social Network Analysis for Water and Natural Resources Management Companion Website

Collaborative Capacity Inventory

Based on Antony S. Cheng and Victoria E. Sturtevant, "A Framework for Assessing Collaborative Capacity in Community-Based Public Forest Management." *Environmental Management*, 31 December 2011.

Individual—rate your own:					
Organizing					
Leadership committed to group success	1	2	3	4	5
Systems thinking ability	1	2	3	4	5
Social networks	1	2	3	4	5
Learning					
Leadership committed to learning	1	2	3	4	5
Systems thinking ability	1	2	3	4	5
Communication competencies—active listening and effective speaking and writing skills	1	2	3	4	5
Deciding					
Communication and negotiation skills	1	2	3	4	5
Authority to decide on behalf of constituency or organization	1	2	3	4	5
Standing and persuasion within constituency or organization	1	2	3	4	5
Acting					
Knowledge of how to operationalize desired goals/activities	1	2	3	4	5
Knowledge of what constitutes operational feasibility	1	2	3	4	5
Knowledge of contracting mechanisms appropriate for tasks	1	2	3	4	5
Evaluating					
Champion or group of champions advocating for monitoring and evaluation	1	2	3	4	5
Expert knowledge and/or experience in both ecological and socio-economic monitoring	1	2	3	4	5
Legitimizing					
Social networks encompassing community leaders and other collaborative groups	1	2	3	4	5
Social networks encompassing individuals at higher authority levels	1	2	3	4	5
'Standing' within one's peer group or organization	1	2	3	4	5
Persuasion skills	1	2	3	4	5

Collaborative group—rate this group's:					
Organizing					
Ability to recruit and retain right participants	1	2	3	4	5
Systems for regular communications internally and externally	1	2	3	4	5
Knowledge of effective organizational design	1	2	3	4	5
Conflict management competencies	1	2	3	4	5
Grant-writing, project management and writing skills	1	2	3	4	5
Human and financial resources to carry out tasks	1	2	3	4	5
Learning					
Learning facilitators	1	2	3	4	5
Access to external expertise and knowledge	1	2	3	4	5
Access to data and information; skills and resources to compile and synthesize information	1	2	3	4	5
Report organization and writing skills	1	2	3	4	5
Physical, financial and human resources to carry out learning tasks	1	2	3	4	5
Deciding					
Knowledge of decision space	1	2	3	4	5
Ground rules governing behavior, interactions and decision-making	1	2	3	4	5
Strategic planning experience/competency	1	2	3	4	5
Report organization and writing skills	1	2	3	4	5
Physical, financial and human resources to carry out planning and decision-making tasks	1	2	3	4	5
Acting					
Acquire and coordinate adequate human, technical and financial resources	1	2	3	4	5
Ability to develop and follow through with intermediate outcomes (e.g. pilot or demo)	1	2	3	4	5
Organizational structure and personnel that ensure assets are applied to activities	1	2	3	4	5
Knowledge, skills and resources for effective advocacy	1	2	3	4	5
Evaluating					
Ability to sustain the organizational structure, time and space for monitoring and evaluation	1	2	3	4	5
Access to expertise, data and information through social networks	1	2	3	4	5
Data storage, analysis and interpretation resources and competencies	1	2	3	4	5
Report organization and writing skills	1	2	3	4	5
Sufficient human, financial and technical resources to conduct monitoring	1	2	3	4	5
Legitimizing					
Human, financial and technical resources to develop and disseminate communication materials	1	2	3	4	5
Knowledge, skills and resources for advocacy in state and federal policy venues	1	2	3	4	5

Home organization—rate your home organization:					
Organizing					
Authority and resources for representatives to participate	1	2	3	4	5
Technology and technical expertise	1	2	3	4	5
Logistics assistance	1	2	3	4	5
Procedures beneficial to collaborative outcomes	1	2	3	4	5
Learning					
Data, information, geological information systems (GIS) assistance	1	2	3	4	5
Subject matter specialists	1	2	3	4	5
Deciding					
Authority to representatives to make decisions on behalf of organization	1	2	3	4	5
Technical expertise and assistance	1	2	3	4	5
Acting					
Ability to exert authority over work plans, personnel and budgets to contribute to implementation of group goals in short time frame	1	2	3	4	5
Assigning operations-oriented technical expertise to operationalize group goals	1	2	3	4	5
Contract, administration and accountability mechanisms to ensure work gets done correctly	1	2	3	4	5
Evaluating					
Field crews, subject matter experts	1	2	3	4	5
Data, information, remotely-sensed imagery and GIS technology	1	2	3	4	5
Recruiting and organizing volunteers	1	2	3	4	5
Training in measurement techniques	1	2	3	4	5
Legitimizing					
Explicit leadership support for organizational representatives' participation	1	2	3	4	5
Explicit political and financial support for collaborative group functioning and activities	1	2	3	4	5

APPENDIX F. GIS SPATIAL DATA SOURCES AND MODELING

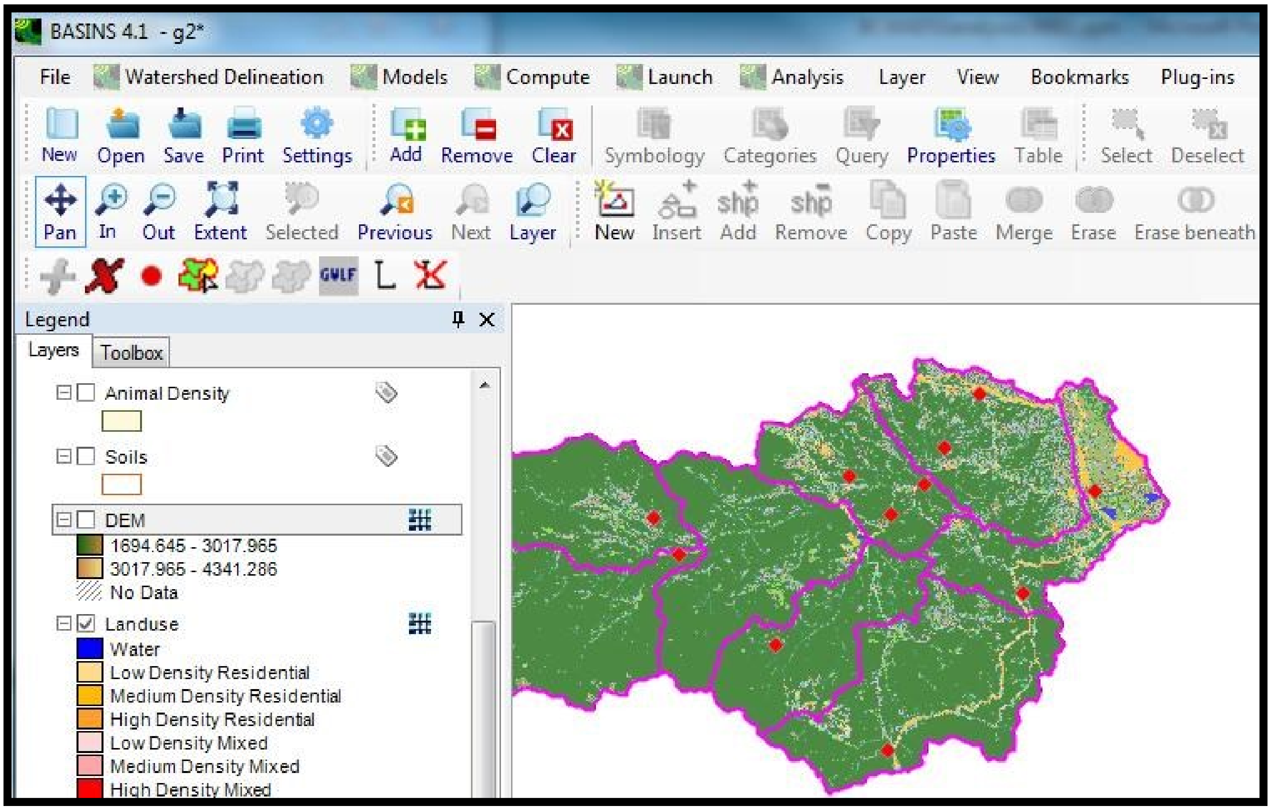
EXHIBIT 1. GIS DATA SOURCES

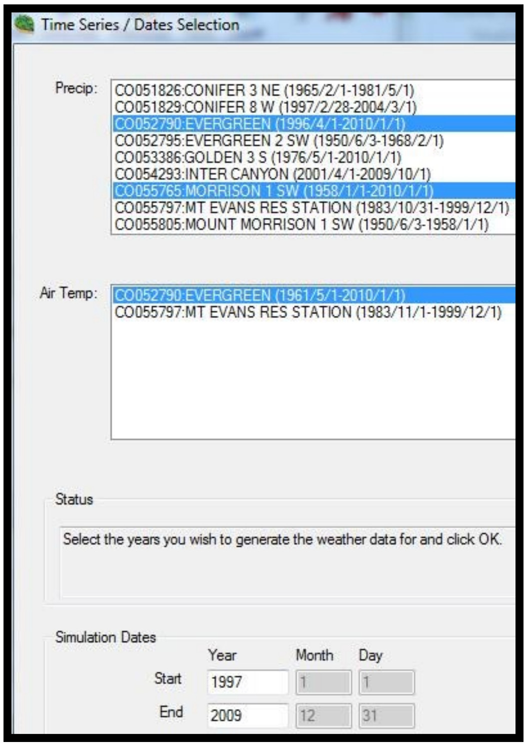
Source Type	**Source**	**Dataset Name**	**Dataset Description**
Federal	USGS	HUC-10, HUC-12	Hydrologic unit boundaries of the Bear Creek Watershed (HUC-10) and its 8 subbasins (HUC-12)
Federal	USGS	National Hydrologic DS	Streams and water bodies
Federal	USGS	Digital Elev. Model	Raster layers by quadrangle of elevation in 30m
Federal	EPA	South Platte *Surf your watershed* data	Most federal datasets by HUC-8 South Platte basin, including census, 303d listing, landuse, water quality
Federal	EPA	NPDES dischargers	Discharge point locations with water quality, flow
Federal	EPA-R8	Canopy Study	WQ and other parameters from multi-site study
Federal	NRCS	SSURGO/STATSGO2 Soil Survey	Downloaded soil polygons by subbasin, required tedious linking to desired database attributes
Federal	FEMA	FIRM update 2014	Obtained from counties newly delineated floodplain
State	DWR	Water Rights & Wells	Coordinates for all diversions and monthly data
State	WQCD	Stream Segments	Used in defining sections with 303d quality issues
State	WQCD	NPDES Dischargers	ECHO system point discharge locations and data
State	CWCB	Instream Flow Righs	Reach lengths, names and flows for ISF rights held
State	CPW	Fish counts, survey	BCR stocking reports since 1977 & fish surveys
State	CoMAP	Public Landowners	Federal, state, and local public land polygons
State	CNHP	Designated lands	Heritage program geodatabase of ecosystems
State	DOLA	Special Districts	Water, Fire, and Sanitation Districts polygons
Regional	CDM	Aquifer Study 2011	Geology, wells, population data in GIS format
Regional	DrCOG	Water Resources	Great Metro Denver Area districts, watersheds, etc.
Regional	JW	Phase I & II Fire Study	Major Streams, fire hazard priorities, landuse, lakes
Local	DMP	Public lands	Parks and Conservation Tracts throughout BCW
Local	JCOS	Public lands	Public open space throughout Jefferson County
Local	Jeffco	Planning Dept.	2012 aerial photos, roads, parcels, permits, contours
Local	CCC	Online shapefiles	2009 aerial photo, roads, parcels, buildings, contours
Local	Park County	No data yet, but soon	No data, but most in public lands, will updated soon
Local	Districts	District corrections	District boundary area corrections from state sources
Local	BCLP	BCLP features	Geodatabase of updated park roads, trails and layers
Local	BCWA	WQ Monitoring Data	Fish counts, MMI scores, water quality & flow data
Local	Audubon	Bird Counts, Recreation	Bird Counts at BCR and BC survey sites, Overuse
Local	ETU	Streamside Issues	Illegal ponds and lawn watering along Bear Creek
Local	Denver EHS	WQ Monitoring Data	Sites and results from WQ monitoring
Derived	ACM DSS	OWTS points and areas	OWTS from parcels with structures w/o sewer service
Derived	ACM DSS	Pastures and stables	Horse properties located from 2012 aerial photos
Derived	ACM DSS	Pre-sed basins	Possible locations to pre-permit sed basins
Derived	ACM DSS	WWTF services areas	Multiple sources combined and reviewed by BCWA
Derived	ACM DSS	Land ownership map	Federal, state, local public land ownership
Derived	ACM DSS	Composite Fire Hazards	JW Phase II Fire Study layers combined into one map
Derived	ACM DSS	BCR bathymetry	Digitized from contours rectified with USACE data
Derived	ACM DSS	2013 Flood Sediment	Fine sediment volumes from exposed sed thickness
Derived	ACM DSS	BCR volumes and areas	Hypsograph chart from Volume/Area relationships
Derived	ACM DSS	Unpaved Roads	Digitized to connect structures to county roads
Derived	ACM DSS	WWTFs discharges	Lat/Long and TP loads for use in GWLF-E model
Derived	ACM DSS	Ecology Maps	MMI scores, fish counts and surveys, birds by site
Derived	ACM DSS	Watershed wide DEM	40-ft CCC and Jeffco counties with river/road breaks
Derived	ACM DSS	BCLP Sewer Line	Estimate of length, location of proposed sewer sys.

EXHIBIT 2. EPA BASINS GWLF-E ANALYSIS RESULTS

Screening Level Nonpoint Source Contribution Results

EPA GWLF-E modeling results are preliminary and will require additional refinement using more advanced EPA BASINS extensions. Results indicate that the over 9,000 septic systems in the watershed may contribute a similar TP load as wastewater point discharges or slightly more of about 1000 pounds. However, groundwater is also considered a source of about 1000 pounds of TP, though it is unclear if this includes only non-septic sources. Pastures and cropland contribute about 200 pounds, while the much greater forested area only contributes about 300 pounds. Streambank erosion contributes about 3,000 pounds annually, which would have been exacerbated during the September 2013 flood. The many roads adjacent to streams, and unpaved private drives, in addition to streambank erosion and urban development, contribute fifteen times more, mostly particulate, phosphorus of about 15,000 pounds. The large contribution of sediment-based phosphorus agrees with the original 1990 Clean Lakes Study estimates, USGS Sparrow model results for the greater Missouri Basin (USGS 2002), and BCWA's own estimates of suspended load from storms, snowmelt runoff, and flooding events. Statistical analysis also indicates that TP does not typically decrease with increasing flow, which would be expected as wastewater discharges were diluted, if they were the main source of TP. This may indicate, as has been found in a recent Poudre River study (Son 2012), that further reduction in WWTF discharge load allowances alone may not improve Bear Creek Reservoir water quality. Therefore, policies and projects that more directly address the effects of nonpoint sources and other reservoir management alternatives should also be targeted more directly in future years. It is important to acknowledge that sources usually interact with one another rather than act independently. As roads add fine sediments to the streams and reservoirs throughout the Bear Creek Watershed, they are not only a source of TP in themselves, but may serve as a sink for TP from WWTF loads during well-oxygenated cold winter seasons. This may then produce apparent higher TP in hotter, lower summer flow periods. Fine sediments may block hyporheic exchange between stream water and groundwater, increasing stream temperatures, which may be incorrectly attributed to WWTFs.





Precip:

CO051826:CONIFER 3 NE (1965/2/1-1981/5/1)
CO051829:CONIFER 8 W (1997/2/28-2004/3/1)
CO052790:EVERGREEN (1996/4/1-2010/1/1)
CO052795:EVERGREEN 2 SW (1950/6/3-1968/2/1)
CO053386:GOLDEN 3 S (1976/5/1-2010/1/1)
CO054293:INTER CANYON (2001/4/1-2009/10/1)
CO055765:MORRISON 1 SW (1958/1/1-2010/1/1)
CO055797:MT EVANS RES STATION (1983/10/31-1999/12/1)
CO055805:MOUNT MORRISON 1 SW (1950/6/3-1958/1/1)

Air Temp:

CO052790:EVERGREEN (1961/5/1-2010/1/1)
CO055797:MT EVANS RES STATION (1983/11/1-1999/12/1)

Status

Select the years you wish to generate the weather data for and click OK.

Simulation Dates

	Year	Month	Day
Start	1997	1	1
End	2009	12	31

GWLF-E

Generalized Watershed Loading Functions-Enhanced

Version 1.0.0, 2011 Edition (BETA)

Input Data Editors

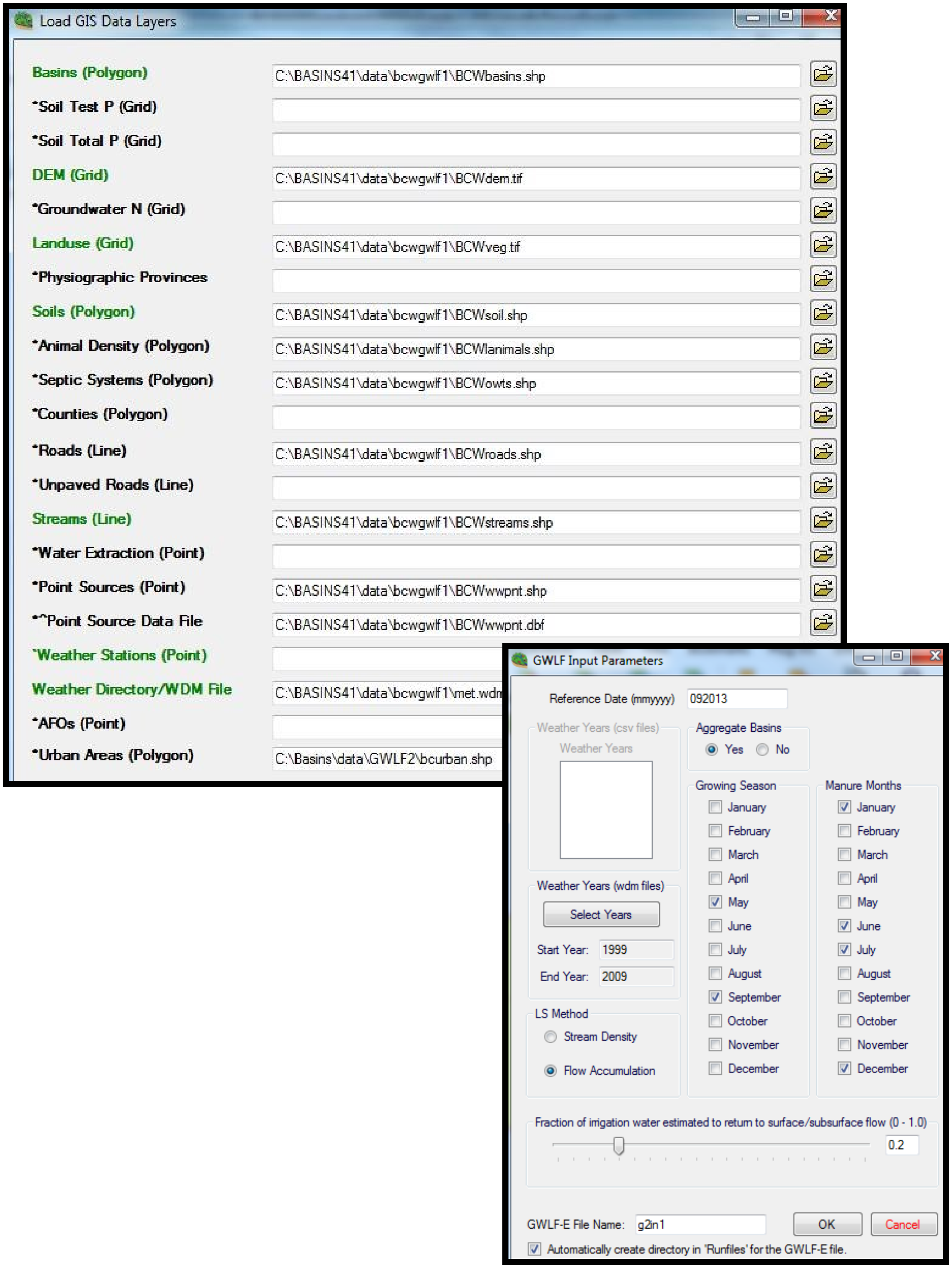
Select input data file: C:\BASINS41\models\GWLF-E\Runfiles\g2input\g2in2.gms

Model Run Setup

Enter model run name: g2o2

☑ Use same input data file loaded in the input data editor.

Output Viewers



Load GIS Data Layers

Basins (Polygon)	C:\BASINS41\data\bcwgwlf1\BCWbasins.shp
*Soil Test P (Grid)	
*Soil Total P (Grid)	
DEM (Grid)	C:\BASINS41\data\bcwgwlf1\BCWdem.tif
*Groundwater N (Grid)	
Landuse (Grid)	C:\BASINS41\data\bcwgwlf1\BCWveg.tif
*Physiographic Provinces	
Soils (Polygon)	C:\BASINS41\data\bcwgwlf1\BCWsoil.shp
*Animal Density (Polygon)	C:\BASINS41\data\bcwgwlf1\BCWlanimals.shp
*Septic Systems (Polygon)	C:\BASINS41\data\bcwgwlf1\BCWowts.shp
*Counties (Polygon)	
*Roads (Line)	C:\BASINS41\data\bcwgwlf1\BCWroads.shp
*Unpaved Roads (Line)	
Streams (Line)	C:\BASINS41\data\bcwgwlf1\BCWstreams.shp
*Water Extraction (Point)	
*Point Sources (Point)	C:\BASINS41\data\bcwgwlf1\BCWwwpnt.shp
*^Point Source Data File	C:\BASINS41\data\bcwgwlf1\BCWwwpnt.dbf
*Weather Stations (Point)	
Weather Directory/WDM File	C:\BASINS41\data\bcwgwlf1\met.wd
*AFOs (Point)	
*Urban Areas (Polygon)	C:\Basins\data\GWLF2\bcurban.shp

GWLF Input Parameters

Reference Date (mmyyyy) 092013

Weather Years (csv files)

Weather Years

Aggregate Basins ● Yes ○ No

Weather Years (wdm files)

Select Years

Start Year: 1999

End Year: 2009

LS Method

○ Stream Density

● Flow Accumulation

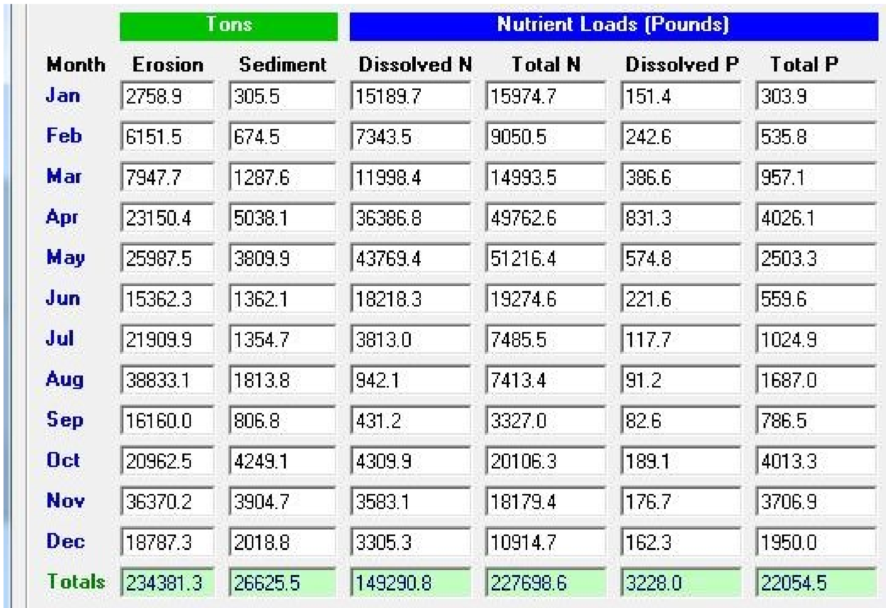
Growing Season	Manure Months
☐ January	☑ January
☐ February	☐ February
☐ March	☐ March
☐ April	☐ April
☑ May	☐ May
☐ June	☑ June
☐ July	☑ July
☐ August	☐ August
☑ September	☐ September
☐ October	☐ October
☐ November	☐ November
☐ December	☑ December

Fraction of irrigation water estimated to return to surface/subsurface flow (0 - 1.0) 0.2

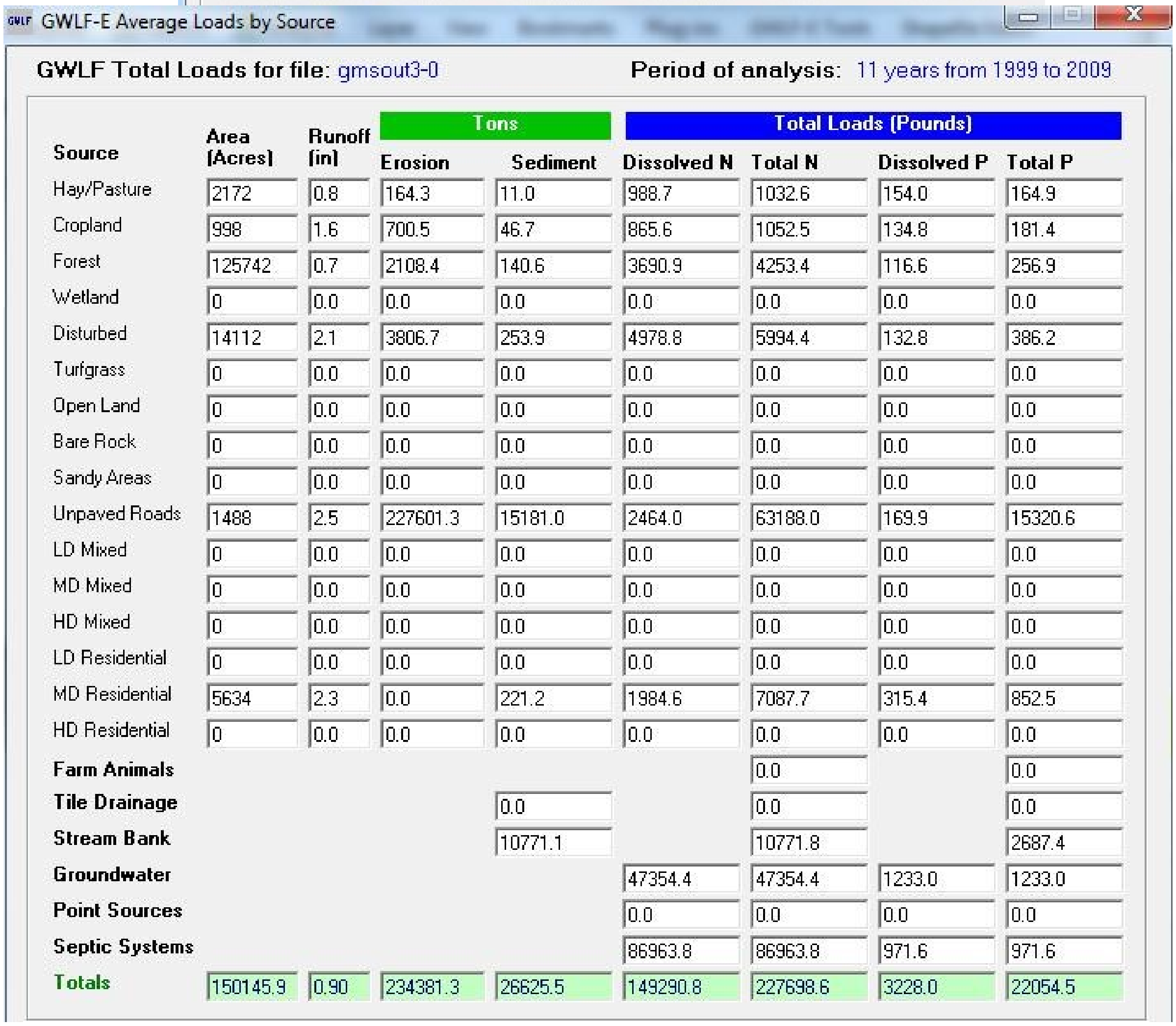
GWLF-E File Name: g2in1

OK Cancel

☑ Automatically create directory in 'Runfiles' for the GWLF-E file.



	Tons		Nutrient Loads (Pounds)			
Month	**Erosion**	**Sediment**	**Dissolved N**	**Total N**	**Dissolved P**	**Total P**
Jan	2758.9	305.5	15189.7	15974.7	151.4	303.9
Feb	6151.5	674.5	7343.5	9050.5	242.6	535.8
Mar	7947.7	1287.6	11998.4	14993.5	386.6	957.1
Apr	23150.4	5038.1	36386.8	49762.6	831.3	4026.1
May	25987.5	3809.9	43769.4	51216.4	574.8	2503.3
Jun	15362.3	1362.1	18218.3	19274.6	221.6	559.6
Jul	21909.9	1354.7	3813.0	7485.5	117.7	1024.9
Aug	38833.1	1813.8	942.1	7413.4	91.2	1687.0
Sep	16160.0	806.8	431.2	3327.0	82.6	786.5
Oct	20962.5	4249.1	4309.9	20106.3	189.1	4013.3
Nov	36370.2	3904.7	3583.1	18179.4	176.7	3706.9
Dec	18787.3	2018.8	3305.3	10914.7	162.3	1950.0
Totals	234381.3	26625.5	149290.8	227698.6	3228.0	22054.5



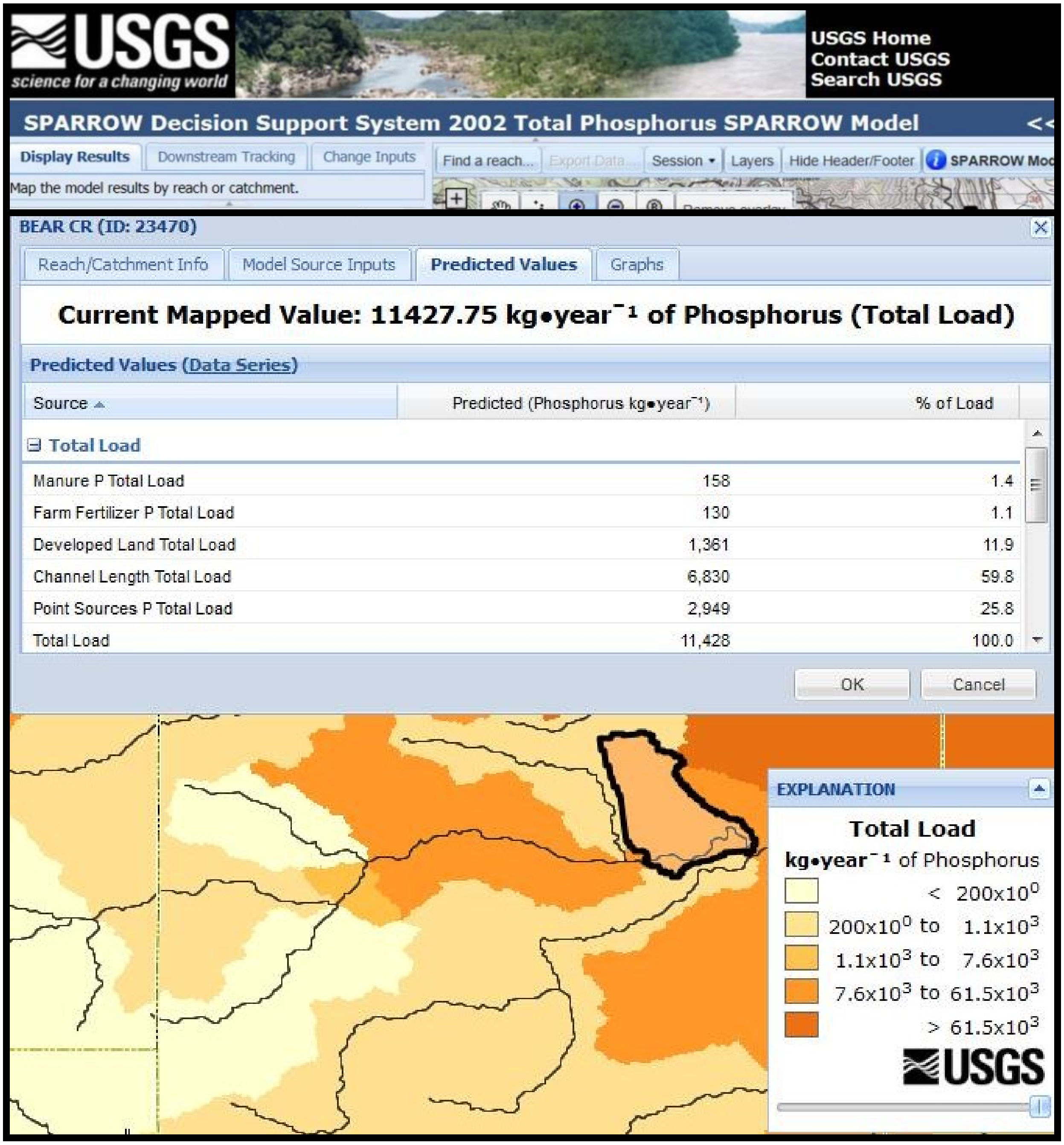
GWLF Total Loads for file: gmsout3-0 **Period of analysis:** 11 years from 1999 to 2009

			Tons		Total Loads (Pounds)			
Source	**Area (Acres)**	**Runoff (in)**	**Erosion**	**Sediment**	**Dissolved N**	**Total N**	**Dissolved P**	**Total P**
Hay/Pasture	2172	0.8	164.3	11.0	988.7	1032.6	154.0	164.9
Cropland	998	1.6	700.5	46.7	865.6	1052.5	134.8	181.4
Forest	125742	0.7	2108.4	140.6	3690.9	4253.4	116.6	256.9
Wetland	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Disturbed	14112	2.1	3806.7	253.9	4978.8	5994.4	132.8	386.2
Turfgrass	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open Land	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bare Rock	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sandy Areas	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unpaved Roads	1488	2.5	227601.3	15181.0	2464.0	63188.0	169.9	15320.6
LD Mixed	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MD Mixed	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HD Mixed	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LD Residential	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MD Residential	5634	2.3	0.0	221.2	1984.6	7087.7	315.4	852.5
HD Residential	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Farm Animals						0.0		0.0
Tile Drainage				0.0		0.0		0.0
Stream Bank				10771.1		10771.8		2687.4
Groundwater					47354.4	47354.4	1233.0	1233.0
Point Sources					0.0	0.0	0.0	0.0
Septic Systems					86963.8	86963.8	971.6	971.6
Totals	150145.9	0.90	234381.3	26625.5	149290.8	227698.6	3228.0	22054.5

EXHIBIT 3. USGS SPARROW DSS 2002 TP TOTAL LOAD COMPARISONS

U.S. Department of the Interior | U.S. Geological Survey
URL: http://cida.usgs.gov/sparrow/map.jsp?model=58 (http://water.usgs.gov/nawqa/sparrow/dss/)
Page Contact Information: SPARROW DSS Administrator
Page Last modified: 09/14/2014 19:26:16 (Version: 1.4.32.26 (09/14/2014 19:26:16) - Release)

USGS Sparrow DSS: Bear Creek Total Proportional TP Load



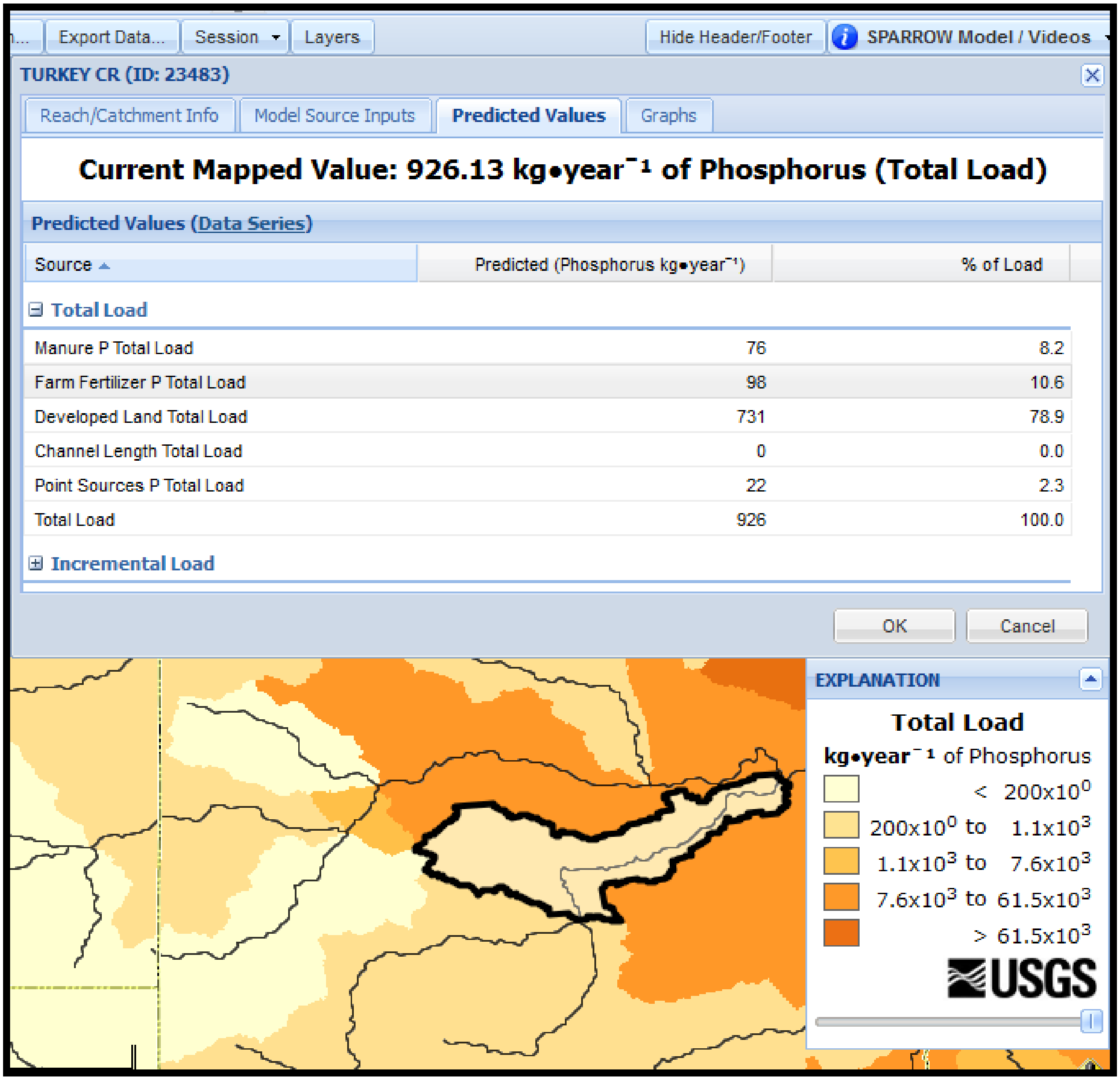
BEAR CR (ID: 23470)

Current Mapped Value: 11427.75 kg•year^{-1} of Phosphorus (Total Load)

Predicted Values (Data Series)

Source	Predicted (Phosphorus kg•year^{-1})	% of Load
Total Load		
Manure P Total Load	158	1.4
Farm Fertilizer P Total Load	130	1.1
Developed Land Total Load	1,361	11.9
Channel Length Total Load	6,830	59.8
Point Sources P Total Load	2,949	25.8
Total Load	11,428	100.0

USGS Sparrow DSS: Turkey Creek Total Proportional TP Load



TURKEY CR (ID: 23483)

Current Mapped Value: 926.13 kg•year^{-1} of Phosphorus (Total Load)

Predicted Values (Data Series)

Source	Predicted (Phosphorus kg•year^{-1})	% of Load
Total Load		
Manure P Total Load	76	8.2
Farm Fertilizer P Total Load	98	10.6
Developed Land Total Load	731	78.9
Channel Length Total Load	0	0.0
Point Sources P Total Load	22	2.3
Total Load	926	100.0
Incremental Load		

Only the Platte Basin in the Missouri River Basin showed high loads from point sources and developed areas. In most other areas, manure and farm fertilizer sources of nutrients predominated. More refined estimates of actual point source discharges in the Bear Creek Watershed indicate results are overestimated by this model by more than 7 times. Large mountain streams like Bear Creek were found to be a net source of Phosphorus, while lower flow and less steep Turkey Creek was not shown to contribute directly. (Brown et al. 2011).

References

Brown, J. B., L. A. Sprague, and J. A. Dupree. 2011. Nutrient Sources and Transport in the Missouri River Basin, with Emphasis on the Effects of Irrigation and Reservoirs. Journal of the American Water Resources Association, 47 (5): 1034 – 1060. (DOI: 10.1111/j.1752-1688.2011.00584.x)

LIST OF ABBREVIATIONS

AF – Acre-Feet (volume measurement)

ACM – Adaptive Co-management

BASINS – EPA Better Assessment Science Integrating Point and Nonpoint Sources

BCLP – Bear Creek Lake Park

BCR – Bear Creek Reservoir

BCWA – Bear Creek Watershed Association

BMPs – Best Management Practices

BTCA – Bear / Turkey Creek Alliance

CCC – Clear Creek County

CDOT – Colorado Dept. of Transportation

CDPHE – Colorado Department of Public Health and Environment

Chl-a – Chlorophyll-a

CLRMA – Colorado Lake and Reservoir Management Association

CMS – Content Management System

CDPW – CO Dept. of Parks and Wildlife

CPOW – Colorado Professionals in Onsite Wastewater

CPR – Common Pool Resource

CWA – Clean Water Act

CWCB – Colorado Water Conservation Board

CSM – Colorado School of Mines

CSU – Colorado State University

CoMap – Colorado Ownership, Management and Protection Open Space Inventory

DEM – Digital Elevation Model

DMP – Denver Mountain Parks

DO – Dissolved Oxygen

DrCOG – Denver Regional Council of Governments

DSS – Decision Support System

DWR – Colorado Division of Water Resources

EBPR – Enhanced Biological Phosphorus Removal

EPA – U.S. Environmental Protection Agency

EMD – Evergreen Metro District

ETU – Evergreen Trout Unlimited

FEMA – Federal Emergency Management Agency

gpd – gallons per day

GIS – Geographical Information Systems

GWLF-E – Generalized Watershed Loading Functions (Enhanced)

HAB – Harmful Algae Bloom

ICWE – International Conference on Water and the Environment

IWRM – Integrated Water Resources Management

JCOS – Jefferson County Open Space

JCD – Jefferson Conservation District

Jeffco – Jefferson County

LID – Low Impact Development

LIDAR – “light” + “radar”, remote sensing tool

LID – low impact development

mg / L – milligrams per liter (1 ppm)

mg / kg – milligrams per kilogram (1 ppm)

MCDA – multiple-criteria decision analysis

MEA – Millennium Ecosystem Assessment

MGD – Million Gallons per Day (WWTF)

MMI – Multimetric Macroinvertebrate Index

MOOC – Massive Open Online Course

MSL – Mean Sea Level (elevation datum)

MS4 – Municipal Separate Storm Sewer System

NPS - Non-point Source Pollution

MWAT – maximum weekly average temperature

NAS – National Academies of Sciences

NPDES – National Pollution Discharge Elimination System

NPS – nonpoint source pollution (but may also refer to National Park Service)

NRC – National Research Council

NRCS – Natural Resource Conservation Service

OWTS – Onsite Wastewater Treatment System

RBDMS – Relational Database Management System

RBER – Rapid Biotic and Ecosystem Response

SaaS – Software as a Service

SC - specific conductivity

SD – Secchi Depth

SDLC – Software Development Life Cycle

SNA – Social Network Analysis

SWP – Source Water Protection

TMDL – Total Maximum Daily Load

TN – Total Nitrogen

TP – Total Phosphorus

TRS – Technical Review Session (meeting)

TSI – (Carlson) Trophic State Index

TSS – total suspended sediments

UBCWSD – Upper Bear Creek Water and Sanitation District

UC – University of Colorado

UDFCD – Urban Drainage and Flood Control District

µg / L – micrograms per liter (1 ppb)

USACE – U.S. Army Corps of Engineers

USGS – U.S. Geological Survey

USFS – U.S. Forest Service

WHO – World Health Organization

WRT – Water Residence Time

WQCC – Water Quality Control Commission

WQCD – Water Quality Control Division

WWTF – Wastewater Treatment Facility