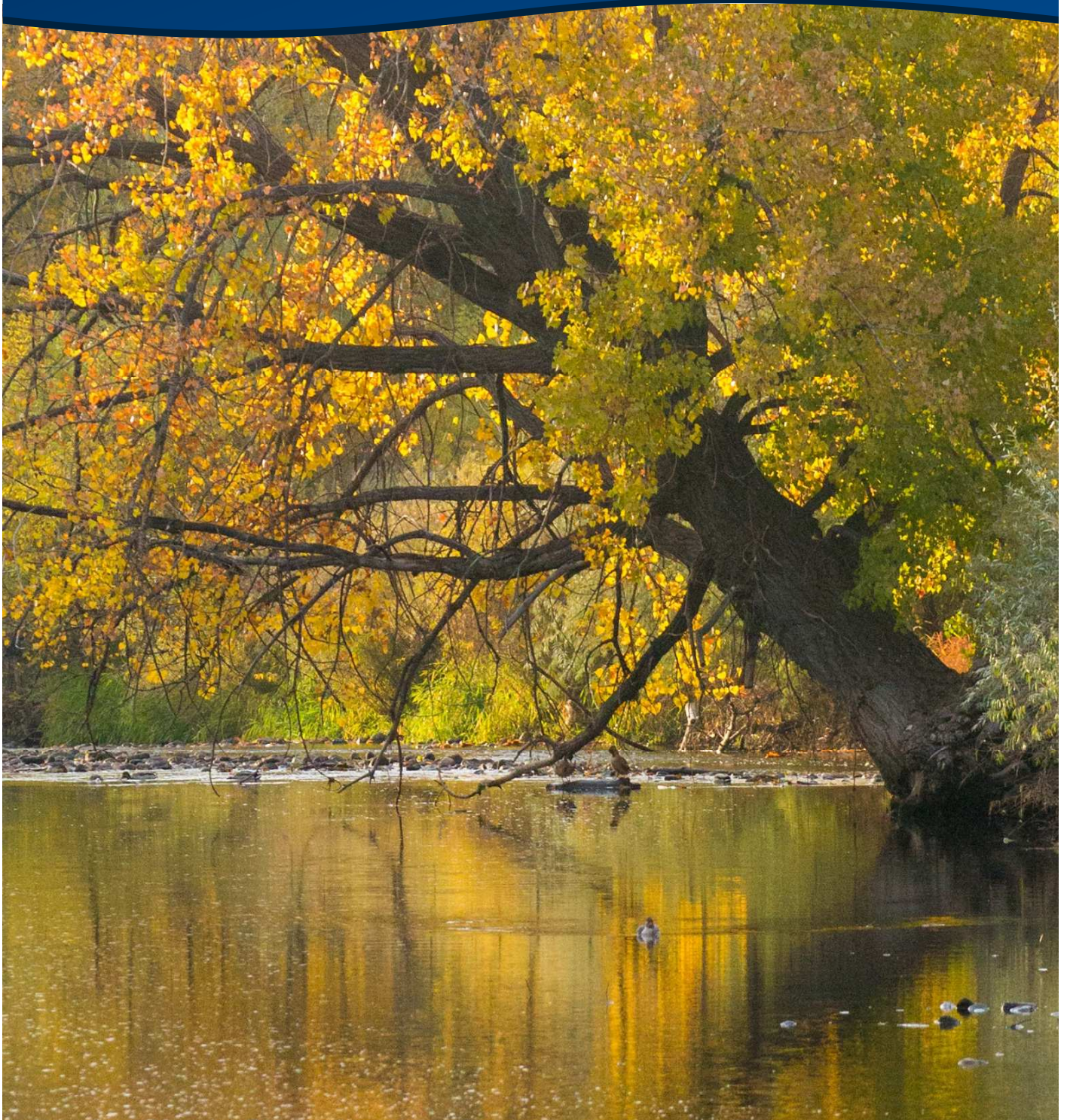




An **Ecological Response Model** for the Cache la Poudre River through Fort Collins

EXECUTIVE SUMMARY

DECEMBER 2014



INTRODUCTION

The Cache la Poudre River (hereafter Poudre River or “river”) is a treasured community asset. The City of Fort Collins recognizes that the Poudre River provides the community with a broad set of ecological, agricultural, municipal, industrial, and recreational benefits that are greatly valued by the public. Ecosystem benefits include a high quality water supply, flood conveyance, habitat in the river and its adjacent forest, and a variety of opportunities for recreation and enjoyment.

In 2011, the City of Fort Collins Natural Areas Department initiated a collaborative project with scientists to develop the Ecological Response Model (ERM) for the Poudre River through Fort Collins. The ERM effort supports a community-driven quest to manage for an ecologically healthy and resilient Poudre River.

The core purpose of the model is to identify probable ecological responses to a range of potential future changing conditions related to streamflows and important secondary factors affecting the river system. Nine separate model scenarios were developed to provide a lens through which the past, present, and potential future conditions of the river may be examined. The ERM findings, not surprisingly, confirm that the urban Fort Collins reach has been fundamentally altered from its native condition (for the purpose of this model defined as prior to the development of the past 150 years). More importantly, the Poudre continues on a trajectory of change that is difficult for the casual observer to perceive – and is likely to be headed towards a different future than what we see today.

The ERM is an integrated model designed to improve our overall understanding of the Poudre River ecosystem and the many factors that influence it, and to model the status and trends

of its key resources. As a tool, the model contributes to the City’s evaluation of a variety of interacting questions, such as:

- How do increasing societal demands for water, an altered floodplain, and a highly modified river channel intersect with the native ecological system to result in today’s conditions?
- Does the river retain some characteristics of what is considered to be healthy river, and will it be able to retain or improve those characteristics in the future?
- What will it take to achieve a future river condition that our community desires?

The ERM demonstrates there is no single answer to these complicated questions. Yet, it provides a clearer understanding of key issues, potential management actions, and strategies that may help the City achieve the community’s long term vision for the Poudre River.

What Is the Community’s Vision?

Numerous City and community-adopted planning documents reflect broad support and vision for a ***healthy and resilient Poudre River***.



The ERM can help quantify conditions necessary to realize the integrated vision of clean water; vibrant plant and animal communities; and, a river that provides for the economy and the community’s lifestyle. While this long-term goal is challenging, its attainment is made more likely if the community is able to make well-informed choices and strategic investments today.

By exploring the relationship between streamflow and the interdependent components of the river ecosystem, the ERM helps provide an understanding of the condition and potential trajectories of key ecological indicators such as fish, aquatic insects, and riverside vegetation. In turn, this assists in informing the projects' **two overarching goals**:

1. To provide a broad and integrated evaluation of future river conditions given past, present, and potential future flow scenarios and multiple interacting ecological factors; and,
2. To inform flow and management scenarios and actions that help the community attain its vision of a healthy river.

Who Created the ERM?

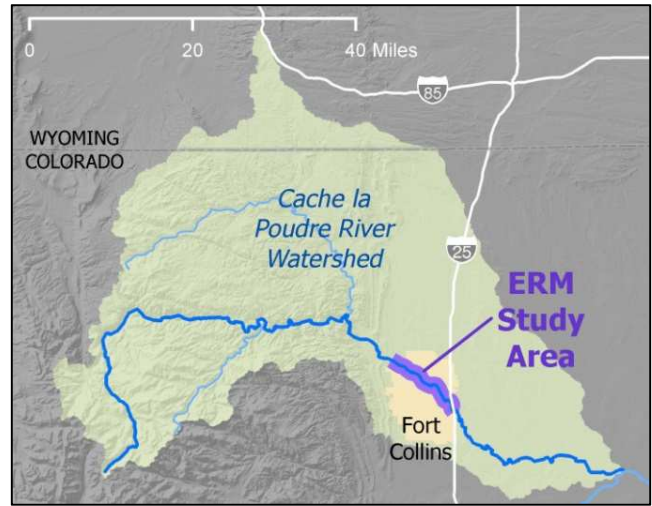
In the fall of 2011, the City of Fort Collins Natural Areas Department convened an interdisciplinary team of river scientists, planners and engineers to develop the ERM. This collaboration of nine team members brought together expertise in a variety of river science disciplines from organizations including Colorado State University, U.S. Forest Service, The Nature Conservancy, the U.S. Geological Survey, and the City of Fort Collins. Collectively the team has contributed to a broad spectrum of river science and management issues through the collective publication of more than 370 peer-reviewed articles.

Study Area

The ERM study area covers a 13-mile segment of the Poudre River. This study area lies along the Front Range of northern Colorado Rocky Mountains and runs through the City of Fort Collins from Overland Trail to Interstate 25 (Figure 1). For the purpose of the ERM this largely urban stretch of the Poudre was segmented into eight reaches as determined by the location of major diversion structures and changes in channel form. Three of the eight reaches were chosen as representative of the

range of physical conditions across other reaches and thus were included in the model.

FIGURE 1 – ERM STUDY AREA



HOW WAS THE ERM BUILT?

The ERM team developed an integrated model to explore how river flow patterns interact with physical and biotic systems to influence several indicators of ecosystem condition.

The general structure of the model is depicted in Figure 2. Long term daily flow patterns are the primary input. A series of secondary inputs and ecological interactions are built into the intermediate nodes of the model. The ERM output is key ecological indicators of river condition.

FIGURE 2 OVERVIEW OF ERM STRUCTURE

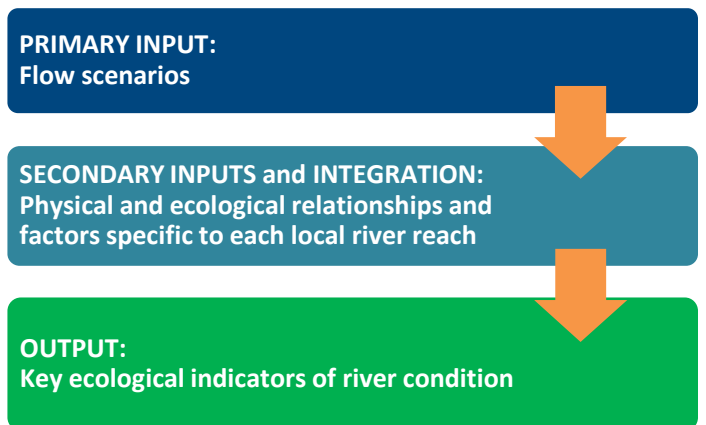


TABLE 1 – ERM INPUT: IMPORTANT ATTRIBUTES OF THE NINE FLOW SCENARIOS*

General Group ↓	Attribute →	Average annual peak flow	Average summer base flow	Average winter base flow
Past and Present	Reconstructed Native	3287	347	70
	Recent Past (1969-2010)	1947	126	24
	Present Operations	1094	81	12
Possible Futures with Less Water	Additional Water Development	524	52	5
	Driest Climate	472	13	4
Environmental Flow Test Scenarios	StableBase - HighPeak	2535	61	35
	HighBase - ModeratePeak	1900	188	55
	DryBase - HighPeak	2555	67	21
	StableBase - LowPeak	1000	59	24

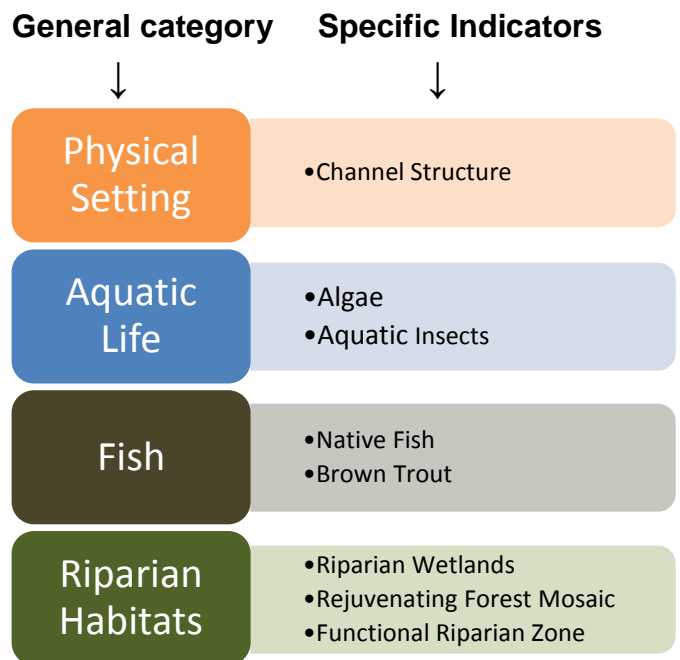
*flow values are reported in cubic feet per second (cfs)

For the model input, nine flow scenarios were developed and are best described in three general groups (Table 1). The first group (past and present) is based on considerable data. These scenarios model the flows running through the Poudre prior to and during the past 150 years of agriculture and urban development. The second group represents two possible futures with less water. While there are numerous reasons why the Poudre may have less water in the future, there remains a great amount of uncertainty regarding the specific details. It is important to interpret model output for this group of scenarios within this context of uncertainty. The third group, the environmental flow test scenarios, was developed to explore the response of the system to a very specific set of flow attributes (such as those represented in Table 1). These test scenarios inform the City's ongoing efforts at matching management actions with river health goals.

The model output provides a representation of the response of the key ecological indicators to various flow scenarios. Indicators were selected based on their role in ecosystem function, their regulatory implications, or their social value. Eight indicators were selected to meet these

criteria and are presented in four general categories (Figure 3).

FIGURE 3. ERM OUTPUT: KEY ECOLOGICAL INDICATORS OF RIVER CONDITION



The ERM modeling framework allows for the integration of physical and biological factors and many relationships important to the resilience of the river ecosystem. This provides results that provide a broad perspective of system-wide trends.

MODEL OUTPUT: RESULTS AND DISCUSSION FOR THE KEY ECOLOGICAL INDICATORS

The nine flow scenarios evaluated by the ERM include a combination of flow increases and decreases throughout the seasons. The nine flow scenarios were applied to three physically distinct river reaches. With flow scenarios and physical setting combined the ERM provides 27 unique responses for the potential condition of the each of the indicators. The following discussion provides an overview and synthesis of the extensive set of ERM results. Please refer to the ERM report for the full set of results associated with all the model runs.

Physical Setting

Context: The physical setting (also called channel structure) includes the shape of the river and its floodplain and the composition of the riverbed. It is the central factor that interacts with flows to determine aquatic and riparian habitat potential. The physical setting of the Fort Collins reach of the Poudre River is affected and fundamentally altered by man-made structures such as bridges, bank stabilization, and floodplain development.

ERM Results and Discussion: Results for channel structure demonstrate the net benefit when important functions of both flows and the physical setting are intact. In those reaches with lower banks and less infrastructure the scenarios with higher and longer spring peak flows (such as the recent past, reconstructed native, and the two “High Peak” test flow scenarios) lead to a better predicted condition for channel structure. This condition is characterized by mobility of the riverbed and diversity of habitats, which in turn, benefits all other river indicators.

The results also indicate today’s flows (as represented by the Present Operations scenario) sometimes approach but rarely exceed thresholds necessary to maintain a channel structure that functionally supports habitat creation and maintenance. Thus, further declines will likely reduce sediment flushing and riverbed rejuvenation to frequencies and durations that preclude a flushed, clean and physically diverse channel.



Additionally, widespread bank stabilization to limit meandering of the channel in urban or agricultural landscapes reduces the potential of the channel to function naturally in building and maintaining habitats. Hence, further reductions of high flows are likely to interact with extensive channel modifications, armoring, and levee construction to substantially limit the ecological potential of the riparian corridor and the biota supported in the stream channel.

Reconnecting the river with its floodplain through removing or widening the distance between stable banks in carefully targeted safe zones (away from human infrastructure) could positively impact the biological indicators of the system. Given extensive changes to the landscape and the variety of human alterations along the river, it is important to identify local physical conditions, constraints, opportunities, and associated flushing flow needs to ensure that the channel structure functionally supports the biological indicators of the system.

Aquatic Life

Context: Algae are an important base of the aquatic food web. However, excessive amounts of algae can have negative ecological consequences and are not aesthetically desirable. Elevated nutrient levels, reduced frequency of scouring flows, and low summer base flows resulting in higher water temperatures create very favorable conditions for excessive algae growth. This in turn can reduce aquatic insect habitat and species diversity.

Aquatic insects play an intermediate role in the stream food web by consuming algae and providing a main source of food for fishes and wildlife such as birds in the riparian corridor. The distribution, abundance, and species diversity of aquatic insects can be used as an indicator of Poudre River water quality.



Photo: David Rees

ERM Results and Discussion: The ERM test scenarios demonstrate aquatic life benefits in all modeled river reaches from improved base flows as well as peak flows that meet thresholds necessary to scour and turn over the riverbed. ERM results for the present and recent flow scenarios match observations of an increase in undesirable levels of algae which is likely contributing to depressed aquatic insect diversity and abundance. Further reductions of flushing flows and increased concentrations of nutrient pollution will likely increase algae blooms and further stress aquatic insects.



Fish

Context: Fishes lie near the top of the food chain and depend upon nutrients, algae, and aquatic insects. Abundance, size, and numbers of species are also influenced by the physical habitat which is controlled by patterns of streamflow, particularly spring peak and base-flow levels. Extreme low flows during the base-flow periods can negatively affect fish through a combination of reduced habitat volume and low water quality. These issues are amplified when channel structure and habitat are simplified (see Physical Setting above). Therefore, native fishes and trout are sensitive indicators of various river conditions and may be viewed as barometers of river health. In addition, trout are a valued recreational asset.

ERM Results and Discussion: ERM results suggest the number of native fish species and their abundance has declined over time under recent and current flow conditions. This is due mainly to reduced base flows and lack of diverse habitat created by peak flows. The ERM indicates the potential for declines for trout under recent and current flow scenarios. However, fish populations can change rapidly and observations from the past few years indicate trout abundance has increased, perhaps due to higher river flows, particularly in winter.

The ERM indicates reductions in base or peak flows would likely reduce fish populations from present conditions. The model indicates that habitat for native fish would improve most with higher base-flows combined with improvements to channel structure which is directly dependent on peak flows that cleanse and refresh the riverbed. ERM results show limited potential improvement for native fish because many sensitive species are already locally extinct, and others may be additionally limited by predation from trout and river fragmentation caused by irrigation dams that prevent downstream-upstream movements. Based on these

conditions, a multi-faceted management approach that addresses issues related to habitat limitations and connectivity, siltation, and invasive species as well as high and low flow restoration is needed to ensure self-sustaining and abundant populations of native and sport fishes.

Riparian Habitats (Riverside Forests)

Context: Riparian forests and the mosaic of habitat types commonly found within them, provide critical habitat and resources needed by wildlife in semiarid landscapes. In urban settings riparian corridors are a valued recreational asset and provide a range of important ecological services such as pollutant filtration and floodwater attenuation. The health of riparian habitats is supported by, and dependent on, the river's flow regime.



High flows seasonally saturate and connect the floodplain to the river and provide opportunities for seedling establishment. Stable base flows serve to maintain riverside wetlands and floodplain vegetation that is connected to shallow groundwater. Floodplain groundwater levels are also influenced by many factors in the surrounding uplands which are highly altered in urban and agricultural environments compared to undeveloped landscapes.

Natural streamflow has been changed substantially over the past 150 years resulting in shifts in vegetation through Fort Collins. Changes to flow patterns along with channel confinement, bank stabilization, land clearing

and development in the floodplain have resulted in a narrow and simplified riparian zone that is characteristic of the Poudre River through central Fort Collins.



ERM Results and Discussion: ERM results indicate today's flows still support wetlands and many important ecological functions necessary for sustaining a productive diverse riverside forest (but to a lesser extent than historically). These functions include: nutrient cycling, decomposition, saturation of the soil, recharging groundwater within the floodplain and maintaining areas with shallow water tables to support wetlands within the forest. Results of the ERM that simulate a decrease in frequency and volume of overbank flows indicate a future narrowing of riparian forests and reductions in the extent of streamside wetlands.

Conversely, ERM results indicate riparian wetlands, functional riparian areas, and the riparian mosaic further from the channel would respond positively to an increase in peak flows that flood overbank for at least two weeks during the growing season in most years. The best areas for potential flow-related restoration of riparian forests are along less confined reaches and those that have been widened and physically reconnected to the channel.

Management actions that reconnect the river to its floodplain, allow the river channel to move across the floodplain in safe and feasible locations, and provide adequate streamflow will lead to the most favorable riparian outcomes.

PUTTING IT ALL TOGETHER: WHAT HAVE WE LEARNED?

How Has the River Changed in the Past 150 Years and What is its Current Condition?

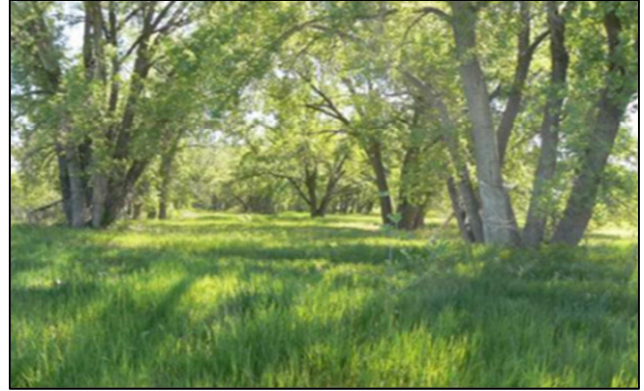
Although the Poudre River continues to support remnants of native riparian and aquatic communities, this contemporary urban ecosystem has experienced significant changes over the last 150 years. Land use and water management have substantially modified native aquatic and riparian communities, in turn altering the ecological function of the Poudre River. Indicators of this altered function include lost or diminished populations of sensitive native fishes and aquatic insects, narrowing of the riparian forest in some reaches, and limited ability of high-value native plants along the river, especially native plains cottonwood trees, to reproduce and replace declining stands of mature trees.

Despite these changes, the system still exhibits important, albeit diminished, ecological functions. These include; occasional flushing flows that have the potential to refresh riverbed habitat in some locations, overbank inundation of riparian areas that support important ecological services such as nutrient storage and processing, flood peak attenuation, provision of seasonal habitats, and maintenance of productive vegetative communities.

How Long Do Changes Take to Manifest in This System?

Changes to the river's ecosystem can occur slowly over decades or even centuries, or rapidly over shorter time scales ranging from hours to a few years. Of the indicators examined in this report, the riparian forest is the slowest to respond as cottonwood trees have the longest lifespan and can reflect ecological conditions present 100 years ago or more. Alternatively, the

shape of the channel may appear to change slowly in dry periods and then be altered quickly and significantly by a single flood or fire. This underscores the importance of thinking over the long term when planning river management activities.



The model input scenario representing today's flows ("Present Operations") helps provide an understanding of conditions that are likely to occur if today's water management practices continue over the coming decades. Because of the lag time in ecosystem response, such as for cottonwood regeneration, the results from the ERM may surprise the reader because they indicate that current river management practices are likely to yield ongoing changes and decline in ecological condition in the future compared to the present.

What Does The ERM Indicate about the Future Poudre River?

Given the potential for future water development and climate change, the possibility of a future urban Poudre River with less water must be considered. River science over the last several decades has clearly established that declining flows can cause both gradual and abrupt shifts in ecosystem condition. Several ERM flow scenarios allow us to look at changes that may occur with lower flows and, as might be anticipated, the condition of ecological indicators will likely decline.

The current and likely future flow scenarios of the ERM paint a future of changing river conditions that represent a substantial departure from the City of Fort Collins' goal of a healthy and resilient river. Despite this possibility, model test runs have revealed that this departure from a biologically thriving river is not a foregone conclusion and that carefully designed environmental flows could improve the state of the Poudre River ecosystem.

Why are Environmental Flows Important?

Environmental flows define specific patterns of flow (volume, timing, frequency, and duration) necessary to meet desired ecological and societal objectives for a river. The ERM is a first step in identifying environmental flows specific to the Fort Collins segment of Poudre River. These environmental flows are a key element to reach the community's vision of a healthy and resilient river.

The ERM demonstrates that environmental flows which combine adequate base flows during the majority of the year with late spring/early summer high flows are likely to synergistically improve all biological indicators across the system. One of the test scenarios indicates substantial improvements in the river ecosystem can be achieved with flow volumes similar to (but delivered more strategically) those observed in the river over the last half century of intensive water development. These results underscore how the river ecosystem can be sustained and improved through active management while still maintaining the economic benefits and the Poudre's role as a working river.

Flow management alone is not a panacea given the extent of river modifications that have already occurred. Significant ecological benefits from environmental flows are most likely to occur if flow management is strategically combined with other management actions that promote upstream-downstream and channel-floodplain

connectivity along the river corridor. This includes reconnecting side arms and oxbow lakes, removing or modifying diversion structures, widening the distance between stabilized features and creating gradients of habitat rather than abrupt steep banks.



What will the 21st Century Poudre River Ecosystem Look Like?

Through the in-depth exploration of specific Poudre River reaches, it became evident this river has a complex history of development and a legacy of change that should be considered in future management scenarios. The contemporary Poudre River ecosystem is characterized by a patchwork-like set of physical conditions and an evolving biological composition. It is likely to have reduced ecological resilience to both human and natural stressors. However, while the ERM provides important insight, but as a simplified ecosystem representation, it does not precisely predict the Poudre River's future. It does, however, provide a suite of potential conditions and options to consider in the future management of the river.



How Can the ERM Help Direct Future Management of the Poudre River?

The ERM was designed to represent the multi-dimensional character of this urban river. It provides a scientific foundation that can serve as a decision support tool and foster a more informed community discussion about the future of the river. It can assist managers in identifying specific and potentially obtainable goals for key indicators of river health and help to link them to management actions based on the understanding of the likely response of the Poudre River ecosystem to environmental flow management and other stewardship activities.

The model evaluates probable ecological responses to the range of potential future changes, with little restraint as to what is affordable, or administratively possible. Accordingly, the ERM team recognizes the challenge of integrating the model results with legal, jurisdictional, fiscal, and managerial constraints. Decision-makers must ultimately weigh a variety of stakeholder interests and the ecological, economic, and societal consequences associated with all policy options in an atmosphere of uncertainty.

Probability-based assessments like the ERM can provide a rational, scientific and transparent basis for prediction and decision-making by

explicitly recognizing uncertainty and helping clarify the likely consequences of policy choices and management activities.



Final Thoughts

The ERM provides valuable new insight on the effects of changing flow patterns, the relative magnitude of changes expected for ecological indicators, and other landscape factors uniquely influencing the Fort Collins portion of the Poudre River. Despite the challenges identified through the ERM, it has also identified opportunities. For example, aquatic and riparian habitats are likely to respond in relatively short time frames to favorable physical conditions and management actions. These actions, as well as policy initiatives, provide options that will help build a sustainable river ecosystem that supports wildlife, recreation, and economic activity as well as great natural beauty.

