FINAL REPORT

PARTNERSHIPS FOR WETLAND PROTECTION, RESTORATION AND PLANNING IN AN URBAN SETTING

FY 06 104(b)(3) CD 966400-01, Project 1

Submitted to:

OKLAHOMA CONSERVATION COMMISSION
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and

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DECEMBER 2011

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1.0 INTRODUCTION

1.1 Background

Urban development historically has not considered the intrinsic functions of stream systems. In most settings, stream channels are converted to engineered storm water conveyance structures designed to efficiently manage runoff and prevent flooding. Little regard is given during the planning and development of residential and commercial areas to the myriad of benefits that a natural creek system would provide. Most city planners and engineers have been slow to embrace avant-garde approaches to stream and riparian area management. Unfamiliarity with the concepts and lack of proven or practical examples commonly inhibit the adoption of modern management ideas or alternative development approaches. The City of Norman (City) is no different. Past urban development has relegated whole watersheds to impervious surface with an emaciated network of channelized drainage ways. Riparian areas are filled-in to maximize the development footprint and no consideration is given to water quality, aesthesis, or wildlife benefits.

Photo 1: Urban development within Brookhaven Creek watershed

The Clean Water Act Section 104(b)(3) grant project "*Partnerships for Wetland Protection, Restoration and Planning in an Urban Setting"* was envisioned to address problems such as these and to tackle ignorance and overcome some of the "unknowns" that prevent the adoption or implementation of these alternative ideas. By demonstrating environmentally friendly stream stabilization and restoration approaches and providing opportunities to implement low impact development techniques, ideally natural systems would be incorporated into urban watershed planning.

Watershed Restoration, Inc.'s (WRI)[1] mission focuses on restoration and enhancement of watersheds degraded by anthropogenic activities. WRI saw this grant opportunity as a mechanism to improve a portion of an urban stream corridor, but more importantly as a chance to influence and potentially enlighten decision makers, planners and engineers in one of Oklahoma's larger urban areas. By changing people's perspective and creating working relationships or partnerships between the various stakeholders—developers, planners

Photo 2: Earth disturbance activities next to Brookhaven Creek

[1] WRI is a 501(c)(3) non-profit ad hoc group comprised of environmental scientists, engineers and professionals.

engineers, citizens, environmental groups, regulators—perhaps the adverse impacts to watersheds could be avoided or at least minimized in future developments.

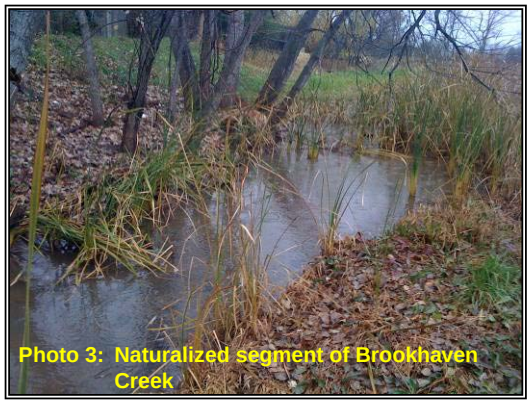


Photo 3: Naturalized segment of Brookhaven Creek

For demonstration purposes, an upper segment of a degraded urban stream was selected. Brookhaven Creek was ideally suited for this project because of past development practices and its uncertain future. It is located on the west side of Norman with most of the watershed already developed. This stream was channelized and modified in the 1970s and 1980s to maximize developable area and to convey water downstream as quickly as possible. In-stream detention basins were constructed in some areas to trap sediment during neighborhood development. Although the channel and sediment basins were designed to be maintained, the creek received minimal attention. Decades later, some reaches of Brookhaven Creek have reestablished themselves into a functioning stream with respect to the new land use. Along certain portions, riparian vegetation has colonized the slopes, a stream channel has evolved and become stable, and wetland areas have developed. Despite the emergence of this natural system, the City perceived it as a problem, particularly during high flow events when portions of the adjacent residential lots flooded and the Crossroads Boulevard reinforced concrete box-culvert (RCB) overtopped. As a solution to the perceived problem, the City proposed a concrete, trapezoidal channel to convey water more efficiently and to lower flood stage, but their plans were halted by local environmental groups and concerned citizens opposed to the idea. Although the more naturalized creek was better overall, the City firmly believed homes were at risk and water had to be managed using classic engineering techniques.

As a solution to this impasse, WRI, the Oklahoma Conservation Commission (OCC), local citizens, and some City staff proposed a project that would use less invasive and more natural techniques of stream management (including fluvial geomorphology (FGM)) to rehabilitate the stream as an alternative to concrete channelization. The design would allow the stream to convey its water and sediment load, while lowering the flood stage elevation and maintaining the riparian wetland area along the stream course. Instead of completely destroying the habitat and the stream channel, WRI[2] proposed a design that enhances riparian and wetland habitat and function, maintains the aesthetics of the urban wildlife corridor, and simultaneously meets water conveyance needs. WRI saw this as an opportunity to create a tangible solution to a common problem observed throughout the municipality. By working with the City Engineer/

Photo 4: Naturalized marsh wetland adjoining Brookhaven Creek

[2] For ease in discussion, all participating groups, individuals, agencies, et cetera, associated with this grant project will be referred to as "WRI". This should not discount individual project roles or usurp individual contributions to the project.

Stormwater Engineer and other staff, an educational opportunity was created which would ultimately produce an example for local developers and decision makers to reference when planning future developments. The timing of the project also coincided with the start of City's Storm Water Master Plan process. The City's attitude towards watershed development was in a formable stage with important issues such as water quality, wildlife habitat, and floodplain integrity as key issues of concern.

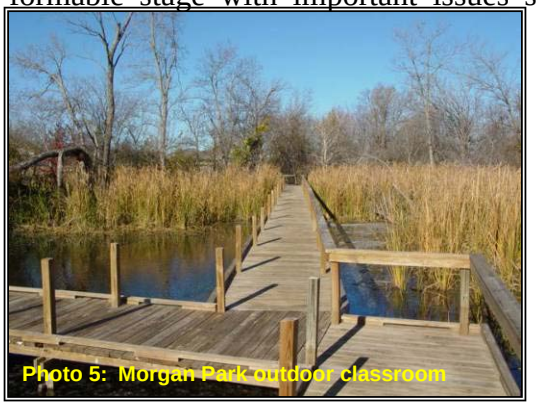


Photo 5: Morgan Park outdoor classroom

This project also complimented OCC's educational efforts. Over the past several years, OCC targeted developers, engineers, and urban planners by sponsoring training classes (e.g., Norman, OK in 2002 and Grove, OK in 2004) that promoted and fostered the principles of FGM in channel design. The Oklahoma Stream Team presented these concepts to a targeted audience in Norman in 2005. Also, in 2000 - 2001 the OCC installed an outdoor wetlands classroom at Morgan Park which adjoins Brookhaven Creek.

1.2 Project Area Description

Brookhaven Creek is an urban stream located on the west side of Interstate 35 in Norman, OK. An upper watershed segment between the Robinson Street bridge and just north of Rock Creek Road was selected. (Refer to Figure 1.) The study area was divided into two segments or project areas—"North" and "South"—based on its relationship to Crossroads Boulevard.

Brookhaven South

Photo 6: Brookhaven Creek South stream channel

The location south of Crossroads Boulevard included approximately 3,200 feet of stream, 2.5 acres of adjoining marsh, and 8 acres of bottomland forest wetland. (Refer to Figures 1 & 3 and Photos 6, 8 & 13.) This segment was originally slated for channelization by the City. Lower portions of residential lots become flooded during large storm events when the marsh, Morgan Park and other portions of the floodplain become inundated, but no homes were ever flooded.

Brookhaven North

The portion north of the Crossroads Boulevard RCB included approximately 3,800 ft of main stem channel and roughly 400 ft of the east-west tributary stream south of Prairie Creek Park (Refer to Figures 1 & 2 and Photos 7, 9 & 14-19.) This segment is mowed by the City at least twice a year and is treated as a grass swale

Photo 7: Brookhaven Creek North stream channel

rather than a first and second order stream system. Minimal riparian habitat is maintained other than incidental herbaceous forb and grass species. The project area also extended north across Rock Creek Road to include a pond and associated wetland areas. This portion was associated with the a separate I-35 overpass construction project.

1.3 Project Objectives & Outcomes

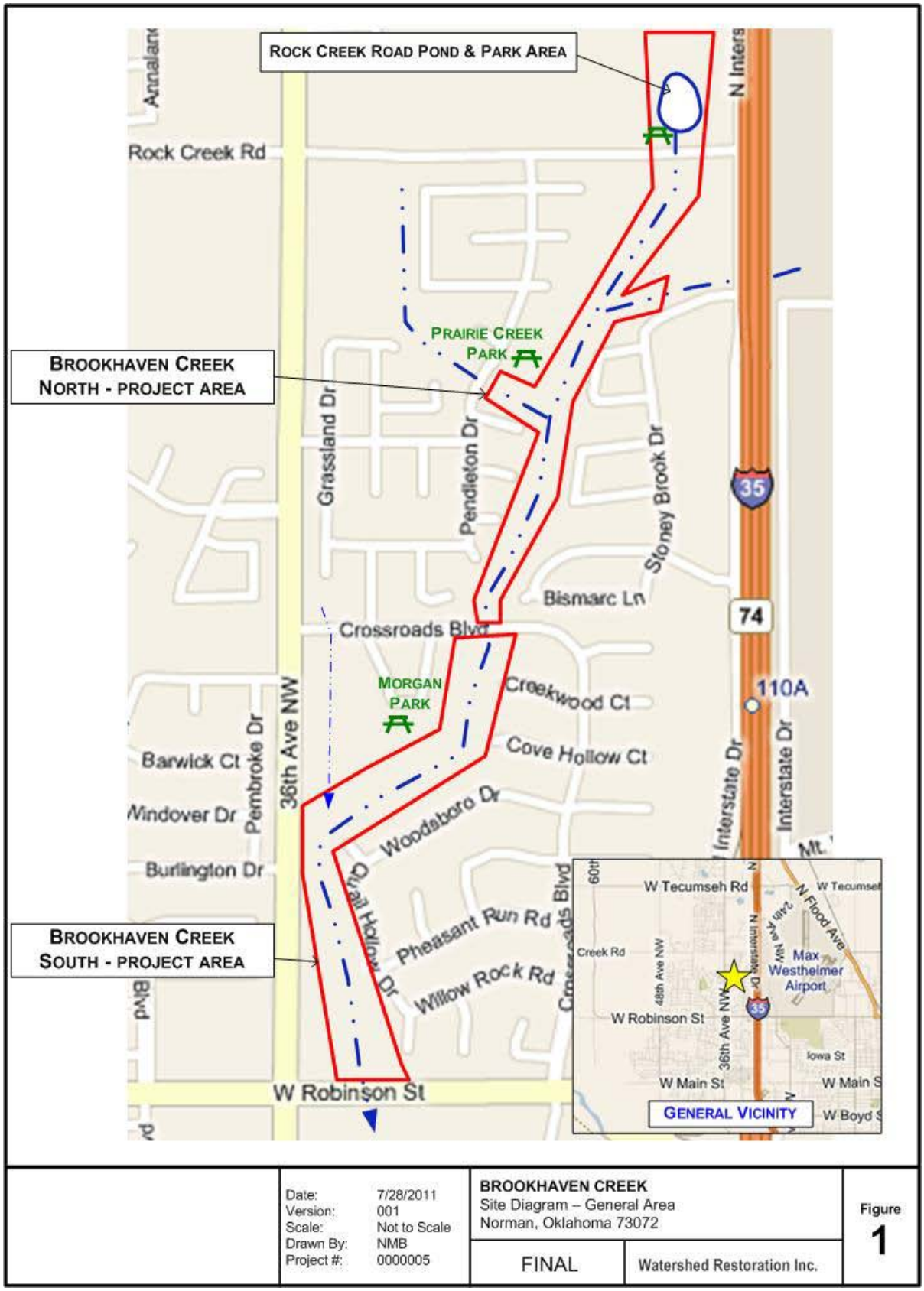
Overall, the project objectives were to present alternative development approaches to maximize wetland area and decrease flood impacts; demonstrate environmentally friendly stream stabilization techniques; and include wetlands and natural environments in the urban planning process. These objectives were couched in the need to create partnerships, change attitudes, and address misconceptions towards stream systems and wetlands.

As originally proposed in the project workplan, the expected outcomes included:

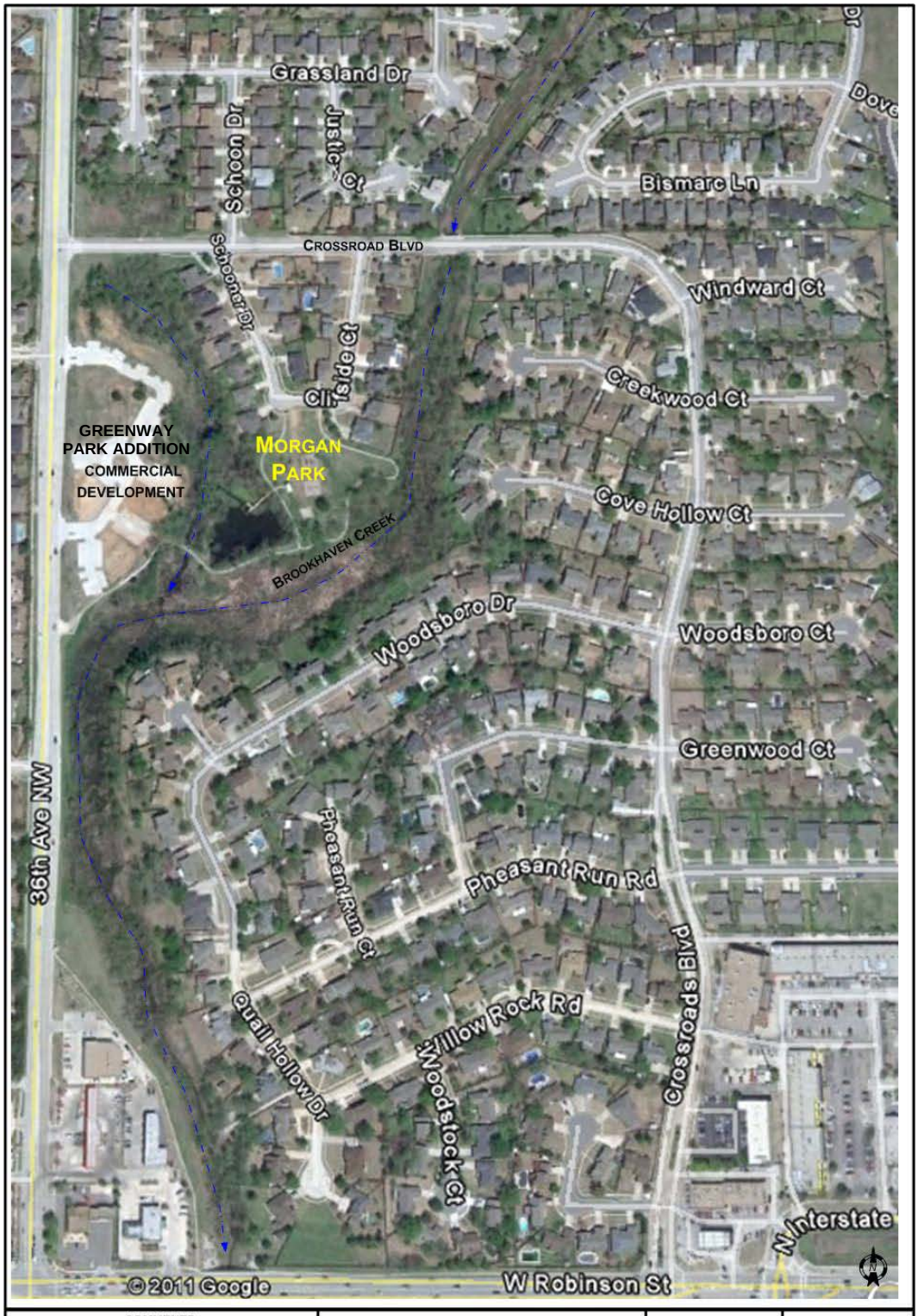
1. Design and implementation of steam stabilization techniques to convey storm water as an alternative to a concrete channels;
2. Demonstration of low impact development design techniques (e.g., intact riparian areas, permeable surfaces, etc.) for the preservation and protection of wetlands, floodplains, riparian areas, and waterways; and
3. Development of an urban watershed plan emphasizing the importance and protection of wetland and riparian areas with respect to storm water in the City of Norman.

Like every outreach effort the desired outcomes morphed with the process as some objectives became more successful than others. For this project, the City attitudes towards natural stream systems evolved and the importance of wetlands and stream channels became paramount. Although this grant project cannot take full credit for the paradigm shift, it was instrumental in the overall process.

Photo 8: Brookhaven Creek cattail marsh


ROCK CREEK ROAD POND & PARK AREA
BROOKHAVEN CREEK NORTH - PROJECT AREA
BROOKHAVEN CREEK SOUTH - PROJECT AREA
PRAIRIE CREEK PARK
MORGAN PARK
Rock Creek Rd
Grassland Dr
Pendleton Dr
Stoney Brook Dr
Bismarc Ln
Crossroads Blvd
Creekwood Ct
Cove Hollow Ct
Woodsboro Dr
Pheasant Run Rd
Willow Rock Rd
Quail Hollow Dr
Crossroads Blvd
W Robinson St
36th Ave NW
Pembroke Dr
Barwick Ct
Windover Dr
Burlington Dr
Interstate Dr
N Interstate Dr
35
74
110A
W Tecumseh Rd
Creek Rd
48th Ave NW
36th Ave NW
N Flood Ave
Max Westheimer Airport
W Main St
Iowa St
GENERAL VICINITY
Date: 7/28/2011
Version: 001
Scale: Not to Scale
Drawn By: NMB
Project #: 0000005
BROOKHAVEN CREEK
Site Diagram – General Area
Norman, Oklahoma 73072
FINAL
Watershed Restoration Inc.
Figure 1

COMMENTS	BROOKHAVEN CREEK Brookhaven Creek "North" Aerial Norman, OK	Watershed Restoration Inc.	Figure 2
	SCALE: NTS VER: 001 PRJ#: NA	DATE: 9/14/2011	DRW BY: AJC	FINAL



COMMENTS	BROOKHAVEN CREEK Brookhaven Creek "South" Aerial Norman, OK		Watershed Restoration Inc.	Figure 3
	SCALE: NTS VER: 001 PRJ#: NA	DATE: 9/14/2011	DRW BY: AJC	FINAL

2.0 PROJECT APPROACH & METHODOLOGY

In order to achieve the objectives presented above, four (4) project tasks were proposed in the project workplan. Tasks 1 and 2 were designed to influence the City's planning process by providing tangible examples of engineering and practical approaches that are more harmonious with natural conditions rather than diametrically opposed. The outreach component of Task 3 facilitates the process by educating various development and private sector groups, regulators and the general populous, to the benefits and importance of a balanced natural system within the urban environment. Task 4 includes a combination of efforts which highlight the need for a well conceived and crafted storm water master plan. Each of these tasks is introduced below with the results of the project effort presented and discussed in Section 3.0.

2.1 Task 1: Alternative Stream Channel Development

As discussed above, the City had developed plans in the 1990s to channelize Brookhaven Creek to improve drainage and prevent flooding. It was assumed that development along Brookhaven Creek and within the watershed had placed homes at risk of flooding. As the basin continues to be developed, the City assumed the chances of flooding would increase because the system was not functioning as originally designed.

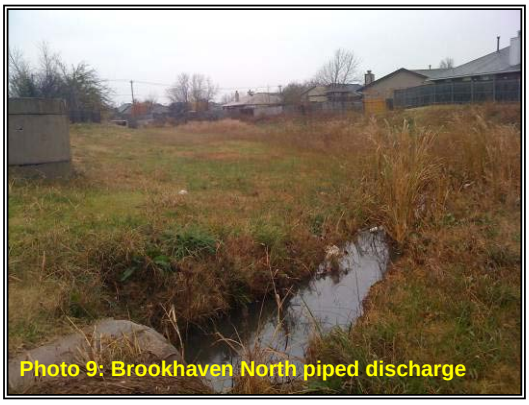


Photo 9: Brookhaven North piped discharge

WRI originally presented an alternative solution that met the objective of decreasing flooding while maintaining the environmental integrity of the system. The idea was to re-design the Brookhaven South reach using less invasive and more natural techniques that are based on FGM principles. The intent was not only to save the wetland and riparian habitat, but enhance it as well. By restoring a portion of the creek, the human-urban environment is protected and the diversity and benefit of the natural environment is preserved.

However, after surveying, studying, and modeling the creek, WRI determined that the stream segment slated for channelization was actually a stable, functioning system and there were no homes at risk of flooding. Any stream modification would have been detrimental and financially irresponsible. Consequently, Task 1 changed to focus on techniques to restore the riparian corridor and how to incorporate natural processes and wetland benefits into storm water management controls. The project site for this task moved upstream to the Brookhaven North segment.


Photo 10: Brookhaven North; Rock Creek Road Pond pre-construction (DEQ 2010 aerial)

Specific activities included:

Sub-Task 1.1: Implementation of Stream Restoration Activities
Planning, design, and construction of a natural stream and riparian area restoration project to restore channel stability and re-develop a stream thalweg.

Sub-Task 1.2: Pre & Post-Implementation Monitoring
Pre and post-implementation biological and habitat monitoring conducted to estimate the habitat improvement at the site. Information from habitat collections, biological monitoring, and photo documentation collected for comparative purposes for the pre-implementation conditions at the site. (This information is included in the Appendix for future evaluation once the system matures over the coming years.)

Sub-Task 1.3: Incorporate Natural Processes & Wetland Benefits Into Storm Water Management Controls.
Planning, design, and construction of a detention/retention pond and wetland area to demonstrate other benefits such as water quality improvement, wildlife habitat and aesthetics.

2.2 Task 2: Alternative & Low Impact Development Techniques

Development in urban areas is typically centered on financial gain rather than the attributes of aesthetics, wildlife habitat, water quality protection, or open space. However, low impact development can lead to financial benefits by creating an environment that is desirable and which people demand. Riparian areas and floodplains provide open, green space which creates an attractive quality that can be priceless in terms of environmental benefit and actually increase property values. Like most established urban areas, development pressure within the watershed and immediately adjacent to Brookhaven Creek is high. The riparian zone has been greatly reduced in most places and the remaining open land is dedicated parks or has been platted for development.

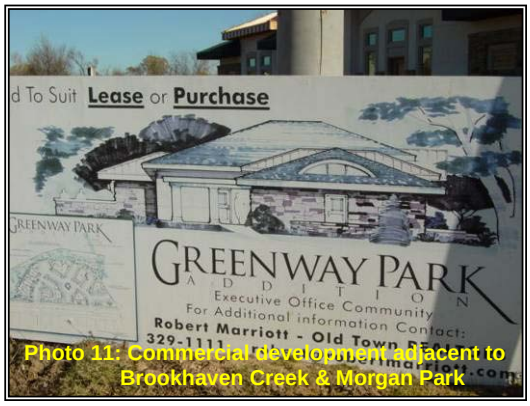


Photo 11: Commercial development adjacent to Brookhaven Creek & Morgan Park

As part of this project, two developers with planned projects adjacent to the north and south segments of Brookhaven Creek participated by agreeing to adopt best management practices and implement alternatives designed to reduce runoff quantity and improve quality as compared to classic storm water management and development approaches. Stream integrity would also be protected and preserved by creating low to no impact zones in critical areas. Trails, green space, and natural areas would be incorporated to increase economic and aesthetic values. The intent was to use the adjoining developments as examples for the City and the development community to use when considering future projects. The designs and techniques for the best management practices will be promoted and made available to other developers to reduce future impacts to wetlands and streams.

2.3 Task 3: Outreach and Education

The purpose of this task was to continue the educational efforts championed by OCC and others and to tout the benefits of stream and storm water management approaches that protect and enhance the natural system while benefitting the urban environment. Developer, consulting and municipal groups were targeted since their actions directly impact streams, wetlands, and riparian systems. The City, OCC, and WRI would provide technical assistance to encourage stream restoration, wetland protection, and watershed planning.

2.4 Task 4: Storm Water Master Plan

Lake Thunderbird provides the majority of the City's drinking water, but is subject to storm water pollution associated with urban development and runoff. As the City grows rapidly, the pressure on the lake and stream corridors could reach a breaking point. Realizing the importance of protecting these critical natural systems and sensitive waterbodies, the City needed to develop a master plan that incorporates innovative approaches, novel ideas, and proven best management practices that afford protection and foster environmental compatible alternatives. Norman committed to developing a program to ensure that drainage systems control storm water runoff, protect the public during major events, maintain property values, safeguard water quality, and balance storm drainage planning approaches to complement open space and recreation corridors. A comprehensive Storm Water Master Plan[3] (SWMP) was in the development stages when this project was conceived. It was an obvious fit to use this project as a tangible tool to foster the development. As the grant progressed, WRI participated in the public process and became members of advisory boards to encourage the City to consider the intrinsic values of natural stream systems.

As part of the development process, practices that were protective of sensitive waterbodies, riparian corridors, wetlands and floodplains were identified and specifically adopted into City's overall storm water effort. Guidelines would be adopted that incorporate alternatives to classic urban planning and storm water management, while embracing and promoting low impact development methods.

Figure 4: City of Norman Storm Water Master Plan

[3] Online link ttp://www.ci.norman.ok.us/sites/default/files/WebFM/Norman/Public%20Works/StormWaterMasterPlanFinalDraft.pdf)

3.0 PROJECT RESULTS & DISCUSSION

As the project proceeded, the whole dynamic evolved to take on a new fervor not anticipated when the grant was originally conceived. The City's commitment, private sector contributions, outside involvement, and public interest coalesced in support of the project. In some ways, this effort was an iterative exercise rather than a specifically defined project, but in the end the outcome was more successful than anticipated. A summary review of each of the project tasks introduced in Section 2 is presented below.

3.1 Task 1: Alternative Stream Channel Development

Background

As discussed previously, Brookhaven Creek was slated for channelization based on perceived flooding risks and overtopping concerns at Crossroad Blvd. The City had developed engineering plans to remove the marsh and bottomland hardwood wetland areas and create a concrete, trapezoidal channel in its stead. The City believed that the vegetation was restricting flow and causing backwater conditions. Given the entrenched engineering solution mentality, the City had to be sold on the benefits of alternative stream channel design. With its imperiled status, Brookhaven South was targeted for FGM-based restoration, but after evaluating the stream it was determined that no real benefit would be gained by constructing anything—it was a functioning and stable system. Consequently, a new demonstration location was selected immediately upstream—Brookhaven North. The process of evaluating Brookhaven South and switching to the Brookhaven North site was the most important but unexpected benefit of the whole project. Through this process, the City fully appreciated the limitations and devastating harm classic engineering solution can have. This was truly an eye-opening experience that changed the perspective of City staff. With this as a background, the efforts for both stream segments are discussed below.

Brookhaven South

Over the past 20-30 years, 2.5 acres of cattail marsh, 8 acres of bottomland hardwood forest, and associated riparian area had developed around a fully functioning stream. In fact, this stream segment is one of the most stable E-channels in this part of the state. The system was created in part by the influence of a beaver dam, beaver foraging habits, and the lack of City maintenance. Wildlife colonized the area creating a diverse urban oasis with over 40 species of birds, along with several mammal (e.g., deer, fox, rabbit, etc.), reptile and fish species. Ironically, the system is protected and stabilized because of urban development. Construction of the Robinson Street bridge and Crossroads Blvd. RCB created two grade-stabilizing points that have prevented headcuting and

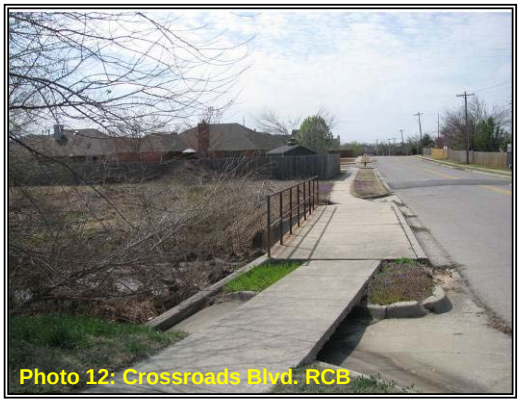


Photo 12: Crossroads Blvd. RCB

channel entrenchment. Unfortunately, the City perceived this area to be unkempt, overgrown and in need of channel reconstruction.

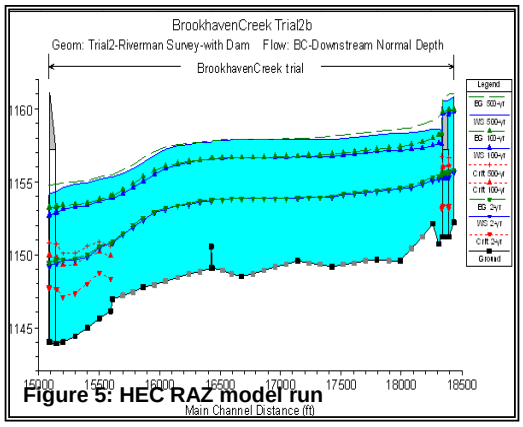


Figure 5: HEC RAZ model run

WRI helped to dispel some of the City's misconceptions and prove that there would be no net benefit to constructing a concrete channel. This was no easy task. Some of the concerns identified by the City merited additional review and engineering assessment. It would be irresponsible to make decisions based solely on professional judgment when there are homes at risk of flooding. Consequently, a limited hydrology and hydraulics study was performed.

The modeling effort began by evaluating the input data and the conditions surrounding the City's concerns (i.e., flooding risks and overtopping issues). After the initial review it was determined that the assumptions were based on an old survey, previously modeled information, and an outdated FEMA map. As a result, WRI had to collect new information (e.g., field survey) and re-model the system. Spring and fall 2008 were spent collecting data and running the models.

WRI modeled four scenarios using the available input information and field-collected data. These included: 1) current conditions, 2) trapezoidal channel, 3) meandering channel, and 4) enhanced stream/wetland channel. This effort proved to be no easy task; the modeling evolved into a lengthy exercise involving at least 15 trials with multiple variables (e.g., beaver influence, multiple roughness scenarios, etc.). Each trial addressed slightly different inputs and assumptions in order to truly evaluate the City's concerns. (Refer to Appendix A for a copy of the engineering report generated by Mr. Russ Dutnell, Riverman Engineering.)

After assessing the new FEMA maps, reviewing the finished-floor elevations, conducting additional field survey and evaluations, and running the various model scenarios, the following three main conclusions were drawn:

1. In the study area, there were no houses with finished-floor elevations below the base flood elevation (BFE). They were not all above the two-foot City ordinance requirement, but they were meeting FEMA requirements and theoretically not at risk of flooding.
2. Channel and floodplain vegetation do not significantly affect the back-water condition at the Crossroad Blvd. RCB. The modeling effort proved that a concrete-lined channel would not improve the existing conditions commensurate with the cost associated with construction, loss of habitat and resulting public acceptance. Back-water conditions would not significantly

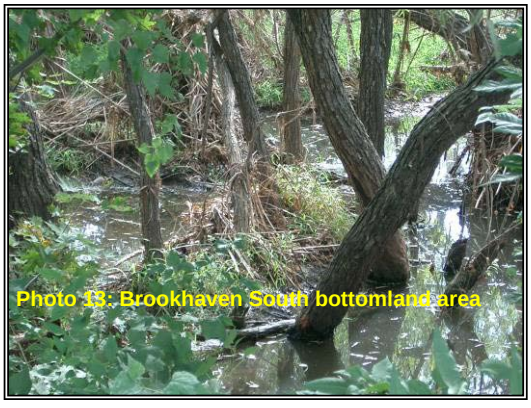


Photo 13: Brookhaven South bottomland area

improve at the RCB (6-8 inch decrease with overtopping during 100-yr event) and only a modest decrease in surface water elevation (0.12 inches) would be gained downstream.

3. The Brookhaven South segment was determined to be a very stable stream with a well defined channel and intact floodplain. Any restoration effort would be wasted on a healthy system.

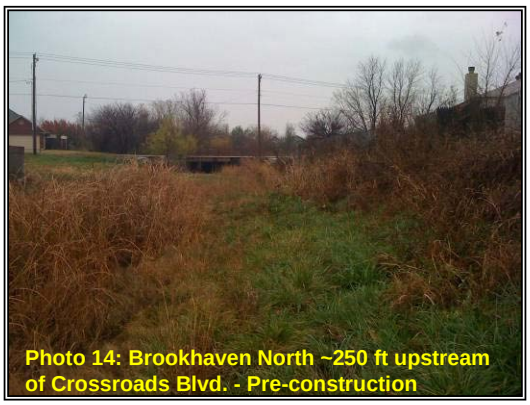


Photo 14: Brookhaven North ~250 ft upstream of Crossroads Blvd. - Pre-construction

Results of the modeling effort were presented to the Public Works Director, City Engineer/Stormwater Engineer, and Capital Projects Engineer for review and discussion. (Refer to Appendix B for a copy of the WRI summary memo.) After assessing the results, it became clear to the City that the proposed work in Brookhaven South would not have the desired results.

In effect, this effort saved the stream segment from future exploitation and unnecessary reconstruction. By using proven modeling approaches (HEC-RAS), the City was willing to accept the information and began to realize that a natural stream system can function within an urban environment without having to be re-engineered. This aspect of the grant fulfilled a larger role in the educational and outreach objective (i.e., Task 3) by enlightening the City Engineer/Stormwater Engineer, other departmental staff. In some respects, this portion of the grant was the most important part since it changed attitudes and opened minds to the idea that what appeared to be a wild, vegetation-choked marsh, infested with beaver could function to convey water and not cause flooding. Perhaps natural stream systems could function in the urban environment. (The only problem with this change in attitude was the realization that the grant no longer had a demonstration site.)

Brookhaven North

WRI proposed that the project location be move immediately upstream to the Brookhaven North segment. This reach was an obvious choice since the stream had been channelized and converted to a vegetated swale as part of residential development. However, the City's concern for overtopping Crossroads Blvd. and the potential for upstream flooding now had to be addressed. If the "overgrown" Brookhaven South segment was not the culprit, then why did the RCB overtop in the recent past? Ideally, the City would like to prevent overtopping and reduce the flood stage so that all homes were in compliance with the City's requirement of two feet above the BFE. Perhaps FGM techniques could be used to achieve these goals. Consequently, the City requested WRI to conduct a bridge hydraulic analysis to evaluate the Brookhaven North segment and determine what was causing the problem. In turn, WRI hired a local engineering firm (EST, Inc. Norman, OK) to conduct a hydraulic study on the

Photo 15: Brookhaven North ~600 ft upstream of Crossroads Blvd. - Pre-Construction

upper watershed. Winter 2008 through spring 2009 were spent assessing the watershed and modeling (HEC-RAS) the flow conditions. A final report was submitted to WRI and the City in June 2009.

EST, Inc.'s report identified the following four conditions. (Refer to Appendix C for a copy of the report.)

1. The RCB theoretically overtops between the 50-yr and 100-yr event. However, this meets the City's design requirement for the 50-yr storm flow.
2. In order for the RCB to handle the 100-yr storm event, peak flows would have to be reduced by 50 CFS.

Photo 16: Brookhaven North ~1000 ft upstream of Crossroads Blvd. – Pre Construction

3. In order to meet the City requirement of a two-foot elevation difference between the base flood elevation and the finished floor elevation, peak flows in the study watershed would have to be reduced by 175 CFS.
4. Upstream detention would be required, perhaps in two locations given the large area needed to accommodate the volume of flow.

WRI then evaluated the possibility of detaining water within the confines of the existing watershed. However, urban development had consumed most of the available property with the exception of dedicated parkland. WRI assessed the idea of using a park to detain water as well as create a hands-on education opportunity. With the help of Riverman Engineering, conceptual plans were developed to convert a portion of Prairie Creek Park into a wetland and detention area with off-stream storage using FGM techniques. Generic designs were prepared to meet the 175 CFS storage requirement to lower the BFE. These designs would transform part of the park from its existing function into an outdoor classroom with storm storage capacity and riparian and wetland area plantings. The existing baseball diamond and soccer field open space would be affected to meet the detention requirements. WRI presented the concepts to the City Engineer\Stormwater Engineer and the City's Parks Department. Unfortunately, the impact to Prairie Creek Park was unacceptable and the proposed benefits untenable. Community support for the park was strong and any perceived reduction in park capacity or function would not be accepted by the local users. Since this grant was designed to build partnerships and not create strife, the City chose to reject the idea of a multiuse park and detention area. In the end, the theoretical risk of over-topping and flooding did not supersede the benefit of the park landuse.

One bright spot in the whole exercise was the realization of the importance to preserve riparian and floodplain areas to address peak flows. After going through the modeling process and developing the various solution scenarios, the City Engineer/Stormwater Engineer and other City staff understood the importance of including riparian areas and wetlands in watershed planning. Trying to retrofit detention structures in an urban system is virtually

Photo 17: Brookhaven North Prairie Creek Park

impossible without sacrificing other desirable amenities such as parks. If Brookhaven North had been designed to function as a stream with an intact floodplain and riparian area when the urban development was originally planned, then the risk of flooding and potential impact on infrastructure could be reduced.

Photo 18: Brookhaven North ~1600 ft upstream of Crossroads Blvd. – Pre-Construction

Although both modeling efforts theoretically proved that the homes were not in eminent danger of flooding, and that the Crossroads Blvd. RCB met the City's 50-yr storm flow requirements, the grant still needed a project location to demonstrate natural stream channel design. WRI slightly modified the grant outputs to demonstrate riparian corridor restoration and show how a conventional storm water detention structure could be redesigned to concurrently function as a natural lentic/wetland system. Brookhaven North was still an ideal location to demonstrate these concepts because of the degraded riparian corridor and since a detention area was planned in the upper reaches. WRI developed detailed engineering and landscape plans for both the riparian corridor and the wetland area. The remainder of the section is divided into these two aspects.

Riparian Corridor As discussed, Brookhaven North was selected for the riparian restoration because it had been channelized and converted to a grass swale. (Refer to Photos 14-19.) A main sewer line paralleled the creek and several other utilities crossed the channel throughout its length. The City treated this reach as a utility corridor with little appreciation of the ancillary benefits it could provide. As part of the City's maintenance program, the stream banks and channel were mowed regularly so there was virtually no woody vegetative or cover. In fact, tractor tire ruts formed the unstable, braided channel observed in the field. (Refer to Photo 19.) Although bank erosion was limited, there was some concern that continued urban development in the watershed would result in future problems. The stream was in a perpetual state of disturbance and functioned as a conveyance channel rather than a healthy creek system.

WRI proposed balancing the City's needs with the benefits that a natural stream could provide. In order to do so, the stream segment was studied and evaluated. Field review included longitudinal and cross section surveys, habitat assessments (from a functionality perspective) and vegetation inventories. Several meetings were held with City personnel, including the maintenance supervisors and staff, to determine their needs and incorporate their ideas into the design. After several months of assessments (fall 2009 through spring 2010), evaluations, information gathering, and discussions, a generic demonstration and restoration concept plan was developed. This plan would incorporate FGM principles to stabilize the channel and meet the City's needs for maintaining flow and accessing utilities while restoring the riparian corridor.

Photo 19: Brookhaven North ~2000 ft upstream of Crossroads Blvd. – Pre-Construction; tire ruts

To begin with, the stream channel would be improved by providing grade stabilizing rock ramp crossings based loosely on the Newberry riffle design (Newbury Hydraulics, British Columbia, Canada). Ten crossings were proposed and designed by Riverman Engineering between Crossroads Blvd. and Rock Creek Road. The structures would allow City maintenance vehicles to mow the upland areas and cross the creek without disturbing flow or destroying habitat. The structures would help the stream channel to reestablish by eliminating chronic disturbance and by allowing a thalwag to develop. They were also designed to create riffle and pool habitat and simulate a more natural stream system. After surveying the stream and developing several iterations, a final set of plans was submitted to the City in June 2010. (Refer to Appendix D for a copy of the Phase I: Rock Ramp Construction Plans.) Construction of the rock ramp crossings was completed in September 2010.

Photo 20: Rock Ramp Crossings - construction; fabric and crushed stone base

With a stabilized stream channel as the backbone of the plan, the next step was to restore the vegetation and create the basis for a functioning riparian corridor. In order to maintain the stream channel, the bankfull elevation was planted with native trees. Over 160, 2-inch caliper bald cypress (*Taxodium distichum*), sycamore (*Platanus occidentalis*), and hackberry (*Cetis occidentalis*) trees were positioned so that over time a riparian woodland would reestablish. Other species, including willow, cottonwood, ash, and elm, would naturally colonize the corridor as well. The plantings were designed to compliment the in-stream rock structures (e.g., plantings near pools to provide shade and physical support) and be aesthetically pleasing. After 16 iterations, a final set of planting plans were submitted to the City in September 2010. (Refer to Appendix E for a copy of the Phase II: Riparian and Wetland Planting Plan.) Tree planting began in the fall of 2010 and continued through the winter of 2011.

Given the extreme drought and exceedingly hot 2011 summer, several of the trees perished. Re-planting efforts were planned, but would not occur until conditions were more favorable. As part of the planting contract with the landscaping company, a 2-year maintenance agreement was signed to guarantee tree survivability. All of the dead trees will be replaced in the late 2011 or early 2012.

A corridor maintenance plan was also developed with the City to protect the stream. Mowing and other disturbance restrictions were placed around the channel. Regular mowing was allowed in the upland areas, but the trees served as a demarcation zone to protect the channel and banks. Realizing the City's need to maintain flow and remove debris, provisions were made to allow for some in-stream work. Occasionally, (i.e., once every 1-3 years) shrubby growth (e.g., willows) could be addressed without

Photo 21: Rock Ramp Crossing - construction; crushed stone base & surge layer

disturbing the bank. Mechanized equipment would not be allowed in the stream and herbicides are prohibited.

In effect, this aspect of the project demonstrated that urban needs (e.g., water conveyance, utility placement, etc.) can be balanced with a natural system that provides ancillary benefits (e.g., water quality improvement, aesthetics, wildlife habitat, etc.). In total, approximately 4,200 ft of riparian corridor was reestablished and protected. Over the coming decades this segment will grow up and form a system similar to the naturalized bottomland hardwood area associated with Brookhaven South. Stream habitat assessments, fish collections, and photo documentation were done by OCC. This information can be used in the future to document the improvement over time. (Refer to Appendix F for OCC's Habitat Assessment and Fish Collection forms and information. Refer to Appendix G for OCC's photo documentation.)

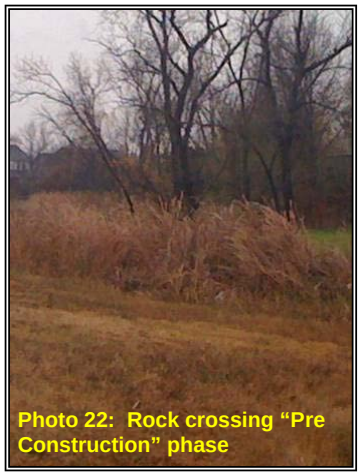


Photo 22: Rock crossing "Pre Construction" phase


Photo 23: Rock crossing "Construction" Phase


Photo 24: Rock crossing "Post Construction" Phase

Wetland Detention Area The demonstration site for the lentic/wetland system was selected just north of Rock Creek Road. As part of an unrelated infrastructure project (i.e. Rock Creek Road I-35 overpass), the City had plans to drain a naturalized in-stream ½-acre pond (Photos 26) and associated bottomland/wetland habitat (~2.5 acres) and construct a dry-bottom, detention area in its stead. This type of rectangular, grassed structure is typically used in urban settings because it functions well and is easy to construct and maintain; however, there are no ancillary benefits. As an alternative, WRI proposed to enhance the detention pond to create a 1.5-acre water feature with a functioning littoral zone and two adjoining wetland areas totaling approximately 0.5 acre. The proposed changes were designed to incorporate water quality improvement, habitat, aesthetics and the engineering requirements into one project that the City could use as a demonstration site. The pond, littoral zone and wetland areas were designed to improve water quality and create habitat for aquatic and terrestrial species. The shape of the pond was softened to include curves and plantings to improve the appearance, and the upland area was designated to become a park that includes a spur of Norman's Legacy Trail. The intent was to convert the unattractive detention pond into a


Photo 25: Brookhaven North ~1600 ft upstream of Crossroads Blvd. – Post-Construction Planting

destination rather than a dead-space ordinance requirement.

Although the City was excited about the idea, it became a bureaucratic exercise to get approval for change orders from various state and federal entities. Also, the adjacent landowner (S&S Family Properties) (S&S) had an agreement with the City to use the land for a road crossing and for future development detention. The relationship between the City and the landowner was a tenuous one because of the difference in opinion over the proposed use of the property. S&S wanted to maximize the land for future commercial development and the stream and detention pond were seen as impediments and cost liabilities. WRI, in partnership with the City, negotiated with S&S to create a solution that would benefit all parties. After a series of meetings and legal debates an amenable agreement was reached. WRI, with engineering assistance from EST, Inc., re-designed the proposed detention area to include a road crossing and to account for future storm water detention capacity. (Final pond construction plans were submitted to the City in December 2009 and construction began in the spring 2010 and continued through October 2010.)

Photo 26: Rock Creek Road Pond – Pre-construction

The new designed detention/retention area was excavated to a max depth of 12 feet and a concrete stem wall was poured to create a 1.5 acre pond. A 0-18-inch deep sloping bench was constructed around the perimeter of the pond to create the littoral zone. Evaporation calculations were made to ensure water levels were elevated even during drought conditions. Stratification concerns were taken into consideration with respect to phosphorous precipitation and re-entrainment. Wetland species (refer to Table 3-1) selection was based not only on physiologic requirements, but on the aesthetics and potential use of the area. The west pond bank (closest to the park) was planted with low growing species that could handle trampling and some compaction. Hopefully, people would come down from the upland park area and interact with the water feature. Tough plant species were selected knowing that that mowing would occur during dry periods. The far banks were design and planted to physically restrict access. Steeper slopes (e.g., 2:1) were needed in order to meet the volume detention requirements, but these areas could not be mowed easily. Consequently, the east and south banks were planted with dense and taller wetland vegetation. Native riparian tree species (e.g., pecan (*Carya illinoinensis*) and black walnut (*Juglans nigra*)) were selected to screen the interstate highway on the east side, but also to handle the flashy water level changes that will occur as the pond functions as detention structure. Tree plantings will create woodland habitat and eliminate the need for mowing on the banks. Upland tree plantings of Chinkapin oak (*Quercus muehlenbergii*) and American elm (*Ulmus americana "Valley Forge"*) will provide structure, aesthetic value, and habitat in the future park area.

Photo 27: Rock Creek Road Pond – Main Pond; Post- construction

Photo 28: Rock Creek Road Pond – North Wetland Area; Post-construction

The two adjoining wetlands were created to provide habitat and improve water quality. These areas serve as forebay treatment systems to trap sediment and reduce nutrient loadings. They were designed to retain 6-8 inches of water, but are capable of holding several feet of surge during storm events. Each area was planted with a variety of herbaceous wetland species with placement based on micropool elevations requirements. (Refer to Table 3-1 for a list of wetland species.) Tree species (e.g., bald cypress (*Taxodium distichum*) and American sycamore (*Platanus occidentalis*)) were planted to compliment the wetland plants in terms of aesthetics, habitat, and structure.

In total, approximately 6800 wetland plants and 33, 1.5-2.5-inch caliper trees were planted in this project area. A final set of planting plans were submitted to the City in September 2010. (Refer to Appendix E for a copy of the Phase II: Riparian and Wetland Planting Plan.) A partial planting of the north wetland began in late fall of 2010 but the remainder of the plantings had to be suspended until November 2011 because of severe winter and summer drought.

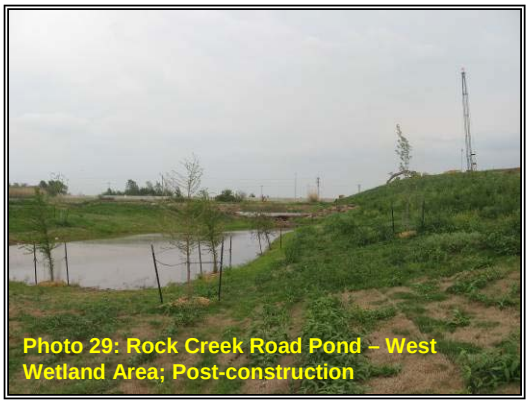


Photo 29: Rock Creek Road Pond – West Wetland Area; Post-construction

Table 3-1: Wetland herbaceous plant species

COMMON NAME	SCIENTIFIC NAME
Sweet Flag	*Acorus americanus*
Swamp Milkweed	*Asclepias incarnata*
Palm /Muskingum Sedge	*Carex muskingumensis*
Tussocks Sedge	*Carex stricta*
Spike Rush	*Eleocharis* spp.
Blue Flag Iris	*Iris virginica*
Soft Rush	*Juncus effusus*
Path / Poverty Rush	*Juncus tenuis*
Torrey's Rush	*Juncus torreyi*
Pickerelweed	*Pontederia cordata.*
Kansas Arrowhead	*Sagittaria ambigua.*
Lizard Tail	*Saururus cernuus*
Softstem Bulrush	*Schoenoplectus tabernaemontani*


Photo 30: Rock Creek Pond decorative rock spill way

In addition to the functional aspects of the plan, quality of life and aesthetics were also considered. For instance, a detention pond typically becomes an overgrown "dead-space" in most urban developments; few people interact with or use the land. The Rock Creek Road project area was designed to invite people to the space by creating a 10-ft wide concrete spur off of the City's Legacy Trail. Legacy Trail connects west Norman with the downtown and the University of Oklahoma (OU). Hopefully pedestrians and bicyclists will stop off and enjoy the area. The topography and pond shape were designed to create an overlook to allow people to interact with the aquatic environment. Once the project is complete, the upland area will become part of the City's park system and maintained regularly. Decorative rock (funded by the City of Norman) was selected for the dam spillway to soften the sterile and industrial feel that detention structures typically have and also to make a more inviting atmosphere. The physical design and species selection were also purposefully chosen to create an outdoor educational study location. Arrangements have been made to evaluate vegetation, habitat, and wetland function over time. Already, several OU classes have used the site as an outdoor laboratory, lecture venue, and water quality research site.

3.2 Task 2: Alternative & Low Impact Development Techniques

This project was effective at demonstrating and incorporating low impact development (LID) techniques from both the private sector and the City. Two developers have implemented or will implement LID concepts and best management practices (BMPs) as part of their planned developments. One site was located in Brookhaven South near Morgan Park and the other was located in Brookhaven North near the Rock Creek Road pond area.

Brookhaven South

Greenway Park Addition is located just south of Crossroads Blvd. on 36th Street. It is a 3.5-acre commercial development that adjoins Morgan Park's outdoor wetland classroom and discharges storm water directly to Brookhaven Creek. The developer, Mr. Robert Marriott, wanted to take advantage of the natural beauty associated with the riparian vegetation and tie into the City's trail system that leads to the park. However, commercial viability was limited by the relatively small size of the property and the infrastructure requirements (e.g., storm water detention, parking, etc.). To have enough area for these features and to be profitable, the land along the creek would have to be cleared. Not wanting to destroy the habitat, he worked with the City and OCC in developing a mutually beneficial plan to minimize the impact on the creek while trying to maximize the amount developable property and meet the City's requirements. In 2008, the City allowed Mr. Marriot to use the Morgan Park pond to meet his storm water detention requirements. In exchange, he would enhance the pond to make it more of


Photo 31: Morgan Park Pond/Greenway Park Addition's detention structure

a water feature and protect the vegetation along the creek. Mr. Marriott created a buffer along the riparian zone associated with the Morgan Park tributary to Brookhaven Creek.

In addition, runoff from the entire development was channeled to a 4,500 ft^2 portion of pervious pavement before discharging. This was specifically designed as a demonstration to see if this BMP would work in commercial development situations. Also, potential impacts to water quality were further reduced by avoiding direct storm water discharge. Once the water left the site, it flowed through a diffuse area of vegetation rather than being collected and piped directly to the creek.

Photo 32: Greenway Park Addition's pervious pavement parking area

Overall, this was a successful partnership that demonstrated the benefits of natural areas and how alternative arrangements can be made to reward all parties involved. Greenway Park Addition indirectly benefited from the added aesthetic value of trees and green space and directed profited by maximizing the developable property. Without this agreement, not only would approximately 700 linear feet of riparian corridor have been lost, but the educational opportunity would have been missed. This LID-partnership and example of proactive thinking can be applied to other developments around the City.

Brookhaven North

S&S Family Properties (S&S) also partnered with the City in a mutually beneficial endeavor. S&S owned the property where the Rock Creek Road retention pond was built. As part of an unrelated negotiated settlement, the City acquired land from S&S in order to create the dry-bottom detention pond. Given the location of the property, the land was very valuable for future commercial development. A typical development would have filled in the riparian area to increase the developable footprint, but because of floodplain issues developable land was lost and access to the I-35 frontage road was severed.

WRI was able to come up with a plan that benefited all parties involved. A road crossing was designed through the detention pond to connect the S&S properties. This road created the divide between the main pond and the north wetland area. The main pond was also re-designed to account for future detention capacity when S&S develops their site. In exchange, S&S paid for half the cost of construction the retaining wall ($3,500) and will implement some form of LID or environmental friendly storm water management BMP, such as rain gardens, to improve runoff water quality from their site.

Figure 6: Pond/wetland design schematic

The City also demonstrated LID techniques. Various design practices and planning tools were used to conserve, protect and restore the natural system and mitigate adverse environmental impacts. By allowing the extreme transformation of a detention pond to a retention pond situated

in a park setting with trees, landscaped vegetation and wildlife habitat, the City was able mitigate the loss of 3 acres of pond, wetland and bottomland area. Wildlife habitat was restored and potential impacts were avoided. Already waterfowl, raptors, and aquatic species have utilized this urban ecosystem.

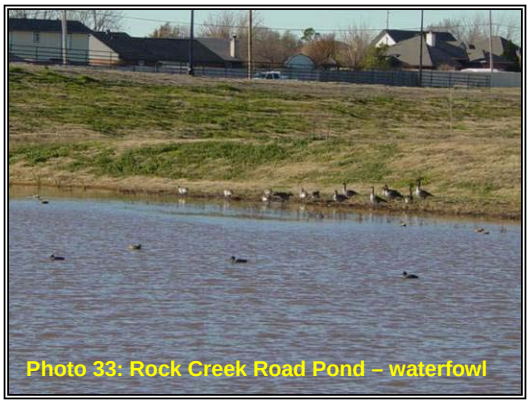


Photo 33: Rock Creek Road Pond – waterfowl

3.3 Task 3 Outreach and Education

In actuality, the entire project was one multifaceted educational and outreach effort. Every step of the process involved some sort of learning opportunity to impart the benefits of natural channel design, riparian restoration, low impact development, water quality benefits, etc.

Educational efforts began with City staff and City Council members when the idea for the grant was first proposed. These entities were specifically targeted not only to facilitate the project implementation, but also to change their opinions and attitudes towards watershed development and stream management. Several meetings were held with the Public Works Director, City Engineer/Stormwater Engineer, Parks Department staff and others to discuss the possible alternative to stream channel alteration. As described in Section 3.1, the whole process of modeling Brookhaven South was the best way to show engineering and science-minded individuals the virtues of FGM and natural system function. Using models that engineers are familiar with and trust to point out how a system can function without concrete is very powerful. When the classically trained City Stormwater Engineer, who originally designed the trapezoidal channel for Brookhaven Creek, changes his perspective and starts referring to himself as a "tree-hugger", then one could assume the educational effort was successful.

Outreach efforts also targeted the private sector developers and engineers. Several meetings and discussions were held with a variety of individuals but most of the outreach targeted the two developers which partnered on the project.

The first entity was a realtor and land developer in Norman (Robert Marriott). He owned commercial property adjacent to the Brookhaven Creek South stream segment. Through discussion with the OCC and the City, Mr. Marriott agreed to partner on this project and implement LID practices as well as enhance environmental best management practices to protect water quality and riparian habitat. (These are discussed in more detail in Section 3.2).

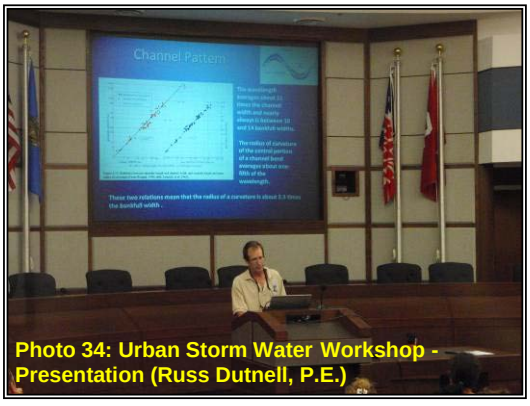


Photo 34: Urban Storm Water Workshop - Presentation (Russ Dutnell, P.E.)

The second group contacted was a leading, local development engineering firm (Spear & McCaleb, Oklahoma City, OK) and the landowners affiliated S&S Family Properties. They were engaged on several occasions to develop a mutually beneficial outcome for the property north of Rock Creek Road.

Some contentious disagreements between the City and S&S were transformed into the development of alternative solutions. (These are discussed in more detail in Section 3.2).

In addition to direct interaction with City staff and private sector individuals, a City sponsored outreach event was held on September 14, 2011. The City promoted this event as an Urban Storm Water Workshop and invited public and private sector folks and other individuals from around the state. The workshop included two 30-minute presentations followed by a field tour of the Morgan Park outdoor wetland classroom and the Brookhaven North restoration project.

Photo 35: Urban Storm Water Workshop field session at Brookhaven North

Mr. Russell Dutnell, P.E. (Riverman Engineering) gave an informative presentation over the benefits of FGM in the management of streams and storm water in his talk entitled "*Fluvial Geomorphology: A Tool for Sustainability Stormwater Management*". His presentation was followed by OU Professor and WRI President, Dr. Robert Nairn's talk "*Influence of Wetland and Riparian Zones on Water Quality*", which related the role of streams and wetlands in urban settings and the influence on water quality. In both of these presentations the science and engineering associated with the Brookhaven Creek project were emphasized. These concepts were then reinforced and specifically highlighted in a field tour led by WRI Vice President Dr. Geoff Canty. The natural wetland systems that evolved along the Brookhaven South channel and the LID BMPs of Greenway Park Addition development were toured and discussed. Also, the Brookhaven North stream restoration project's rock ramp crossings, tree plantings and corridor maintenance plan was presented and reviewed. Approximately 20 people attended the outreach event which included regulators, engineers, developers, students and municipal representatives from around the Oklahoma City metropolitan area. Refer to Appendix H for a copy of the flier and attendance roster.

3.4 Task 4 Storm Water Master Plan

In 2007 the City began the process of developing a Storm Water Master Plan (SWMP) with specific goals designed to reduce flooding hazards, protect water quality, reduce stream side erosion, and enhance the natural environment, among others. Many of the ideas directly applied to this project. This was an ideal opportunity to help direct and demonstrate the benefits of natural riparian corridors and management of watersheds and floodplains in an ecologically sound manner. Tangential issues such water quality, aesthetics, recreation and urban wildlife could all benefit from the development process of the SWMP. Implementing this project simultaneously with the SWMP allowed for practical discussion of alternative development approaches and concepts relatively foreign to the City's lexicon of thinking.

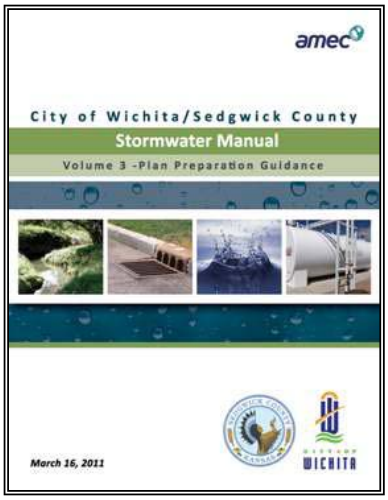


Figure 7: City of Wichita KS Strom Water Manual

As part of this project, several direct and indirect outcomes were realized. Three members of the WRI team participated directly on the Storm Water Master Plan Task Force. This was an excellent opportunity to inform and champion the driving principles directly related to the grant. Over a period of three (3) years WRI helped to shape the plan and craft ordinance language that would be included as part of the over management process. As a direct result, the City adopted Ordinance O-1011-52 on June 28, 2011 to protect water quality and riparian areas within the Lake Thunderbird watershed. This ordinance included "water quality protection zones" (i.e., 100-ft buffers adjacent to streams) designed to protect stream corridor integrity, reduce downstream pollution, and minimize flood hazards. Also included in the ordinance was a direct reference to encouraged the use of the City of Wichita's storm water manuals which includes LID techniques, storm water BMPs, and overall management practices for addressing storm water quality. Through this effort, the City now has tools at their disposal to integrate natural stream and wetland system protection and restoration as part of urban watershed planning for Lake Thunderbird.

Photo 36: Brookhaven North – "Pre-Construction"

Photo 37: Brookhaven North – "Construction"

Photo 38: Brookhaven North – "Post-Construction"

4.0 SUMMARY

The overall project objectives were to present alternative development approaches to maximize wetland area and decrease flood impacts; demonstrate environmentally friendly stream stabilization techniques; and include wetlands and natural environments in the urban planning process. The grant project exceeded these objectives and created partnerships, changed attitudes, and addressed misconceptions towards stream systems and wetlands.

Project success can be measured against the expected outputs listed below.

Output 1: *Design and implementation of steam stabilization techniques to convey stormwater as an alternative to a concrete channels.*

Through practical demonstrations and theoretical modeling, WRI was able to successfully address this output. By installing ten rock ramps (modified Newberry riffles) and planting 193 trees and 6,800 wetland plants, a stream restoration demonstration site was created (i.e., Brookhaven North), to show how a natural system can function to effectively convey storm flows while simultaneously providing ancillary benefits such as aesthetics, habitat and water quality improvements. Also, by modeling the adverse impacts a concrete channel can have on a stable and functioning stream reach (i.e., Brookhaven South), it was clearly demonstrated that natural systems can function in urban settings. Both of these efforts were very effective at conveying information to planners, engineers and decision makers.

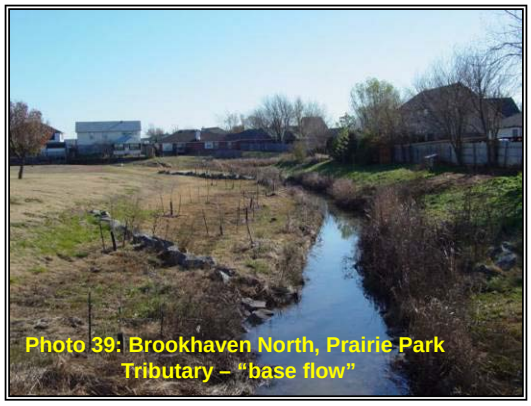


Photo 39: Brookhaven North, Prairie Park Tributary – "base flow"

Photo 40: Brookhaven North, Prairie Park Tributary – "~bankfull flow"

Output 2: *Demonstration of low impact development design techniques (e.g., intact riparian areas, permeable surfaces, etc.) for the preservation and protection of wetlands, floodplains, riparian areas, and waterways.*

Through practical demonstration and partnerships, low impact development techniques and best management practices were effectively implemented and demonstrated during this project. In addition to the riparian corridor restoration and protection aspects, WRI was able to transform a detention area into a lentic ecosystem with a functioning littoral zone and associated wetlands. Private sector partners incorporated pervious pavement and improved water quality and avoided riparian habitat impacts as part of their developments, which ultimately leads to the preservation and protection of wetlands, riparian areas, and waterways.

Photo 41: Morgan Park trail adjoining Greenway Park Addition

Photo 42: Morgan Park Tributary protected by Greenway Park Addition's LID implementation

Output 3: *Development of an urban watershed plan emphasizing the importance and protection of wetland and riparian areas with respect to storm water in the City of Norman.*

WRI helped to shape a plan and craft language that would be included as part of the City's overall storm water management process. As a direct result, the City adopted an ordinance (O-1011-52) specifically designed to protect water quality and riparian areas within the Lake Thunderbird watershed. This ordinance included "water quality protection zones" that will protect stream corridor integrity, reduce downstream pollution, minimize flood hazards and preserve wetland habitat. Adoption of this ordinance along with other aspects of the City's SWMP was clearly a highlight of the project.

APPENDICES

A. Riverman Engineering Report (12/04/2008)
B. WRI Status Update Memo (12/08/2008)
C. Bridge Hydraulic Report, Crossroad Blvd. Over Brookhaven Creek (EST, Inc. 6/23/2009)
D. Brookhaven Creek Improvement Project - Phase I: Rock Ramp Construction Plans (6/22/2010)
E. Brookhaven Creek Improvement Project - Phase II: Riparian & Wetland Planting Plan Plans (8/17/2010)
F. OCC's Habitat Assessment and Fish Forms
G. City of Norman Urban Storm Water Workshop information (9/14/2011)

APPENDIX A

Riverman Engineering Report
12/04/2008

APPENDIX B

WRI Status Update Memo
12/08/2008

APPENDIX C

Bridge Hydraulic Report, Crossroad Blvd. Over Brookhaven Creek
EST, Inc.
6/23/2009

APPENDIX D

Brookhaven Creek Improvement Project - Phase I: Rock Ramp Construction Plans
6/22/2010

APPENDIX E

Brookhaven Creek Improvement Project - Phase II: Riparian & Wetland Planting Plan Plans
8/17/2010

APPENDIX F

OCC's Habitat Assessment and Fish Collection Forms

APPENDIX G

City of Norman Urban Storm Water Workshop information
9/14/2011

ADDENDUM

FISH & HABITAT ANALYSIS

Monitoring Design

As discussed in the main body of the report, Brookhaven North was selected for the riparian restoration because it had been channelized and converted to a grass swale. This reach measures approximately 680 meters and includes accumulative impacts of urban management. The riparian area was non-existent due to routine mowing up to and through the stream bed. Tractor ruts contained the flow during seasonal base flow conditions. A sewer line paralleled the creek and several other utilities crossed the channel throughout its length.

The goal of this portion of the project was to establish and protect a riparian corridor, thereby reestablishing as much of the natural functionality of the stream segment as practically possible. Newberry Riffles were established and riparian trees planted, as well as restrictive mowing agreements negotiated. The goal of the monitoring strategy was to track the progress of this functionality. A thorough study of this area would include monitoring the change in physical habitat, fish community, macroinvertebrate community, water chemistry, sedimentation rates and potentially additional parameters. Due to the timeframe of this grant, little time remained at the end of this project for success monitoring. Therefore, the Oklahoma Conservation Commission completed pre and post-implementation in-stream habitat and fish community assessments. The response of the in-stream habitat and fish community following the reestablishment of the riparian area and the subsequent reduction in streambed disturbance from the continual maintenance (primarily mowing) should demonstrate improvement. Macroinvertebrate community assessments were not completed due to a lack of flow and reliable habitat.

Two primary obstacles remained through the last two years of this project. First was the short timeframe to demonstrate changes in the physical habitat and biological communities. The second and compounding problem was extended drought. Rainfall was so infrequent and slight that seasonal flow was rarely achieved and anything above seasonal base-flow was brief. It has been reported that bank-full flows were never achieved through the final year of the project. Due to the lack of flow, the stream thalweg did not develop and fish communities were not able to fully establish in the pools created by the emplacement of the Newberry Riffles. Understanding that these impediments to assessing the true value of the reestablishment of this stream reach exist, the data was analyzed for summary in this report.

In summarizing the monitoring effort during the pre and post-implementation phase of this project, it is important to understand the study boundaries. The study area extended from Crossroads Boulevard upstream approximately 680 meters. The portion of Prairie Creek from Brookhaven Creek upstream to Pendleton Drive was also included (125 meters) as work was to be completed on this stretch as well. This stretch included only one small pool at the bridge during the pre-implementation survey and no fish were collected. This 125 meter segment of stream contained water the entire 125 meters during the post-implementation survey and the majority of fish were collected out of this relatively short reach.

Results

A summary of the fish collected from the pre and post-implementation surveys is included in Table 1.

Table 1. Comparison of fish collected during the pre and post-implementation survey.

Collection	Total Number	Total Species	%Top Predators	Sunfish Species	Intolerant Species	Percent Tolerant	Species Comprising 75% of Sample
Pre-Implementation	330	4	0.30	2	0%	100%	1
Post-Implementation	515	5	4.27	3	0%	100%	1

An Index of Biotic Integrity (IBI) was calculated from the combination of the Brookhaven Creek proper and Prairie Creek fish data. These IBIs for the pre and post-implementation survey were compared to the reference condition IBI for the Crosstimbers Ecoregion developed and utilized by OCC in standard data analysis.

The metrics utilized in the IBI are listed below.

- Total Number Individuals
- Number of species
- Proportion top predators
- Number of sunfish species
- Number of intolerant species
- Proportion of tolerant individuals
- Species comprising 75% of sample

Table 2 shows the comparison of the pre and post-implementation IBI scores and condition.

Table 2. Comparison of pre and post-implementation IBI scores and condition.

Collection	IBI score	% Reference IBI	Condition
Pre-implementation	7	31	Very poor
Post-implementation	11	48	poor

The completed habitat assessment forms are included in this appendix. The two most influential habitat components for fish in small streams and the most likely project-impacted features are stream depth and surface area. Table 3 includes components of stream depth and surface area.

Table 3. Pre and post-implementation average width, depth and total surface area for the study segment.

Collection	Avg Width	Avg Depth	Wetted Length	Total Water Surface Area
Pre-implementation	1.97 m	0.11 m	680 m	1340 m^2
Post-implementation	2.38 m	0.15 m	305 m	762 m^2

Discussion

The pre-implementation survey indicates that the stream supports a very poor fish community as compared to the regional reference condition. This is indicative of the channelized stream and highly disturbed streambed. The post-implementation habitat survey shows that the overall wetted stream length decreased by over half. The average width, where pools occurred, was 21% wider than during the pre-implementation survey. This rendered a total post-implementation study area 43% less than during pre-implementation. This is most likely due to the extended drought that intensified during the last year of the project. Although the Brookhaven Creek study reach was intermittent during the post-implementation survey, the Prairie Creek reach contained water for the entire 125 meter length. This reach was dry prior to the stream work completed in 2010 and early 2011. Even though the stream area decreased from pre to post-implementation, total fish numbers, proportion of top predators, IBI scores and condition scores improved slightly.

The slight increase in fish numbers, IBI score and condition score occurred in spite of less water and a more stressful year in regards to rainfall and temperatures. This increase may be attributable to deeper pools and more stable habitat. If this is the case, a return to more normal or average rainfall and temperature may allow for a much enhanced fish community. The OCC hopes to include this stream reach in future studies to track the long-term success of this portion of the project.