FALCON DRAINAGE BASIN PLANNING STUDY

SELECTED PLAN REPORT

FINAL - SEPTEMBER 2015

Prepared for:

El Paso County Public Services Department
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Matrix Project No. 10.122.003

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BOCC

RESOLUTION NO. 15-387

BOARD OF COUNTY COMMISSIONERS
COUNTY OF EL PASO, STATE OF COLORADO

RESOLUTION TO RECOGNIZE AND ADOPT THE FALCON DRAINAGE BASIN PLANNING STUDY AND TO ESTABLISH A DRAINAGE FEE AND BRIDGE FEE FOR THE BASIN (CHWS1400)

WHEREAS, the Board of County Commissioners of the County of El Paso ("Board") has the authority granted to it under the provisions of §§30-11-101, (1)(e), and 30-11-107, (1)(e), C.R.S., to represent the County and exercise its further powers to address concerns of the County in all cases where no other provisions are made by law; and

WHEREAS, a plan for the development of drainage basins of mutual concern was adopted by the El Paso County Planning Commission as part of the County Master Plan on December 17, 1984 and has been subsequently amended; and

WHEREAS, Section 30-28-133(11), C.R.S., authorizes counties to adopt subdivision regulations providing for the payment of a sum of money or proof of a line of credit or other fees in equitable contribution to the total costs of the drainage facilities in the drainage basin in which the subdivision is located; and

WHEREAS, Section 8.5.5 of the *El Paso County Land Development Code* provides for the assessment of drainage basin and bridge fees and for the repayment to a subdivider, from any surplus basin funds available, of any costs the subdivider incurs because of compliance with the plans for the development of drainage basins in excess of the sum of the drainage basin fees assessed against the subdivider's impervious acreage; and

WHEREAS, the Board of County Commissioners of El Paso County, Colorado, Resolution 87-178A, authorized creation of the *City of Colorado Springs/El Paso County Drainage Criteria Manual* to set forth provisions for drainage policies, criteria, finance, and administration; and

WHEREAS, said manual has been further modified by Resolutions Nos. 88-58, 91-334, 95-81, 01-384, 04-483, 15-42 and others; and

WHEREAS, the El Paso County Public Services Department initiated an update to the Falcon Drainage Basin Planning Study dated December 15, 2000 (approved by the Planning Commission on October 17, 2000 and the Board of County Commissioners on December 14, 2000); and

WHEREAS, in accordance with the procedures outlined in the aforementioned *City of Colorado Springs/El Paso County Drainage Criteria Manual*, the El Paso County Public

Services Department has reviewed the Falcon Drainage Basin Planning Study dated September 2015 as prepared by Matrix Design Group; and

WHEREAS, the El Paso County Public Services Department has reviewed the aforementioned Drainage Basin Planning Study and associated Drainage Basin and Bridge Fees, and finds them to be in substantial conformance with the procedures of said *City of Colorado Springs/El Paso County Drainage Criteria Manual*; and

WHEREAS, the City/County Drainage Board has recommended approval of the Falcon Drainage Basin Planning Study at their October 3, 2013 meeting; and

WHEREAS, the El Paso County Planning Commission approved the Falcon Drainage Basin Planning Study as an amendment to and component of the El Paso County Master Plan on September 17, 2013 (MP-13; and

WHEREAS, the Housing & Building Association of Colorado Springs has offered their support of the Falcon Drainage Basin Planning Study and adoption of the associated fees and also request a commitment from the County that Staff continue coordination with regional stakeholders concerning the El Paso County Drainage Basin Fee Program and evaluate options for program improvements, specifically the following options: trading of credits among property owners within each basin and the formation of Title 37 Conservancy Districts; and

WHEREAS, since the development of the Falcon Drainage Basin Planning Study in 2013, the El Paso County Board of Commissioners have adjusted the drainage and bridge fees in the amount of 4.3% in accordance with Resolution 14-128 (Reception No. 214028996) based upon various economic indexes for the region and the drainage fees of $23,217 and bridge fees of $3,189 per impervious acre calculated in the study should also be adjusted accordingly resulting in the fee the be established as $24,215 per impervious acre and $3,326 per impervious acre respectively; and

WHEREAS, the Board having reviewed the Falcon Drainage Basin Planning Study has determined that it is in the best interest of the public to recommend adoption of this Study, which is attached hereto as Exhibit A, and incorporated herein by reference.

NOW THEREFORE BE IT RESOLVED by the Board of County Commissioners of El Paso County, Colorado finds that:

1. The Falcon Drainage Basin Planning Study and final fee recommendations prepared by Matrix Design Group dated September 2015 shall be formally adopted as the official Drainage Basin Planning Study for all properties lying within the boundaries of the Falcon Drainage Basin, Basin No. CHWS1400, as defined in said document.

2. Drainage Fees and Bridge Fees shall be established as $24,215 per impervious acre and $3,326 per impervious acre respectively.

3. This resolution shall become effective immediately and be applied to all development within the Falcon Drainage Basin boundaries in the County where the County has not accepted a final plat submittal as of the date of the adoption of this resolution.

BE IT FURTHER RESOLVED that the Board of County Commissioners of El Paso County, Colorado, hereby directs the County Engineer and appropriate staff, including but not limited to the Public Services Department and Development Services Department, to conduct a coordinated effort to evaluate options for improvements to the El Paso County Drainage Basin Fee Program including but not limited to those aforementioned options proposed by the Housing & Building Association of Colorado Springs and provide an update concerning any recommended program changes to the El Paso County Board of Commissioners by December 31, 2016 which will include receiving recommendations by the appropriate El Paso County advisory committees that report to the El Paso County Board of Commissioners; and

BE IT FURTHER RESOLVED that Amy Lathen, duly elected, qualified member and Chair of the Board of County Commissioners, or, Dennis Hisey, duly elected, qualified member and Vice Chair of the Board of County Commissioners, be and is hereby authorized on behalf of the Board to execute any and all documents necessary to carry out the intent of the Board as described herein.

DONE THIS 6th day of October, 2015, at Colorado Springs, Colorado.

ATTEST:

By: ______________________
Chuck Broerman
County Clerk and Recorder

BOARD OF COUNTY COMMISSIONERS
EL PASO COUNTY, COLORADO

By: ______________________
Amy Lathen, Chair

DISCLAIMER:

This report has been prepared based on certain key assumptions made by Matrix Design Group, Inc., which substantially affect the conclusions and recommendations of this report. These assumptions, although thought to be reasonable and appropriate, may not prove true in the future. The conclusions and recommendations made by Matrix Design Group, Inc. are conditioned upon these assumptions.

Background information, design bases, and other data have been furnished to Matrix Design Group, Inc. by third parties, which Matrix Design Group, Inc. has used in preparing this report. Matrix Design Group, Inc. has relied on this information as furnished, and is not responsible for and has not confirmed the accuracy of this information.

Information that became available after data procurement was complete was not incorporated.

This report is a planning document and is not to be used as the basis for final design, construction or remedial action, nor as the sole basis for major capital decisions.

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1.0 INTRODUCTION

1.1. Contract Authorization

The El Paso County Public Services Department (County) authorized Matrix Design Group, Inc. (Matrix) to conduct analyses and prepare this report, *Falcon Drainage Basin Planning Study Update*, under contract number 10-042. The performance location for this contract lies mostly within unincorporated El Paso County, Colorado within the Black Squirrel Creek watershed.

1.2. Purpose and Scope

The purpose of this Drainage Basin Planning Study (DBPS) is to update the existing plan for managing stormwater in the Falcon Watershed and to develop a plan to address future stormwater and infrastructure needs within the Falcon Watershed. The process used to develop a DBPS provides opportunity for interested parties to offer input on drainage issues, needs, and facilities within the watershed. The specific scope of work for this DBPS includes the following phases:

1. Scoping and Stakeholder Involvement
    a. Project schedule
    b. Public collaboration plan
    c. Stakeholders list
    d. Initial notification to stakeholders
2. Problem Identification for Existing and Future Conditions
    a. Data collection
    b. Hydrologic analysis
    c. Hydraulic analysis
    d. Initial stakeholders meeting
3. Alternatives Development, Evaluation and Selection
    a. Analysis of possible alternatives
    b. Stakeholder meeting
    c. Analysis of feasible alternatives
    d. Stakeholder meeting
    e. Analysis of preferred alternatives
    f. Stakeholder meeting
    g. Alternatives report
4. Plan Development
    a. Conceptual design and cost estimate
    b. Stakeholder meeting
    c. Conceptual design report
5. Fee Development
    a. Fee calculation
    b. Stakeholder meeting
    c. Fee development report
6. Plan and Fee Adoption
    a. Submit plan and fee to County for review and adoption
    b. Public notification meeting
    c. Drainage board meeting
    d. Planning commission meeting
    e. Board of County commissioners meeting

The DBPS, along with all technical data and findings, were completed and executed in accordance with applicable City, County, State, and Federal regulations, criteria and policies with the intent and goals described therein.

1.3. Previous Studies

URS Corporation completed a Drainage Basin Planning Study for the Falcon Watershed in 2000. Pieces of information from this previous study were used in this DBPS as noted. A complete list of reference reports is located in Section 3.

1.4. Summary of Data Obtained

Data used to complete the analysis for this DBPS, includes: topography, aerial photography, soils, land use, stormwater infrastructure, rainfall, field survey, U.S. Geological Survey (USGS) gage data, along with pertinent information from previously completed studies. A majority of the data was collected and utilized in a Geographic Information Systems (GIS) format. Table 1-1 outlines the major data collected along with the data source.

Table 1-1. Major Data Sources and Data Obtained

Data Obtained	Data Source
Aerial photography	El Paso County
2011 Aerial photography (Orthorectified)	Aerial Mapping Services
LIDAR data	El Paso County
2011 Digital Terrain Model	Aerial Mapping Services
Planimetric Data	Aerial Mapping Services
Existing and Build out land use	El Paso County
Zoning	El Paso County
Parcels	El Paso County
Right of Way	El Paso County
Easement	El Paso County
Building Footprints	El Paso County
Storm sewer infrastructure	El Paso County
Drainage basins	El Paso County
Roads	El Paso County
Road	TIGER
Bridges	El Paso County
Surface water course	El Paso County
Wetlands	El Paso County
Geologic hazard area	El Paso County
Vegetation	El Paso County
NRCS Soils	El Paso County
Wildlife Impact	El Paso County
NHD Flow line	National Hydrography Dataset
2000 Falcon DBPS	El Paso County
Final Drainage Reports	El Paso County
Rainfall Data	NOAA

Field work was performed to document, photograph, survey, and analyze channel characteristics of the Falcon Watershed.

1.5. Project Coordination

Throughout the course of this DBPS preparation, meetings were held with representatives of the City, County, State, and Federal agencies as well as interested citizens and stakeholders. The primary reason for the coordination effort was to obtain technical information and to identify concerns with regard to the development of stormwater facilities within the Falcon Watershed.

1.6. Acknowledgements

During the preparation of this DBPS several government agencies and interested individuals were routinely involved in coordination activities. Additionally, Olsson Associates provided quality reviews of technical modeling and reports and Smith Environmental & Engineering provided the summary of environmental resources and technical editing services. The Matrix project manager was Graham Thompson, P.E. A list of the individuals and agencies involved on a regular basis during the preparation of this DBPS includes:

Name	Agency
Andre Brackin	El Paso County Public Services Department
Jennifer Irvine	El Paso County Public Services Department
Mike Cartmell	El Paso County Public Services Department
Jeff Rice	El Paso County Development Services
Graham Thompson	Matrix Design Group
Lucas Babbitt	Matrix Design Group
David Krickbaum	Olsson Associates
Deb Ohlinger	Olsson Associates
Peter Smith	Smith Environmental & Engineering
Darrin Masters	Smith Environmental & Engineering

2.0 SUMMARY OF ENVIRONMENTAL RESOURCES

In general, the landform of the Falcon Watershed promotes a mixture of ecological types ranging from wetlands and short/midgrass prairie (modified as rangeland) to ponderosa pine (Pinus ponderosa) - dominated coniferous forest that enhances the biodiversity of the area. The environmental resources within the Falcon Watershed study area are illustrated on the attached map and described below. Geospatial data for this project were obtained from the Natural Diversity Information Source (NDIS) through the Colorado Division of Wildlife (CDOW), NatureServe databases, and the Colorado Natural Heritage Program (CNHP), and was verified by an onsite field visit. In addition, locations of potential point sources of pollution from hazardous materials were obtained from Environmental Data Resources Inc. (EDR) and cultural resource information and locations from the Colorado Office of Archaeology and Historic Preservation (COAHP). Soils data and depth to water table information was obtained from the Natural Resource Conservation Service (NRCS) soil survey for El Paso County. Water quality information was obtained from the Colorado Department of Public Health and Environment (CDPHE).

2.1. Wildlife

Several hundred birds, mammals, reptiles and amphibians inhabit the Falcon Watershed either as year-round residents or seasonally; all of which contribute to the functioning ecosystem as a whole. However, some species are of greater state and federal concern and are therefore either protected or managed for conservation and sustainability. For the purpose of the environmental resource map, wildlife species described herein were selected based on regulatory priority.

Migratory Birds

The Migratory Bird Treaty Act (MBTA) of 1918, as amended protects the majority of birds in the United States with few exceptions (invasive birds). All active (wild) bird nests and bird eggs are federally protected under the MBTA. It is also illegal to wound or kill any bird protected by the MBTA except for those managed under regulated hunting seasons.

Migratory birds within the Falcon Watershed can be found nesting in wetland and riparian areas, grassland/rangelands, forests, and within urban habitats. Migratory birds include perching birds (sparrows, warblers etc.), water fowl, game birds, and raptors (birds of prey).

State and Federal Threatened and Endangered Species

The U.S. Fish and Wildlife Service (FWS) lists 12 species as Threatened, Endangered, or Candidate under the Endangered Species Act (ESA) in El Paso County. The state of Colorado also lists 12 species as either state Threatened or Species of Concern. While not federally protected, state Species of Concern have a higher management priority by the CDOW. Of these, the species listed in Table 2-1 have either the potential to occur or have potential habitat within the Falcon Watershed.

Big Game

Big Game distribution within the drainage basin includes the American black bear (Ursus americanus), pronghorn (Antilocapra americana), mule deer (Odocoileus hemionus), white-tailed deer (Odocoileus virginianus), and mountain lion (puma concolor). Both the mountain lion and black bear are known to occur in El Paso County and the ponderosa pine forest, riparian corridors, and forested wetlands within the Falcon Watershed provide suitable habitat. While it is possible for both species to follow drainages and forested areas from the mountains to the Falcon Watershed in search of food, their occurrence in the drainage area is likely uncommon. The drainage area has suitable habitat for elk, but their occurrence is also uncommon in the area. White-tailed deer and mule deer are fairly common to common both in El Paso County and within the drainage area. The Falcon Watershed also provides suitable habitat for pronghorn, which were observed during the field visit.

Other Significant Wildlife

The Bald and Golden Eagle Protection Act of 1940 provides further protections for eagles. While both Bald and Golden eagles are uncommon to rare in El Paso County, potentially suitable habitat does exist in the Falcon Watershed.

Table 2-1. Federal and State Threatened and Endangered Species and Species of Special Concern within the Falcon Watershed

Common Name	Scientific Name	Regulatory Status	NDIS Occurrence in El Paso County	Falcon Watershed and Habitat Comments
Mammals				
Preble's meadow jumping mouse	*Zapus hudsonius preblei*	Federal & State Threatened	Known to occur, uncommon	The well-developed mixed shrub/grass riparian and adjacent upland grasses provides habitat, occurrence is unknown
Black-tailed prairie dog	*Cynomys ludovicianus*	State Special Concern	Known to occur, fairly common	Grasslands/rangelands and unused urban lots provide good habitat
Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	State Special Concern	Known to occur, uncommon	Ponderosa pine forest in the northern part of the drainage provides the best habitat. Forested wetlands along the streams also provides habitat.
Swift fox	*Vulpes velox*	State Special Concern	Known to occur, fairly common	Grasslands/rangelands provide good habitat
Birds				
Mexican Spotted Owl	*Strix occidentalis lucida*	Federal & State Threatened	Known to occur, very rare	Ponderosa pine forest in the northern part of the drainage provides marginal habitat. Forested wetlands along the streams provides foraging habitat. Occurrence would be very rare to unlikely in the drainage.
Mountain Plover	*Charadrius montanus*	Federally Proposed Threatened, State Special Concern	Known to occur, uncommon	The drainage area does have habitat components, but there is no known occurrence.
Whooping Crane	*Grus americana*	Federal & State Endangered	Likely to occur, no occurrence	Wetlands and agricultural areas provide habitat, considered a casual migrant on Colorado's eastern plains.
American Peregrine Falcon	*Falco peregrinus anatum*	State Special Concern	Known to occur, abundance unknown	Wetlands, grassland/rangeland, and pine forests provide habitat.
Burrowing Owl	*Athene cunicularia*	State Threatened	Known to occur, uncommon	Grasslands/rangelands occupied by prairie dogs provides habitat.
Ferruginous Hawk	*Buteo regalis*	State Special Concern	Known to occur, uncommon	Grasslands/rangelands, riparian areas, and prairie dog towns provide habitat.
Amphibians				
Northern leopard frog	*Rana pipiens*	State Special Concern	Known to occur, abundance unknown	Wetlands, riparian, and pine forests provide habitat.

2.2. Wetlands and Riparian Areas

The wetland and riparian polygons presented in Figure 2-1were obtained digitally from the NDIS and were digitized by the CDOW from 1998 National Aerial Photography Program (NAPP) photos. The field visit confirmed the existence of many of the mapped wetlands and riparian areas. Some, however, were no longer present. All three tributaries (east, middle, and west) contained Palustrine Emergent (PE), Palustrine Scrub Shrub (PSS), and Palustrine Forested (PF) wetlands intermittently throughout the drainage area. In addition, alterations in the natural drainage pattern in the form of roadside ditches, irrigation ditches, and detention ponds have promoted the development of PE, PSS, and PF wetlands in many other areas throughout the Falcon Watershed not included in the CDOW mapping.

2.3. Vegetation

Vegetation information throughout the drainage was obtained from the Colorado Vegetation Classification Project (CVCP 2003), which used Landsat™ imagery acquired between 1993 and 1995. Vegetative communities were also verified during the field visit. Since the time of the CVCP mapping, development has resulted in the conversion of some of the original vegetation from rangelands to urban areas. However, considerable open lands still exist. The following descriptions of vegetative communities found within the Falcon Watershed are ranked from most to least prevalent.

1. Rangeland dominated by annual and perennial grasses and grass/forb mixtures. In these areas, species composition can include: needle & thread, western wheatgrass (Pascopyrum smithii), crested wheatgrass (Agropyron cristatum), Kentucky bluegrass (Poa pratensis), bluebunch wheatgrass (Pseudoroegneria spicata), arrowleaf balsamroot (Balsamorhiza sagittata), gumweed (Grindelia spp.), prairie junegrass (Koeleria macrantha), lupine (Lupinus spp.) and other forbs.
2. Coniferous forest dominated by Ponderosa Pine (Pinus ponderosa) and some Gambel Oak (Quercus gambelii). This vegetation type occurs in the northern part of the drainage where it intersects with the Black Forest.
3. PE wetland and riparian areas consist primarily of sedges, which can include water sedge (Carex aquatilis), beaked sedge (Carex rostrata), Nebraska sedge (Carex nebrascensis), Baltic rush (Juncus balticus), and bulrush (Schoenoplectus spp.), and grasses such as tufted hairgrass (Aira spp.), redtop (Agrostis gigantea), cattails (Typha spp.) and reedgrass (Calamagrostis spp.).
4. PSS and PF wetlands and riparian areas exist throughout the drainage, but were not completely mapped by either the CVCP or NWI. PSS wetlands consisted mostly of sandbar willow (Salix exigua) and the PF wetlands/riparian areas consisted of cottonwood (Populus spp.), and crack willow (Salix fragilis).

<u>Noxious Weeds</u>

Russian olive (Elaeagnus angustifolia) was the only noxious weed species observed. It is a Colorado list B species. The Commissioner of Agriculture works with interested parties to develop management plans for List B species to prevent further spread.

2.4. Erodible Soils

The erosion hazard for the soils within the Falcon Watershed was determined by multiplying the erosion factor (k) by the maximum slope of the soil map unit. These data were obtained from the Soil Conservation Service (SCS, since renamed NRCS) soil survey for El Paso County (1981). Results ranging from <0.5-1 indicated a low erosion hazard, 1-3 is moderate, and >3 has a high erosion potential. Figure 2-1 shows the soil map units with a high erosion hazard.

2.5. Shallow Groundwater

Hillier and Hutchinson (1980) mapped the depth to groundwater in the northwestern one-third of the drainage basin. Within this area, they show that the water table is generally greater than 20 ft and more commonly greater than 100 ft below ground surface (bgs). Smith Environmental and Engineering (SMITH) believes that the Black Forest is an infiltration area that recharges the Dawson aquifer because of the course-textured soils that dominate the forest. As groundwater from the Dawson aquifer flows south and southeasterly, it perches on the lower units of the formation (claystone and siltstone) and is 10 to 20 ft bgs in some places (see the attached figure). As elevation decreases in a southeasterly direction, the groundwater surfaces as low discharge springs or seeps. The hydraulic connection between the unconsolidated alluvial deposits in the unnamed tributaries and the Dawson aquifer is greatest where stream valleys have been eroded into the Dawson formation (Hillier and Hutchinson 1980).

The CDOW riparian mapping and NRCS (2010) Web Soil Survey data covers the entire drainage basin. CDOW wetland and riparian polygons generally indicate a water table of less than a few feet bgs. NRCS maps indicate two areas (soil map unit 9 – Blakeland-Fluvaquentic Haplaquolls complex) that partially have groundwater at a depth of one foot (see Figure 2-1). Blakeland soils have groundwater deeper than 6.5 ft bgs, but Fluvaquentic Haplaquolls typically have groundwater less than two feet bgs. Fluvaquentic Haplaquolls generally reflect shallow groundwater perching on the claystone and siltstone aquitard of the lower unit of the Dawson formation.

2.6. Hazardous Materials

SMITH conducted an environmental record search of various regulatory databases by EDR on September 21, 2010 (2010). The search was performed to a maximum radius of two miles from the center of Falcon to accommodate for the large watershed. Sites identified by the EDR search as having the potential to cause environmental impacts are listed in the following sections. All sites listed below have received a No Further Action letter by the Colorado Department of Labor Employment, Division of Oil Public Safety (CDLE-OPS) and are not illustrated on Figure 2-1.

<u>Federally Regulated Sites</u>

RCRA-CESQG: RCRAInfo is EPA’s comprehensive information system, providing access to data supporting the Resource Conservation and Recovery Act (RCRA) of 1976 and the Hazardous and Solid Waste Amendments (HSWA) of 1984. The database includes selective information on sites which generate, transport, store, treat and/or dispose of hazardous waste as defined by the RCRA. Conditionally exempt small quantity generators (CESQGs) generate less than 100 kg of hazardous waste, or less than 1 kg of acutely hazardous waste per month. A review of the RCRA-CESQG list identified one site within approximately 0.5 miles of the Subject Property. The site is listed below:

1. Falcon School District, 10850 East Woodmen Road – The site has no history of violations. The site is unlikely to be an environmental concern to the Falcon Watershed with regard to its status as a RCRA-CESQG.

Facility Index System/Facility Registry System (FINDS)

1. Falcon School District, 10850 East Woodmen Road – The site, listed previously, is also listed on the FINDS System, an EPA database. No other information was provided.

Leaky Underground Storage Tank (LUST)

A review of the LUST database identified two sites within the prescribed search radius. The sites are described below:

1. Falcon School District, 10850 East Woodmen Road – The site had a release in 1997 for which it was issued a No Further Action letter by CDLE-OPS in 1998. A site cannot receive regulatory closure if contamination above regulatory standards has crossed its property boundaries. Therefore, since the site has received regulatory closure it is unlikely to present an environmental impact to the Falcon Watershed.
2. Mountain View Electric Association-Latigo Facility, 11140 East Woodmen Road - The site had a release in 1990 for which it was issued a No Further Action letter by CDLE-OPS in 1998. A site cannot receive regulatory closure if contamination above regulatory standards has crossed its property boundaries. Therefore, since the site has received regulatory closure it is unlikely to present an environmental impact to the Falcon Watershed.
3. PDQ #749, 11769 Hwy 24 (Diamond Shamrock) – The site is registered as a LUST site. Review of the COSTIS revealed that the site had a release in 1994 for which it was issued a No Further Action letter by CDLE-OPS in 2005 after a lengthy period of remediation. A site cannot receive regulatory closure if contamination above regulatory standards has crossed its property boundaries. Therefore, since the site has received regulatory closure it is unlikely to present an environmental impact to the Falcon Watershed.

Leaky Underground Storage Tank Trust (LUST TRUST)

LUST TRUSTS sites are LUSTs that have participated in the reimbursement fund of the State of Colorado.

1. Diamond Shamrock 1173, 11769 Hwy 24 – The site is a LUST TRUST site at the same address and LUST event as the PDQ #749 site mentioned above.

Underground Storage Tank (UST)

A review of the UST database identified six sites within the search radius. Two of the sites were outside of the Falcon Watershed. The remaining four sites are described further below:

- Safeway Fuel Center #4615, 7655 East McLaughlin Road, The site currently has two USTs, containing diesel fuel and unleaded gasoline respectively, in operation. The presence of active USTs presents a potential for future impact to the soil and groundwater of the Falcon Watershed. However, there is no record of a current impact as a result of the UST operation.
- Falcon School District, 10850 East Woodmen Road, The site currently has three USTs, containing waste oil, diesel fuel and unleaded gasoline respectively, in operation. The presence of active USTs presents a potential for future impact to the soil and groundwater of the Falcon Watershed. However, there is no record of a current impact as a result of the UST operation. As noted above, there is a record of a LUST at the site from previously removed USTs. The LUST case is closed.
- Mountain View Electric Association-Latigo Facility, 11140 East Woodmen Road – No active USTs are registered at the site. The site formerly had two gasoline USTs that were closed in 1990. As noted above, there is a record of a LUST at the site from previously removed USTs. The LUST case is closed.
- Falcon Food Store, 11150 Hwy 24, Peyton, CO - The site currently has two USTs, containing unleaded gasoline respectively, in operation. The presence of active USTs presents a potential for future impact to the soil and groundwater of the Falcon Watershed. However, there is no record of a current impact as a result of the UST operation.
- Diamond Shamrock 1173, 11769 Hwy 24 – The site is a registered UST and LUST TRUST site at the same address and LUST event as the PDQ #749 site mentioned above. Additionally it has four registered USTs in operation at the site. The USTs contain diesel fuel, regular unleaded gasoline, mid-grade unleaded gasoline, and premium unleaded gasoline respectively. The presence of active USTs presents a potential for future impact to the soil and groundwater of the Falcon Watershed. However, there is no record of a current impact as a result of the current UST operation.

Above Ground Storage Tank (AST)

A review of the aboveground storage tank database identified eight sites containing registered ASTs within the Falcon Watershed. Six of the sites were outside of the Falcon Watershed. The remaining two sites are described further below:

1. Mountain View Electric Association-Latigo Facility, 11140 East Woodmen Road – The site currently has two ASTs, containing diesel fuel, in operation. The presence of active ASTs presents a potential for future impact to the soil, surface water, and groundwater of the Falcon Watershed. However, there is no record of a current impact as a result of the AST operation.
2. Falcon Food Store, 11150 Hwy 24, Peyton, CO - The site currently has one AST, containing liquid propane gas (LPG), in operation. The presence of one active AST presents a potential for future impact to the soil and groundwater of the Falcon Watershed. However, there is no record of a current impact as a result of the AST operation.

Orphan Sites

SMITH reviewed a list of twelve sites identified as "Orphans" in the environmental database. Orphans are sites whose physical locations could not be located accurately because of an incorrect or incomplete address. Three of the 12 orphan site locations were identified within the Falcon Watershed and are included in the LUST, FINDS, and LUST TRUST sections above.

2.7. Historic Resources

A literature search was conducted through the COAHP COMPASS database and project reports were examined for any cultural properties that are located within the Falcon Watershed. Results of the file search show that seven cultural resource compliance projects have been conducted within the Falcon

Watershed. The seven cultural projects included two block surveys and five linear archaeological investigations. The file search results also identified nine previously recorded sites and isolated finds within the basin. The majority of the sites recorded within the Falcon Watershed are historic and consist of a windmill (5EP4130), a railroad (in three segments) (5EP1815.1, 5EP1815.7, and 5EP1815.8), a trash dump (5EP3322), two houses and associated structures (5EP3791 and 5EP3792), and two historic features associated with ranching and farming (5EP4651 and 5EP4652). The remaining two sites are prehistoric and consist of an isolated find (5EP4650) and an open lithic site (5EP4672). The first of three segments of the Chicago Rock Island and Pacific Railway (5EP1815.1) is officially eligible for the National Register of Historic Places (NRHP) while the other two segments, 5EP1815.7 and 5EP 1815.8, have been recommended as not eligible for the NRHP. All of the remaining historic and prehistoric resources are not eligible for the NRHP. Only eligible sites are illustrated on Figure 2-1.

2.8. Clean Water Act Section 303d

The CDPHE Water Quality Division has assembled a list of impaired waters in Colorado that have Total Maximum Daily Load (TMDL) restrictions for certain pollutants as required by Section 303d of the Clean Water Act. The unnamed tributaries in the Falcon Watershed are not listed and, therefore, are not subject to Section 303d TMDL restrictions. The Falcon Watershed streams are tributary to Black Squirrel Creek, which is tributary to Chico Creek. Chico Creek is tributary to the Arkansas River. While the Arkansas River has 303d list TMDL restrictions to the state border, Chico Creek and its tributaries are not included (CDPHE 2010).

2.9. Development Impacts

Residential and commercial construction throughout the past ten years has resulted in changes to the drainage pattern throughout the Falcon Watershed. These changes can either increase or decrease flows to various parts of the three unnamed channels. In multiple places, roadside ditches, culverts, and detention ponds have been constructed to manipulate historic flow patterns. These alterations can impact the drainage in two ways. First, the loss of hydrology from reducing flows to particular reaches will result in a change in vegetative structure. These areas have likely lost both wetland function and biodiversity. Second, diverted water can overload reaches that have not adapted to historic high flows. This condition usually results in bank erosion or the formation of nick points along the channel.

The construction of roads, water diversion structures, above-ground powerlines, residential communities, and commercial complexes impacts wildlife by fragmenting the vegetative communities important to their survival. Fragmentation can be an isolating mechanism that prevents some sensitive species from accessing important habitats during various life-stages. Fragmentation also creates movement barriers (e.g. roads and fences) for larger animals, which causes changes in behavior and increases mortality (roadkill for mammals and electrocution for raptors perching on powerlines).

Table 2-2. Cultural Resources and Their Eligibility

Site/IF	Site/IF Type (Name)	NRHP Eligibility	Location (T/R/S*)
5EP4130	Historic - Windmill	Not Eligible (officially)	T12S, R64W, S 31
5EP1815.1	Historic Railroad - Chicago, Rock Island and Pacific Railway	Eligible (officially)	T13S, R65W, S 12
5EP1815.7	Historic Railroad - Chicago, Rock Island and Pacific Railway	Not Eligible (field)	T13S, R64W, S 7
5EP1815.8	Historic Railroad - Chicago, Rock Island and Pacific Railway	Not Eligible (field)	T13S, R64W, S 7
5EP3322	Historic - dump	Not Eligible (officially)	T13S, R65W, S 12
5EP3791	Historic - House	Not Eligible (officially)	T13S, R64W, S 7
5EP3792	Historic - House	Not Eligible (officially)	T13S, R64W, S 7
5EP4650	Prehistoric IF	N/A	T13S, R65W, S 13
5EP4651	Historic Feature	Not Eligible (field)	T13S, R64W, S 18
5EP4652	Historic Feature	Not Eligible (field)	T13S, R65W, S 12
5EP4672	Prehistoric Open Lithic	Not Eligible (officially)	T13S, R65W, S 12

Figure 2-1. Environmental Features

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3.0 HYDROLOGIC ANALYSIS

3.1. Watershed Description

The Falcon Watershed is located in the north central portion of El Paso County (County) and flows southeasterly from the southern slope of the Black Forest. The Falcon Watershed contains three perennial streams and has a contributing drainage area of approximately 10.6 square miles (sq mi) at its confluence with Black Squirrel Creek. A routing schematic of the Falcon Watershed is provided in Figure 3-1.

The headwaters of the Falcon Watershed are dominated by ponderosa pine forest and grassland on undeveloped large acreage tracts and 2- to 5-acre (ac) rural residential lots. The middle portion of the Falcon Watershed between Londonderry Drive and Highway 24 has been developed into residential areas consisting primarily of single-family homes, commercial centers, and vacant land. The lower portion of the Falcon Watershed south of Highway 24 is dominated by grassland on undeveloped large acreage tracts and 2- to 5-acre (ac) rural residential lots. A basin map of the Falcon Watershed is provided in Figure 3-2.

3.2. Methodology

Hydrologic analysis for the Falcon Watershed was completed for historical, existing, and future land use conditions by applying a 24-hour storm event with 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals. The following sections provide a summary of the hydrologic analyses. A detailed compilation of hydrology model data, calculations, and results are provided in Appendix A.

3.3. HEC-HMS Model

A hydrology model for the Falcon Watershed was developed using the US Army Corps of Engineers (USACE) Hydrologic Engineering Center – Hydrologic Modeling System Version 3.5 (HEC-HMS) to simulate the rainfall-runoff process and generate flood hydrographs for select storm events. Each component of the model is described in detail following this section. A geospatially referenced basin model was developed in ArcGIS® Version 9.2 using USACE's Geospatial Hydrologic Modeling Extension (HEC-GeoHMS). Using these tools, subbasin and stream reach physical characteristics including area, longest hydraulic flowpath, reach length, slope, and topological connectivity were extracted for calculation of hydrologic parameters. Hydrologic parameters were calculated as outlined below and populated to the basin and meteorological components of the HEC-HMS model. A summary of selected methodologies for each HEC-HMS model component is provided in Table 3-1.

The Specified Hyetograph method was chosen to model the Type IIa hypothetical storm event recommended in the City of Colorado Springs and El Paso County Drainage Criteria Manual (DCM) (1991) with rainfall depths published in *NOAA Atlas II Vol. 3 (Miller et al. 1973)*. These hyetographs were imported into the HEC-HMS precipitation gage manager and applied to each subbasin within the Falcon Watershed. Rainfall was modeled with a uniform spatial distribution across the entire Falcon Watershed.

Infiltration and runoff volumes were modeled using the SCS (since renamed NRCS) Runoff Curve Number (runoff CN) Loss Method. The composite runoff CN was calculated for each subbasin and imported into HEC-HMS. For modeling purposes, initial infiltration loss rates were automatically calculated as functions of composite runoff CNs by HEC-HMS.

Table 3-1. HEC-HMS Model Components

Model Component	Selected Methodology
Meteorological Model	Specified Hyetograph
Infiltration Loss	SCS Runoff Curve Number Method
Runoff Transformation	SCS Unit Hydrograph Method
Channel Routing	Muskingum-Cunge Method
Baseflow Method	None

Notes:
SCS = Soil Conservation Service (since renamed Natural Resources Conservation Service)

The transformation of runoff volume to a runoff hydrograph was modeled using the SCS Unit Hydrograph Method. Subbasin lag times were calculated from the time of concentration as computed using the method outlined in *Technical Release 55* (*TR-55*) (NRCS 1986).

The Muskingum-Cunge Method was selected to develop the channel routing component of the HEC-HMS model. Eight-point cross sections developed from 2-foot (ft) contour data were used to represent open channel reaches while circular and rectangular sections were used to represent storm sewer reaches, as applicable.

3.4. Subbasin Delineation

Matrix subcontracted Aerial Mapping Services to obtain and develop orthometric aerial imagery of the current conditions within the Falcon Watershed to assist with the DBPS. Basin delineation and stream network definition were completed in an ArcGIS® environment using 2-ft contours, information obtained from field reconnaissance, and the storm sewer GIS coverage obtained from the County.

The Falcon Watershed was divided into 65 subbasins with areas ranging from 0.03 sq mi (19 ac) up to 0.33 sq mi (211 ac) as shown on Figure 3-2. Subbasin slopes in the Falcon Watershed range from 2.9% to 8.7%. Subbasins were delineated at tributaries, major road crossings, changes in slope, changes in land use, and major drainage features. Information obtained from drainage plans was used to supplement the basin delineation within developed areas when all other pieces of information did not provide a clear direction of delineation. Table 3-2 lists all drainage plans received from the County that were reviewed and incorporated as necessary.

The Falcon Watershed was divided into 3 major subbasins: West Tributary (WT), Middle Tributary (MT), and East Tributary (ET) as shown on Figure 3-2. The West Tributary consists of 37 subbasins and 10 minor tributaries along the entire length of the watershed from the Black Forest to the confluence with Black Squirrel Creek. These subbasins primarily encompass rural land with pockets of residential development. The Middle Tributary consists of 11 subbasins and 2 minor tributaries and is primarily north of Highway 24. These subbasins encompass rural, residential, and commercial land. The East Tributary consists of 16 subbasins and 1 minor tributary and encompasses residential land north of Highway 24 and rural land south of Highway 24.

Table 3-2. Drainage Plans within the Falcon Watershed

Beckett at Woodmen Hills Filing 1	Meridian Ranch Filing 4
Beckett at Woodmen Hills Filing 2	Paint Brush Hills Filing 4 Drainage Analysis
Beckett at Woodmen Hills Filing 3	Paint Brush Hills Filing 5
Courtyards at Woodmen Hills North Filing 1	Paint Brush Hills Filing 9
Courtyards at Woodmen Hills South Filing 1	Paint Brush Hills Filing 10
Courtyards at Woodmen Hills South Filing 2	Paint Brush Hills Filing 11
Courtyards at Woodmen Hills West	Paint Brush Hills Filing 12
Falcon Highlands Filing 1	Woodmen Hills Filing 1
Falcon Highlands Filing 2	Woodmen Hills Filing 4
Falcon Highlands Market Place Filing 1	Woodmen Hills Filing 5
Falcon Highlands Market Place Filing 2	Woodmen Hills Filing 6
Falcon Vista Subdivision Filing 1	Woodmen Hills Filing 7C & G
Falcon Vista Subdivision Filing 2	Woodmen Hills Filing 8
Forest Gate Subdivision	Woodmen Hills Filing 9
Latigo Business Center Filing 1	Woodmen Hills Filing 10
The Meadows Filing 3	Woodmen Hills Filing 11
Meridian Crossing Filing 1	

The Falcon South (FS) subbasin is a single subbasin at the southern portion of the Falcon Watershed that lies directly to the west of the watershed outlet. This subbasin does not contain any tributaries and discharges directly south of the Falcon Watershed outlet. The drainage area from the FS subbasin was previously included in the Falcon Watershed in the 2000 Falcon DBPS (URS Corporation 2000). However, based on new topographic data and aerial photography it was determined that this subbasin is not a part of the Falcon Watershed but was evaluated as a part of this DBPS for comparison purposes.

The subbasins delineated for the existing watershed condition are assumed to also represent both the historical (undeveloped) and future (full build-out) conditions. The reason for this is to maintain consistent comparison points with identical drainage areas when evaluating detention and channel improvement alternatives later in this report. Subbasin delineations were likely much different in the historical condition due to the absence of development and have the potential to change significantly as a result of future development. These changes are not able to be identified at this point due to data limitations and ambiguity of future development patterns.

Currently, there is a diversion berm that exists in the northwest portion of the Falcon Watershed as shown on Figure 3-1. This berm will divert approximately 195 cfs out of the Falcon Watershed. However, according to the County it can be assumed that this berm did not exist during the historical watershed conditions nor will it exist for the future watershed condition because this area is planned to be developed in the future and will likely result in the berm being removed.

3.5. Hydrologic Soil Groups

Soils are classified into hydrologic soil groups (HSG) by the NRCS for hydrologic modeling. HSG is a parameter assigned to each soil series by the NRCS to reflect the relative rate of infiltration of water into the soil profile. *TR-55* defines HSGs into A, B, C, and D groups.

The HSG was determined for each of the soil mapping units from the NRCS Soil Survey Geographic (SSURGO) data for the County. Only two of the four HSGs are found within the Falcon Watershed. Group B soils, with moderate infiltration rates, dominate the Falcon Watershed at 42% coverage. According to the SSURGO data there is an equally large coverage of HSG A soils, however, most of this coverage lies within or near development. Any areas within the HSG A coverage that have been regraded as part of urban development were regrouped to HSG B for runoff CN calculations that are described later. The reason for this is that as soon HSG A soils are disturbed or regraded the high infiltration rates associated with these soils are lost due to compaction. A HSG map is provided in Figure 3-3 that shows the distribution and coverage of each group within the Falcon Watershed. Table 3-3 shows the percentage of each HSG present in the Falcon Watershed.

Table 3-3. Hydrologic Soil Groups within the Falcon Watershed

Hydrologic Soil Groups	Coverage
A	9.9%
B	41.8%
B (Re-graded A Soils)	48.1%
C	0.0%
D	0.0%
Water	0.1%

3.6. Land Use

Historical land use conditions were assigned based on the land use categories defined in *TR-55* that are consistent with the native land uses within the watershed. Historical land use conditions represent an undeveloped watershed condition and were used as the underlying land use for runoff CN development as described below. Undeveloped land use conditions listed in *TR-55* are separated by good, fair, and poor condition. Woods (Good Condition) is the dominant underlying land use in upper portion of the Falcon Watershed while Rangeland (Good Condition) is the dominant underlying land use throughout the remainder of the watershed. Each of these land uses categories were assigned a good condition based on field observation of ground cover.

Existing and future land use information for the Falcon Watershed was obtained from the County GIS department. Existing land use data was developed in 2010 and was derived from the Assessor's parcel database. Future land use data represents development conditions sometime after 2030 and represents the current prediction of a full basin build-out scenario.

The Falcon Watershed reflects a variety of existing land uses including rural, grazing and farmland, rural residential, urban, commercial and industrial, vacant, and rights-of-way. Due to urban growth, land use is expected to change in the future condition with significant residential development planned in the middle portion of the watershed.

Historical, existing, and future land use conditions are shown in Figure 3-4, Figure 3-5, and Figure 3-6, respectively. Rangeland (Good Condition) was the dominant land use in historical conditions at 94%; while rural/rural residential is the dominant land use for existing and future conditions at 43% and 49%, respectively. Table 3-4, Table 3-5, and Table 3-6 outline major basin coverage by land use class for historical, exiting, and future conditions.

Table 3-4. Historical Land Use Classes within Falcon Watershed

Land Use[1]	Coverage
Woods (Good Condition)	5.9%
Rangeland (Good Condition)	94.1%

Notes:
[1] As defined in *TR-55*

Table 3-5. Existing Land Use Classes within Falcon Watershed

Land Use	Coverage
Rural	27.0%
Rural Residential	16.0%
Urban	14.7%
Vacant > 5 Acres	11.8%
Grazing Land	8.2%
Political Subdivision	4.4%
Commercial	2.4%
State	2.3%
Vacant 2.5 Acres – 5 Acres	1.6%
County	1.1%
Vacant < 2.5 Acres	1.0%
Other	9.5%

Table 3-6. Future Land Use Classes within Falcon Watershed

Land Use	Coverage
5 Acre Rural Residential	43.4%
0.5 Acre Residential	17.4%
Exclusion	16.3%
Single Family Urban	11.0%
2.5 Acre Rural Residential	5.4%
Schools and Colleges	1.9%
Service Commercial	1.5%
Parks	1.2%
Other	1.9%

3.7. Runoff Curve Number Development

Runoff CN is a parameter developed by the NRCS to quantify the relationship between rainfall, infiltration, and runoff. It represents the combination of a HSG and a land use class and condition (McCuen 1998). Runoff CNs are estimated as a function of land use, impervious cover, HSG, and antecedent moisture condition (AMC).

Historical runoff CNs were assigned to each subbasin based on HSG and underlying *TR-55* land use class and condition. Within an ArcMap® GIS environment, discrete grid combinations of HSG and underlying land uses were developed. Assuming an average AMC, runoff CNs were determined for each unique soil/land use combination and composite runoff CNs for each subbasin were calculated.

Existing runoff CNs were assigned to each subbasin based on the percent impervious cover and an underlying *TR-55* land use class and condition. Additionally, public gravel roads were included as a part of the CN calculation but were assigned independently of impervious area and underlying land use. The impervious area coverage was developed from the orthometric data obtained from Aerial Mapping Services that included planimetric data of roads, parking lots, and rooftops. This data was supplemented with manual delineation of driveways and the County's Parcel, Right of Way (ROW), and Building Footprint GIS data. Within an ArcMap® GIS environment, discrete grid combinations of HSG and underlying land uses were developed. Assuming an average AMC, runoff CNs were determined for each unique soil/land use combination based on presence or absence of impervious cover in the grid cell while evaluating gravel roads separately. The impervious areas were given a CN of 98, gravel roads were given a CN of 85, and all underlying areas were given a CN from *TR-55* based on the HSG and a woods-, open space-, or range land-land use. Composite runoff CNs were calculated from the gridded CN values within each subbasin. Figure 3-7 shows the existing impervious areas and provides the percent impervious by land use class and subbasin.

Future runoff CNs were assigned to each subbasin by using the existing CN grid in combination with representative CN values that were assigned to existing vacant land planned for future development. Representative CN values were developed by calculating composite CN values for each land use class in the existing condition that is planned for future conditions. Representative CN values were only developed for vacant land that is identified in the existing land use coverage as Dry Farmland, Grazing Land, County, Political Subdivision, State, Other, and Vacant land. Composite runoff CNs were calculated from the gridded CN values within each subbasin. Table 3-7 outlines representative CN values for future land use classes.

Figure 3-8, Figure 3-9 and Figure 3-10 show the discrete combinations of CNs used to develop the composite CNs for historical, existing, and future conditions, respectively.

Table 3-8 shows the area-weighted CN averages for historical, existing, and future conditions with the Falcon Watershed.

Table 3-7. Representative CN Values by Land Use

Land Use	Representative CN
Single Family Urban	79
0.5 Acre Residential	71
2.5 Acre Rural Residential	64
5 Acre Rural Residential (Rangeland Land Use)	62
5 Acre Rural Residential (Woods Land Use)	58
Schools & Colleges	69
Community Commercial/Service Commercial	81
Light Industrial	96

Table 3-8. Average Runoff Curve Numbers within the Falcon Watershed

Land Use	Historical CN	Existing CN	Future CN
Falcon Watershed	48	62	66

3.8. Initial Abstraction

Initial abstraction represents all water losses before runoff begins and is a function of the potential maximum water retention of soil. Initial abstraction includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration (*TR-55*). Conventional modeling uses an initial abstraction ratio of 0.20 which is also the default value in HEC-HMS. However, newer publications such as *Curve Number Hydrology* (ASCE/EWRI 2009) have revealed that an initial abstraction ratio of 0.20 is far too high for most applications and that an initial abstraction ratio of 0.05 is more appropriate for general application. Additionally, Matrix recently completed an extensive model calibration for the Jimmy Camp Creek watershed using measured rainfall and runoff information as a part of the Stormwater Management Assessment and Standards Development project for the City of Colorado Springs. The results of this analysis showed that an initial abstraction ratio of 0.10 is representative of the conditions in this area. As a result, an initial abstraction ratio of 0.10 was used for runoff calculations for the Falcon Watershed.

3.9. Time of Concentration

The time of concentration (T_c) was calculated by summing the travel time for overland sheet flow, shallow concentrated flow, and channel flow segments along the hydraulically longest flowpath as outlined in *TR-55*. The longest flowpaths were delineated using HEC-GeoHMS and manually modified to match the drainage patterns in the subbasins based on existing topology, roads, inlets, and culvert crossings.

Overland flow was assumed to occur within the first 300 ft and may end before 300 ft if development or a concentrated flow condition is encountered, as described in *TR-55*. Shallow concentrated flow occurs after overland flow and before channel flow occurs. In some instances shallow concentrated flow may not occur if overland flow transitions directly to channel flow. Channel flow occurs after shallow concentrated flow or, in some cases overland flow, where surveyed channel cross section information has been obtained, where a defined channel is apparent in aerial photography or contours, or where streams appear on United States Geological Survey (USGS) quadrangle sheets and transports the runoff to the outlet of the subbasin. Detailed time of concentration calculations are provided in Appendix A.

Time of concentration calculations were completed for existing conditions for each of the 65 Falcon Watershed subbasins using overland, sheet, and channel flow segments. The longest flowpaths and corresponding time of concentration values were likely much slower for historical conditions because of the absence of development. The longest flowpaths and corresponding time of concentration values will also likely change in the future condition but are not able to be identified at this point due to data limitations and ambiguity of future development patterns.

To account for changing development conditions, time of concentration values for undeveloped subbasins were compared to the values calculated for developed subbasins in order to determine the impact that development has on this parameter. Undeveloped subbasins were identified as subbasins with minimal (< 3% impervious area) or no development and where the longest flowpaths and time of concentration calculations were not impacted by development. In this watershed, the time of concentration for developed subbasins was calculated to be approximately 25% shorter for undeveloped subbasins meaning that water moves through the subbasin faster.

Time of concentration values are typically longer for historical conditions compared to existing conditions because the overland and sheet flow segments are not shortened by development or because of an extended channel flow segment. Also, channel flow segments occur in natural channels versus storm sewers and roadway drainage systems, which lengthens the time of concentration due to increased channel roughness. Time of concentration values were lengthened for historical conditions so that the reduction in time of concentration to existing conditions was 25%. This was completed for all subbasins other than the subbasins that were identified as undeveloped for existing conditions.

Time of concentration values for future conditions are typically shorter compared to existing conditions because of the increase in development, reduction in overland and sheet flow segment lengths, and increase in channel flow segment lengths. Time of concentration values were shortened for future conditions by reducing the existing time of concentration values by 25% for all subbasins except where there is no change in development between existing and future conditions.

A summary of the time of concentration values for the Falcon Watershed is provided in Table 3-9.

Table 3-9. Time of Concentration Summary for the Falcon Watershed

	Historical T_c	Existing T_c	Future T_c
Minimum	8 min	6 min	5 min
Maximum	153 min	115 min	86 min
Average	51 min	41 min	34 min

Notes:
min = minutes

3.10. Channel Routing

The Muskingum-Cunge method was used for channel routing in 70 reaches in the Falcon Watershed, which is dominated by a wide, grass bottom channel. Reach delineations were performed for existing conditions and were likely much different historically because of the absence of development. Reach delineations will also likely change in the future condition but are not able to be identified at this point due to data limitations and ambiguity of future development patterns. Manning's channel roughness coefficient (Manning's n) values for earthen channels were assigned based on published values. Storm sewer reaches were represented as either circular or rectangular cross sections and were assigned a Manning's n value of 0.013. Table 3-10 outlines the channel characteristics in the Falcon Watershed.

Table 3-10. Channel Characteristics within Falcon Watershed

	West Tributary		Middle Tributary		East Tributary	
	Slope	Manning's n	Slope	Manning's n	Slope	Manning's n
Minimum	0.50%	0.013	0.40%	0.013	0.40%	0.030
Maximum	2.9%	0.070	2.1%	0.070	2.1%	0.070
Average	1.7%	0.047	1.5%	0.044	1.3%	0.049

3.11. Detention Ponds

Fifteen existing detention ponds were included in the Falcon Watershed HEC-HMS model. According to discussion with the County, no as-built drawings exist for any of these detention ponds and the stage-storage-discharge relationships published in available drainage plans and reports are not reliable. As a result, Matrix developed stage-storage-discharge relationships using 2-ft contour information and field measurements of the outlet structures for each of the 15 detention ponds. The stage-storage-discharge relationships developed for this DBPS should only be used for planning purposes and not for further design of any the existing detention ponds in the Falcon Watershed. Detailed survey information should be obtained for any of the existing ponds where additional design is desired.

According to Falcon Highlands Final Drainage Report Filing No. 1 (URS Corporation 2005), Regional Pond WU was intended to be an off-line detention pond with a constructed weir to control flow into the pond from the main channel. However, based on field observation and measurements Regional Pond WU is an on-line detention pond that captures all flow from the upstream channel up to the elevation of the secondary outlet structure which discharges flow to the adjacent channel.

There are several stock ponds throughout the Falcon Watershed that appear to always remain full and do not have any apparent outlet structures. These ponds provide minimal flood attenuation and were not modeled using a detention reservoir model. All detention pond locations are shown on Figure 3-1. Detention pond characteristics are summarized in Table 3-11.

Note that all detention ponds must be approved by the Federal Emergency Management Agency (FEMA) before a hydrology model can be approved by FEMA. FEMA-approved ponds likely consist only of County- and District-owned and maintained ponds and likely do not include privately-owned and maintained ponds. Some of the ponds included in this analysis are within developments and are possibly privately owned and maintained.

Table 3-11. Detention Pond Summary for the Falcon Watershed

Detention Pond	I.D.	Location	Surface Area (ac)	Vol. (ac-ft)	Initial Condition[2]
Meadows Pond #1	M 1	600 ft east of Towner Ave. on Woodmen Hills Dr.	1.0	2.2	Initial Storage = 0
Meadows Pond #2	M 2	2,100 ft east of Towner Ave. on Woodmen Hills Dr.	1.6	6.3	Initial Storage = 0
Paint Brush Hills Pond #4	PBH 4	Northeast corner of Brockton Ln. & Liberty Grove Dr.	0.90	1.3	Initial Storage = 0
Paint Brush Hills Pond A	PB A	300 ft west of Keating Dr. on Rockingham Dr.	1.1	2.6	Initial Storage = 0
Paint Brush Hills Pond B1	PB B1	North of Duxbury Dr.	1.6	9.2	Initial Storage = 0
Paint Brush Hills Pond B2	PB B2	East of Duxbury Dr.	2.5	12	Initial Storage = 0
Paint Brush Hills Pond C	PB C	East of London Derry Dr. & Rockingham Dr.	1.9	6.8	Initial Storage = 0
Regional Pond MN	R MN	Between Meridian Rd. & McLaughlin Rd.	2.1	7.5	Initial Storage = 0
Regional Pond WU[1]	R WU	Southwest corner of Meridian Rd. & Tamlin Rd.	6.5	41	Initial Storage = 0
Woodmen Hills Pond #1[1]	WH 1	500 ft east of Tompkins Rd. on Woodmen Hills Dr.	3.6	16	Initial Storage = 0
Woodmen Hills Pond #2	WH 2	West of Ledoux Rd.	2.8	9.2	Initial Storage = 0
Woodmen Hills Pond #3	WH 3	North of Tompkins Rd. & Eastonville Rd.	5.5	8.4	Initial Storage = 0
Woodmen Hills Pond #4	WH 4	Northeast corner of Woodmen Rd. & Hwy. 24	8.1	22	Initial Storage = 0
Woodmen Hills Pond #5	WH 5	South of Corbu Heights & Maybeck view	1.5	4.1	Initial Storage = 0
Woodmen Hills Pond H	WH H	Northwest corner of Meridian Rd. & Woodmen Hills Dr.	1.0	2.7	Initial Storage = 0

Notes:
[1] Pond is divided by road. Values represent cumulative value of both areas.
[2] All detention ponds were assumed to be empty at the beginning of the model simulation.

3.12. Hypothetical Rainfall

A hypothetical rainfall event was used to simulate precipitation for hydrologic analyses. The SCS Type IIa 24-hour storm distribution is recommended for temporal distribution in the DCM. Storm events with 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals were selected for hydrologic modeling. These storm events have an equivalent of a 50-, 20-, 10-, 4-, 2-, and 1-percent chance of exceedance annually, respectively.

Isopluvial maps published in *NOAA Atlas 2 Vol. III* (Miller et al. 1973) were used to estimate rainfall in the Falcon Watershed for each recurrence interval. Since the Falcon Watershed is slightly larger than 10 sq mi, an areal reduction of 2% was applied as prescribed by *NOAA Atlas 2 Vol. III*. Table 3-12 provides the 24-hour rainfall depths for each recurrence interval.

Table 3-12. Rainfall Depths within the Falcon Watershed

Recurrence Interval	Unadjusted Rainfall Depths	Areal Adjusted Rainfall Depths[1]
2-year	2.0 in.	1.96 in.
5-year	2.6 in.	2.55 in.
10-year	3.0 in.	2.94 in.
25-year	3.8 in.	3.72 in.
50-year	4.2 in.	4.12 in.
100-year	4.6 in.	4.51 in.

Notes:
[1] Areal reduction of 2% applied to rainfall depths from the *NOAA Atlas 2 Vol. III*

The areal adjusted rainfall depths for all modeled storm events were multiplied by each ordinate of the SCS Type IIa 24-hour temporal unit distribution to develop hyetographs for each storm event.

3.13. Results

The HEC-HMS model for the Falcon Watershed was run to simulate the rainfall-runoff process and generate flood hydrographs for historical, existing, and future land use conditions by applying a 24-hour storm event with 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals. As expected, future peak flows increased over existing conditions in conjunction with planned development. Table 3-15 provides a brief summary of peak flows at points of interest within the Falcon Watershed and Table 3-16 provides a brief summary of flow volumes at the same points of interest. The future conditions model results reported in this section do not reflect any proposed detention, channel improvements, or other alternatives described in later sections of this report. Historical, existing, and future results are summarized graphically on Figure 3-11, Figure 3-12, and Figure 3-13, respectively.

3.14. Model Comparison

Previously published studies and flood flow analyses applicable to the Falcon Watershed include:

- URS Corporation *Falcon DBPS*, 2000
- FEMA Flood Insurance Study (FIS)
- FEMA Letters of Map Revision (LOMR)
- USGS *Analysis of the Magnitude and Frequency of Floods in Colorado*, 2000
- Colorado Water Conservation Board (CWCB) *Guidelines for Determining 100-year Flood Flows for Approximate Floodplains in Colorado*, 2004.

The peak flow results of this modeling effort were compared to the studies and analyses listed above to check for reasonableness. Table 3-14 provides a comparison of peak flow results at the Falcon Watershed outlet from the various flood studies. Flood flows are not published in the FEMA FIS for the tributaries in the Falcon Watershed. However, flood flows at sporadic locations throughout the Falcon Watershed were published in some of the LOMRs completed for developments. A comparison of these flows is provided in Table 3-17.

As shown in Table 3-14 the existing conditions peak flows for this DBPS are higher than the 2000 DBPS for the 5-yr event and lower than the 2000 DBPS for the 100-yr event. The reason for this is because of the lower initial abstraction value that was used for this DBPS. Lowering the initial abstraction ratio has a more noticeable impact on increasing smaller flood flows compared to larger flood flows. A summary of the major differences between this DBPS and the 2000 DBPS are:

- The 2000 DBPS model included 3 detention ponds with a total storage volume of approximately 31 ac-ft while this DBPS includes 15 detention ponds with a total volume of approximately 151 ac-ft.
- The 2000 DBPS did not account for the existing basin diversion in the northwest portion of the watershed
- It is assumed that the 2000 DBPS used an initial abstraction ratio of 0.20. The HEC-1 data that was received from the County shows that the first value in the LS card was left blank which indicates that the default initial abstraction value was used. There is no formal documentation that this value was used, however, this is typically the default initial abstraction ratio for most models. This DBPS used an initial abstraction ratio of 0.10.

A comparison of model parameters between this DBPS and the 2000 DBPS is provided in Table 3-13.

Table 3-13. Comparison of Model Parameters

	CN		T_c (min)		Manning's n	
	2000 DBPS	2011 DBPS	2000 DBPS	2011 DBPS	2000 DBPS	2011 DBPS
Min.	60	41	3.9	6.2	.020	.013
Max.	81	86	33	115	.035	.070
Avg.	61	62	14	41	.034	.047

Table 3-14. Flood Summary for the Falcon Watershed Outlet

Annual Percent Chance Flood Event	Recurrence Interval	Peak Flow (cfs)			
		Matrix HEC-HMS Model[1]		URS Corporation DBPS[2]	
		Existing	Future	Existing	Future
50%	2-year	190	230	--	--
20%	5-year	400	560	222	458
10%	10-year	600	860	--	--
4%	25-year	1,200	1,500	--	--
2%	50-year	1,500	2,000	--	--
1%	100-year	1,900	2,500	2,935	3,303

Notes:
1) Existing and Future peak flows from the Matrix HEC-HMS model prepared as a part of the Falcon DBPS
2) Existing and Future peak flows from the 2000 Falcon DBPS prepared by URS Corporation
3) USGS Regression Analysis equations are from "Analysis of the Magnitude and Frequency of Floods in Colorado" Water-Resources Investigations Report 99-4190. The Plains Region covers the entire portion of the Falcon Watershed. Drainage areas for the study ranged from 5 to 1,000 mi^2. $Q_2=39.0(A)^{0.486}$, $Q_5=195.8(A)^{0.399}$, $Q_{10}=364.6(A)^{0.400}$, $Q_{25}=725.3(A)^{0.395}$, $Q_{50}=1116(A)^{0.392}$, $Q_{100}=1640(A)^{0.388}$, where A = Drainage Area (mi^2)
4) CWCB Regression Analysis equations are from the "Guidelines for Determining 100-Year Flood Flows for Approximated Floodplains in Colorado" by the Department of Natural Resources Colorado Water Conservation Board, June 2004. ARK-5 includes tributaries east of Monument Creek, including the Black Squirrel Creek based east of Colorado Springs, for tributaries between 4 and 75 mi^2. $Q=1343.4(A)^{0.578}$. Where A=Drainage Area (mi^2).

Table 3-15. Peak Flows at Points of Interest within the Falcon Watershed

Location	HEC-HMS Element[2]	Area (sq mi)	Historical Peak Flows (cfs)				Existing Peak Flows (cfs)[3]				Future Peak Flows (cfs)			
			2-year	5-year	10-year	100-year	2-year	5-year	10-year	100-year	2-year	5-year	10-year	100-year
West Tributary														
Raygor Rd.	JWT030	0.14	6	15	23	75	9	20	30	85	9	20	30	85
Stapleton Rd.	JWT120	1.77	58	150	230	750	84	190	300	910	85	190	300	920
Woodmen Rd.	JWT210	3.09	80	200	320	1,000	21	50	170	950	120	250	400	1,300
Hwy. 24	JWT250	3.70	84	210	330	1,100	39	75	100	890	85	210	390	1,100
Falcon Hwy.	JWT260	3.84	86	220	340	1,100	47	92	130	910	86	210	390	1,100
Garrett Rd.	JWT320	6.46	110	290	430	1,500	120	250	370	1,300	160	410	630	1,700
East Blaney Rd.	JWT354	10.30	110	310	470	1,700	190	400	590	1,900	230	560	870	2,500
Upstream of Bennett Ranch Tributary[1]	JWT374_Outlet	10.58	110	310	470	1,700	190	400	600	1,900	230	560	860	2,500
Middle Tributary														
Woodmen Hills Dr.	JMT010	0.29	1	7	13	57	1	11	25	160	1	11	25	160
Woodmen Rd.	JMT070	1.36	24	67	110	350	61	180	280	760	150	350	490	1,200
Hwy. 24	JMT106	1.52	24	68	110	360	45	120	260	800	92	320	490	1,200
Falcon Hwy.	JMT110	1.64	22	63	120	360	46	120	260	820	94	320	500	1,200
Confluence with West Tributary	RMT114	1.64	22	63	110	360	46	120	260	820	94	320	500	1,200
East Tributary														
Stapleton Dr.	JET020	0.36	20	45	67	200	44	85	120	280	74	130	170	390
Woodmen Hills Dr.	JET040	0.71	19	48	74	240	23	59	110	480	27	85	140	570
Eastonville Rd.	JET060	1.11	19	48	77	260	13	28	45	340	13	32	68	430
Hwy. 24	JET090	1.78	17	47	75	260	15	39	64	370	26	47	81	390
Pinto Pony Rd.	JET100	1.83	17	47	75	260	15	40	65	380	27	49	83	390
Falcon Hwy.	JET120	2.16	17	47	77	270	17	48	84	430	49	110	160	450
Garrett Rd.	JET160	2.93	18	48	81	300	32	96	150	620	66	150	230	710
Confluence with West Tributary	RET164	2.93	18	48	81	300	32	96	150	620	66	150	230	710

Notes:
[1] Falcon Watershed Outlet
[2] Reference Figure 3-12 and Figure 3-13
[3] Existing results are less than historic results in some cases because of the diversion berm in the northwestern portion of the watershed. The diversion berm exists for existing conditions but is assumed to not exist for historic and future conditions.

Table 3-16. Peak Flow Volumes at Points of Interest within the Falcon Watershed

Location	HEC-HMS Element[2]	Area (sq mi)	Historical Peak Flow Volumes (ac-ft)				Existing Peak Flow Volumes (ac-ft)[3]				Future Peak Flow Volumes (ac-ft)			
			2-year	5-year	10-year	100-year	2-year	5-year	10-year	100-year	2-year	5-year	10-year	100-year
West Tributary														
Raygor Rd.	JWT030	0.14	1	3	4	9	2	3	4	10	2	3	4	10
Stapleton Rd.	JWT120	1.77	17	35	50	120	21	41	57	140	23	44	61	140
Woodmen Rd.	JWT210	3.09	24	49	71	180	6	12	23	110	47	87	120	270
Hwy. 24	JWT250	3.70	27	57	82	210	16	31	48	160	61	110	150	330
Falcon Hwy.	JWT260	3.84	28	59	85	220	18	35	53	180	63	110	150	340
Garrett Rd.	JWT320	6.46	38	85	120	340	51	99	140	390	100	190	260	580
East Blaney Rd.	JWT354	10.30	45	110	160	460	90	180	270	700	150	290	400	920
Upstream of Bennett Ranch Tributary[1]	JWT374_Outlet	10.58	45	110	160	470	90	190	270	710	150	290	400	930
Middle Tributary														
Woodmen Hills Dr.	JMT010	0.29	1	2	3	11	1	5	7	22	1	5	7	22
Woodmen Rd.	JMT070	1.36	5	13	19	58	15	31	43	110	23	43	58	130
Hwy. 24	JMT106	1.52	5	14	21	63	19	38	53	130	28	51	68	150
Falcon Hwy.	JMT110	1.64	5	14	22	66	21	41	58	140	30	54	73	160
Confluence with West Tributary	RMT114	1.64	5	14	21	66	21	41	57	140	30	54	73	160
East Tributary														
Stapleton Dr.	JET020	0.36	4	8	12	28	7	12	16	36	9	15	20	41
Woodmen Hills Dr.	JET040	0.71	5	10	14	38	13	24	32	70	15	27	35	76
Eastonville Rd.	JET060	1.11	5	11	17	48	12	27	40	99	14	30	43	100
Hwy. 24	JET090	1.78	5	13	20	63	17	42	62	160	21	48	69	170
Pinto Pony Rd.	JET100	1.83	5	13	20	64	17	43	63	160	22	50	71	170
Falcon Hwy.	JET120	2.16	5	14	22	73	20	48	70	180	25	57	81	200
Garrett Rd.	JET160	2.93	5	16	27	92	29	65	95	240	35	76	110	260
Confluence with West Tributary	RET164	2.93	5	16	27	92	29	65	94	240	35	75	110	260

Notes:
[1] Falcon Watershed Outlet
[2] Reference Figure 3-12 and Figure 3-13
[3] Existing results are less than historic results in some cases because of the diversion berm in the northwestern portion of the watershed. The diversion berm exists for existing conditions but is assumed to not exist for historic and future conditions.

Table 3-17. Flood Summary at LOMR Locations

Annual Percent Chance Flood Event	Recurrence Interval	Peak Flow (cfs)		
		Matrix HEC-HMS Model[1]		LOMR
		Existing	Future	
Middle Tributary Confluence with West Tributary[1]				
50%	2-year	46	94	--
20%	5-year	120	320	--
10%	10-year	260	500	--
4%	25-year	540	830	--
2%	50-year	670	1,000	--
1%	100-year	820	1,200	675
West Tributary at Woodmen Road[2]				
50%	2-year	21	120	--
20%	5-year	50	250	--
10%	10-year	170	400	--
4%	25-year	510	760	--
2%	50-year	720	990	--
1%	100-year	950	1,300	1,482
West Tributary at Hwy. 24[3]				
50%	2-year	39	85	--
20%	5-year	75	210	--
10%	10-year	100	390	--
4%	25-year	420	780	--
2%	50-year	680	950	--
1%	100-year	890	1,100	1,225

Notes:
1) FEMA LOMR 01-08-226P-080059, effective 05/14/2002
2) FEMA LOMR 03-08-0385P-080059, effective 11/26/2003
3) FEMA LOMR 07-08-0324P-080059, effective 03/12/2008

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4.0 HYDRAULIC ANALYSIS

4.1. Introduction

The purpose of the hydraulics analysis was to gain an understanding of the open channel flow characteristics and geomorphic conditions within the Falcon Watershed by:

- Performing and inventory of major drainageway structures
- Performing one-dimensional, steady flow hydraulic analysis for the main stems of West Tributary, Middle Tributary, and East Tributary
- Performing normal depth, full-flow Manning's equation calculations for the main line of each storm sewer
- Performing field work and aerial photo analysis to identify areas of geomorphic instability

Objectives of this analysis were to identify areas of potential infrastructure deficiency and delineate approximate floodplain boundaries for both the existing and future hydrologic conditions in Section 3.0.

4.2. Open Channel Hydraulics

Hydraulic analyses for existing and future hydrologic conditions were completed for the main stems of West Tributary, Middle Tributary, and East Tributary. These analyses were completed to represent peak flows for the flood events with 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals. The hydraulic analyses were completed using the USACE Hydrologic Engineering Center-River Analysis System Version 4.1.0 (HEC-RAS). Summaries of the employed methodology, models, characteristics, and input data used in the hydraulic models are summarized in this section.

4.2.1. Hydraulic Structure Inventory & Field Work

All major drainageway structures that the County is responsible for maintaining on the main stem of each of the three tributaries were measured and inventoried over a period of 2 days. The size of each culvert or bridge crossing was measured with a tape and relative measurements were collected for distance below the top of road and orientation within the creek.

Additionally, the field work performed in Section 3.0 was used for the development of the hydraulic model and identification of erosional areas.

4.2.2. HEC-RAS Modeling

Hydraulic modeling was completed using USACE Hydrologic Engineering Center – Geospatial River Analysis System Version 4.2.92 (HEC-GeoRAS) and HEC-RAS. HEC-GeoRAS was used to define all of the physical reach characteristics. After all preprocessing was complete, reach characteristics were exported to HEC-RAS to perform one-dimensional, steady flow hydraulic calculations.

HEC-GeoRAS was used within ArcMap®, to define the stream centerlines, banks, flow paths, and cross-sections for each reach. The stream centerline follows the channel thalweg to define the reach network. The banks lines differentiate the change in Manning's n value that typically occurs at the extent of the low flow channel. The flowpath lines identify the centroid of the flow in the left overbank, main channel, and right overbank in order to determine the respective reach lengths. The cross-section lines define the channel dimension to acquire topography information along the reach. Cross-section topography data was obtained from a triangulated irregular network (TIN) that was created from the contour information obtained from Aerial Mapping Services. A HEC-GeoRAS file that contained three-dimensional coordinates for the stream centerlines and cross-sections, as well as reach stations, bank stations, reach lengths, and stream topology was then imported into HEC-RAS.

Bridges, culverts, and ineffective flow areas were added to the HEC-RAS model after import from HEC-GeoRAS. Physical parameters for measured structures were incorporated into the hydraulic model using HEC-RAS bridge/culvert and cross-section data editors. All of the drainageway crossings were modeled to represent existing conditions which, in many cases, consists of a partially obstructed bridge or culvert. Many of the crossings are obstructed with sedimentation, vegetation growth, and the accumulation of debris. Cleaning and maintenance of these culverts is imperative to restore and maintain flood flow capacities.

4.2.3. Reaches

Each of the three tributaries that were modeled with HEC-RAS was evaluated based upon the existing topography, physical condition of the channel, and the floodplains along each of the tributaries. The modeled reaches are shown in Sheet 4-1 through Sheet 4-37 and described below.

West Tributary: This tributary is the main tributary within the Falcon Watershed and is approximately 9.0 miles in length and flows from Burgess Road to the confluence with Black Squirrel Creek. This tributary is primarily stable and in good condition and consists primarily of a wide grass-lined channel. There are two erosional areas existing along this tributary. One is between Arroya Lane and Stapleton Drive, which is followed by a depositional area, and the other is between Garrett Road and Blaney Road. This tributary crosses 14 structures and one on-line detention ponds that are summarized in Table 4-1. A summary of channel velocities and shear stresses for this tributary are provided in Table 4-2.

Table 4-1. West Tributary Drainageway Crossings

Crossing	HEC-RAS River Station	Location
WT 14	47262	Burgess Rd.
WT 13	45766.17	Pine Park Trl.
WT 11	41441.59	Arroya Ln.
WT 10	21948.92	Woodmen Rd.
WT 9	19961.38	Meridian Rd.
Pond WU Inlet Structure	18654	Tamlin Rd.
Regional Pond WU	17840	Tamlin Rd.
WT 7-2	17647.61	Rail Road
WT 7-1	17517.42	Hwy. 24
WT 6	15318.93	Falcon Hwy.
WT 5	14944.59	Meridian Rd.
WT 5-2	14944.59	Meridian Rd.
WT 4	9806.61	W. Condor Rd.
WT 3	8435.27	Garrett Rd.
WT 1	5398.42	Blaney Rd.

Table 4-2. West Tributary 100-yr Velocity & Shear Stress Summary

Parameter	Existing Conditions		Future Conditions	
	Minimum	Maximum	Minimum	Maximum
Velocity (ft/s)	0.17	12	0.17	13
Shear Stress (lb/ft^2)	0.01	5.9	0.01	6.9

Middle Tributary: This tributary is approximately 2.9 miles in length and flows from Woodmen Hills Drive to its confluence with West Tributary just south of Falcon Highway. This tributary is primarily stable and in good condition and consists primarily of a grass-lined channel north of Woodmen Road and a willow-lined channel south of Hwy. 24. This tributary enters a storm sewer at Woodmen Road through Meridian Road and crosses 8 structures and two on-line detention ponds that are summarized in Table 4-3. A summary of channel velocities and shear stresses for this tributary are provided in Table 4-4.

Table 4-3. Middle Tributary Drainageway Crossings

Crossing	HEC-RAS River Station	Location
The Meadows Pond #2	15205.815	Woodmen Hills Dr.
MT 7	10706	Owl Ln.
MT 6	7238	Woodmen Rd.
MT 6-2	7238	Woodmen Rd.
Regional Pond MN	6420.9204	McLaughlin Rd.
MT 5-1	6276.979	McLaughlin Rd.
MT 4	5184.12	Rail Road
MT 3	5035.56	Hwy. 24
MT 2	3667.171	Swingline Rd.
MT 1	1661.946	Falcon Hwy.

Table 4-4. Middle Tributary 100-yr Velocity & Shear Stress Summary

Parameter	Existing Conditions		Future Conditions	
	Minimum	Maximum	Minimum	Maximum
Velocity (ft/s)	0.43	10	0.6	11
Shear Stress (lb/ft^2)	0.01	9.9	0.02	12

East Tributary: This tributary is approximately 6.2 miles in length and flows from Liberty Grove Drive to its confluence with West Tributary just east of Blaney Road. This tributary transitions between stable, erosional, and depositional areas and consequently transitions between a grass- and willow-lined channel to a sand bottom channel. This reach crosses 12 structures and 6 on-line detention ponds that are summarized in Table 4-5. A summary of channel velocities and shear stresses for this tributary are provided in Table 4-6.

Table 4-5. East Tributary Drainageway Crossings

Crossing	HEC-RAS River Station	Location
ET 32	32376.64	Liberty Grove Dr.
Paint Brush Hills Pond #4	31486	SE of Liberty Grove Dr.
ET 31	28298.89	Stapleton Dr.
ET 30	26454.7	Royal County Down Rd.
ET 26	23413.07	Rio Secco Ln.
Woodmen Hills Pond #1 North	21604.86	Woodmen Hills Dr.
Woodmen Hills Pond #1 South	21169.19	Woodmen Hills Dr.
Woodmen Hills Pond #2	19810.83	McClure Rd.
Woodmen Hills Pond #3	18205.02	Eastonville Rd.
ET 19	18092.76	Eastonville Rd.
Woodmen Hills Pond #4	14543.949	West of Rail Road
ET 15	14364.16	Rail Road
ET 14	14215.6	Hwy. 24
ET 13	12425.19	Pinto Pony Rd.
ET 11	8304.048	Falcon Hwy.
ET 10	6243.929	N. Condor Rd.
ET 9	5333.859	Sunset Trl.
ET 4	2073.649	Garrett Rd.

Table 4-6. East Tributary 100-yr Velocity & Shear Stress Summary

Parameter	Existing Conditions		Future Conditions	
	Minimum	Maximum	Minimum	Maximum
Velocity (ft/s)	0.25	9.9	0.33	10
Shear Stress (lb/ft^2)	0.01	8.8	0.01	9.5

4.2.4. Manning's n Values

Manning's n values were calculated and assigned using the same procedure outlined in Section 3.0. Different Manning's n values were applied across the channel cross-section to reflect changes in vegetative cover between the main channel and overbank areas. The Manning's n values for the channels and floodplains are summarized in Table 4-7.

Table 4-7 Manning's n Values

Tributary	Manning's n Value	
	Channel	Overbank
West	0.03-0.07	0.08-0.15
Middle	0.05-0.07	0.08-0.15
East	0.03-0.07	0.08-0.15

The selected Manning's n values for the channels and the floodplains were based on the following:

- Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Floodplains by the USGS (WSP 2339). This manual allows the Manning's n value to be adjusted for surface irregularities, variation in cross-sections, obstructions, vegetation, and meandering.

- SCS Guide for Selecting Roughness Coefficient "n" Values For Channels. This manual uses visual examples of what specific n values look like along with the corresponding slopes, soils, and vegetation.
- Cottonwood Creek DBPS (Matrix 2010)
- City of Colorado Springs & El Paso County DCM
- Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual
- Colorado Department of Transportation (CDOT) Drainage Design Manual

4.2.5. Cross-sections

Cross-sections were initially placed approximately 400-ft apart and additional cross-sections were added to represent confluences, drainageway crossings, changes in channel form, and changes in channel slope. Cross-sections were automatically stationed from downstream to upstream along tributary. Each cross-section was adjusted to extend across the estimated floodplain and was placed perpendicular to the anticipated direction of flow in both the main channel and left/right floodplains. The cross-sections were bent in some locations to meet this requirement as described in Chapter 3 of HEC-RAS Hydraulic Reference Manual (Version 4.1, January 2010).

Additional cross-sections were added at the major drainageway crossings. At each of these locations, four cross-sections were added to the HEC-RAS model that included an upstream cross-section prior to flow contraction, a cross-section at the upstream face of the structure, a cross-section at the downstream face of the structure, and a downstream cross-section where flow is fully expanded. All bridge and culvert crossings were field surveyed to determine their size, inverts, and material.

The cross sections generated from the surface TIN by HEC-GeoRAS generally represent the top of the vegetated surface. In locations where vegetation is sparse, and not deep, the channel invert is accurately represented. In locations of dense and deep vegetative cover the channel invert was not accurately represented and was much shallower that what actually exists. This condition results in cross sections with less flood capacity than actually exists and leads to a conservative estimation of floodplain widths.

Several non-critical model warnings were generated for each tributary during model runs. To address model warnings by either defining numerous additional cross sections or by interpolating cross sections between every defined cross section would be necessary. Neither of these solutions is practical given the level of detail required for this study and as such were not completed.

Expansion and contraction coefficients in the cross-sections were estimated based on the ratio of expansion and contraction of the effective flow area in the floodplain occurring at cross-sections and at roadway crossings. For subcritical flow conditions where the change in the stream cross-section was gradual, a contraction coefficient of 0.1 and expansion coefficient of 0.3 were used. Wherever the change in effective cross section area was abrupt, such as at bridges and culverts, a contraction coefficient of 0.3 and expansion coefficient of 0.5 were used.

4.2.6. Ineffective Flow

Ineffective flow areas are used to describe portions of a cross section in which water does not actively flow. Ineffective flow is typically used at the upstream and downstream bounding cross sections of a drainageway crossing and for a side channel with stagnant storage. All ineffective flow is considered permanent and will not become effective flow until the barrier is overtopped.

4.2.7. Bridges and Culverts

The information from the hydraulic structure inventory was combined with the surface TIN to develop the bounding cross sections upstream and downstream of each major drainageway crossing. The cross sections generated from the TIN by HEC-GeoRAS were used as a starting point and were amended where appropriate to match the measured invert of each crossing. Only the cross section points in the immediate vicinity of the drainageway crossing were lowered in the event that invert of the cross section developed by HEC-GeoRAS was above the measured invert of the drainageway crossing. This scenario occurred primarily in areas of dense vegetation in the vicinity of a drainageway crossing. In some instances the invert of the cross sections were below the measured drainageway crossing invert. In these instances, the cross section inverts were modified on a case-by-case basis based on field observation.

The required inputs for bridge modeling include data for the deck/roadway, pier, and sloping abutments. The required inputs for culvert modeling include data for the deck/roadway, culvert shape, culvert size, and culvert material. This data was obtained from the hydraulic structure inventory, topography, and aerial photography.

Entrance loss coefficients were used to estimate the amount of energy lost as the flow enters a culvert and is used to determine the upstream headwater elevation for outlet control computations. Entrance loss coefficients for different types of culverts were selected from Table 6.3 of HEC-RAS Hydraulic Reference Manual (Version 4.1, January 2010). Exit losses were set to 1.0 for cases where sudden expansion occurs such as at a typical culvert outlet.

<u>**Special Cases**</u>

In some cases, either a steep slope entrance condition or adverse slope exit condition were created in the channel profile by modifying the bounding cross sections of the drainageway crossings. In these cases, the inverts of next upstream or downstream cross sections were adjusted to match the relative elevation change along the channel profile, reflected on the topography, in order to prevent an artificially improved or reduced hydraulic conveyance condition near a drainageway crossing.

There are two culvert entrances (MT 6 and MT 6-2) on the north side of Woodmen Road along Middle Tributary. These culverts are entrances to two separate storm sewers that eventually connect underground and discharge into Regional Pond MN. HEC-RAS does not have the capability to model a storm sewer and was only used to calculate the headwater elevation at Woodmen Road and not a flood profile between Woodmen Road and Regional Pond MN. It is assumed that these culverts are inlet controlled and that there is no tailwater condition that could exist in Regional Pond MN that would impact that headwater condition at Woodmen Road since the maximum water surface in Regional Pond MN is approximately 18 feet below the invert elevation of MT 6 and MT 6-2. There is only one outlet into Regional Pond MN which was assigned to MT 6. HEC-RAS requires an outlet for each entrance so an artificial outfall was defined for MT 6-2 in order for HEC-RAS to calculate the headwater at Woodmen Road.

4.2.8. Detention Pond Outlet Works

On-line detention pond structures were included in the HEC-RAS model if the outlet structure of the pond consisted of a basic outlet works consisting of a culvert and embankment. In the event that the outlet works of the detention pond was more complex, a rating curve based on the stage-storage-discharge relationship developed in Section 3.0, was input into the cross section upstream of the detention pond outlet works for modeling in HEC-RAS. The detention pond outlet works were not included in the pond hydraulic deficiency analysis; however, a potential deficiency was identified in the event that a spillway was overtopped as shown on Figure 4-38 and Figure 4-39. The operational function of the pond outlet works was further examined in the alternatives analysis.

4.2.9. Steady Flow and Boundary Conditions

Steady flow data were entered for all reaches based on the results of the hydrologic modeling in Section 3.0. Steady flow data corresponding to the peak flow for flood events with recurrence intervals of 2-, 5-, 10-, 25-, 50- and 100-years for existing and future hydrologic conditions was entered for each reach at points of significant hydrologic change as determined in the hydrologic model. A summary of hydrologic flows for each tributary at different points is provided in tabular form in Appendix B.

The boundary condition for the West Tributary was based on the normal depth in the downstream reach of this tributary. The boundary condition for the Middle Tributary was based on the 100-yr water surface elevation in the West Tributary, at the location of this confluence, which is higher than the normal depth in Middle Tributary at this location. The boundary condition for the East Tributary was based on the normal depth in the downstream reach of this tributary which resulted in a higher water surface elevation than using the 100-yr water surface elevation in the West Tributary at the location of this confluence. Only the downstream boundary conditions were required because the more conservative subcritical flow condition was evaluated.

4.2.10. Approximate Floodplains

After the HEC-RAS model analysis was complete, the 100-year water surface elevations were exported back to HEC-GeoRAS for refinement. Approximate floodplains for the existing and future 100-year floods were delineated for all of the tributaries listed above and are shown in Sheet 4-1 through Sheet 4-37. The FEMA floodplains for the Falcon Watershed are overlaid in these figures for comparison to the results of this analysis. Flood profiles for the existing and future 100-year floods are shown in Appendix B. The approximate floodplains and profiles were used to assess where potential drainageway crossing deficiencies exist along the major drainageways and identify areas of potential flooding.

The approximate floodplain information shown on the figures above is intended primarily for the identification of flood prone areas along the tributaries and to aid in the evaluation of potential alternatives. The approximate floodplain data contained herein is not intended to replace the information presented in the City of Colorado Springs and El Paso County Flood Insurance studies (FEMA 1999) but should be used as a planning tool for drainageway development projects. The FEMA floodplain remains as the regulatory floodplain.

Limitations

3. There are locations along each tributary where the cross section does not fully contain the 100-yr flood. The cross sections at these locations were extended; however, some cross sections still do not fully contain the 100-yr flood. HEC-RAS calculates the 100-yr Water Surface Elevation (WSE) for this condition by assuming that a vertical wall exists at the boundary of the cross section. The 100-yr floodplain was delineated at these locations by projecting the calculated depth at the edge of the cross section to the intersecting contour on the topography.
4. As described above, the channel invert was not accurately represented in locations of dense and deep vegetative cover and was much shallower that what actually exists. This condition results in cross sections with less flood capacity than actually exists and leads to a conservative estimation of floodplain widths. This same issue caused difficulties modeling structure crossings.
5. There are numerous locations along each of the three tributaries where split flow occurs and diverges from the primary flowpath. A detailed split flow model is required in order to correctly map the floodplain for the primary and secondary flowpaths and identify what percentage of flow exists within each flowpath. The 100-yr floodplain for all of these locations was mapped based on the maximum extents of the water surface that HEC-RAS calculated at each cross section. Locations where split flow occurs and appears to leave the watershed are:
   a. West Tributary at all of the diversion berms south of Stapleton Drive
   b. Middle Tributary at the depression south of Woodmen Hills Drive
   c. Middle Tributary at the depression south of Salinas Road
   d. East Tributary at Eastonville Road
   e. East Tributary at Falcon Hwy.
   f. East Tributary north of Garret Road and Blaney Road (quantified below due to severity)
6. The East Tributary overtops Blaney Road approximately 1,600 feet north of Garrett Road. Downstream of this location only a portion of the incoming flow remains in the East Tributary while the remainder of the flow overtops Blaney Road and enters a secondary channel. The amount of flow that overtops Blaney Road was estimated by using a lateral weir in HEC-RAS. The approximate floodplain in the secondary channel was delineated based on the results of three normal depth calculations at the beginning, middle, and end of the channel with the overtopping flow. The floodplain in the East Tributary downstream of this location was delineated using HEC-RAS with the remainder of flow that does not overtop Blaney Road. A summary of the split flow quantities at this location is provided in Table 4-8.

Table 4-8 East Tributary Split Flow at Blaney Road

Existing 100-yr Inflow (cfs)	East Tributary 100-yr Flow (cfs)	Secondary Channel 100-yr flow (cfs)
620	310	320
Future 100-yr Inflow (cfs)	**East Tributary 100-yr Flow (cfs)**	**Secondary Channel 100-yr flow (cfs)**
710	330	380

Flow will likely overtop Blaney Road again downstream of this location, however, it was assumed to only overtop at this location for the purposes of this study. The floodplains delineated for East Tributary and the secondary channel downstream of this location are approximate and should be used accordingly. A more detailed and thorough analysis is required at this location to determine the exact extents of the floodplain.

4.3. Storm Sewer Modeling

Storm sewer data was obtained from the County's GIS data set which provided pipe sizes, approximate horizontal layout, and material. Storm sewer slopes were estimated from the 2-ft contours of the ground surface. The Bentley FlowMaster software was used to perform full flow, unpressurized, capacity calculations for all of the main lines of each storm sewer system. Full flow capacity calculations provide a quick method to estimate capacity and screen systems that may have a capacity problem. Additional street capacity was accounted for in situations where flow in excess of the storm sewer could be conveyed down a street in the same direction as the reach while meeting County criteria. Storm sewer capacities were compared to the existing and future hydrology results in Section 3.0 in order to identify potential deficiencies. Each of the storm systems is entirely contained within one of the subbasins of the Falcon Watershed. Proportioned flows were calculated by estimating the approximate drainage area from each subbasin to each of the storm systems and applying that ratio to the calculated peak flow for the subbasin. This method was used in order to avoid artificially identifying a deficiency by using a peak flow that was greater than what will be captured by an individual storm system. Results of this analysis are provided in Appendix B.

4.4. Deficiencies

Deficiencies were broken into four categories:

1. Potential detention pond deficiencies
2. Drainageway crossing deficiencies
3. Storm sewer deficiencies
4. Areas of geomorphic instability

All existing deficiencies also exist in the future hydrologic condition; however, most of these are at a higher level of deficiency due to the increase in flow. Figure 4-38 and Figure 4-39 show areas of deficiency throughout the Falcon Watershed for both existing and future conditions. All deficiencies were evaluated and quantified at a planning level. A detailed design is recommended prior to addressing any deficiency.

4.4.1. Potential Detention Pond Deficiencies

Detention ponds were determined to be potentially deficient if the spillway was overtopped. The 100-yr WSE within each detention pond was calculated using HEC-HMS using the stage-storage-discharge curves developed in Section 3.0 and compared with the 100-yr flood profile calculated by HEC-RAS through each detention pond. The results of the 100-yr WSE varied in some cases because of the way each of the programs calculates the water surface within a detention pond system and because of the limitations described in Sections 4.2.5 and 4.2.7. HEC-HMS calculates the water surface based on detention pond routing equations using with unsteady flow. HEC-RAS calculates the water surface based on culvert hydraulics and steady flow. Detention ponds were determined to be potentially deficient if either program calculated a 100-yr WSE above the spillway elevation. Results of this analysis are provided in Table 4-9 and Table 4-10.

4.4.2. Drainageway Crossing Deficiencies

The drainageway crossing deficiency analysis was performed for all major drainageway structures that the County is responsible for maintaining on the main stem of each of the three tributaries. Crossings were determined to be deficient using the criteria published in the DCM for culverts and bridges and the results of the HEC-RAS model. Results of this analysis are provided in Table 4-11.

4.4.3. Storm Sewer Deficiencies

The storm sewer deficiency analysis was performed for all of the main lines of each storm sewer system. Storm sewers were determined to be deficient if the calculated flow from the hydrologic model was greater than the total system capacity. Total system capacity includes storm sewer capacity and street conveyance capacity. Results of this analysis are provided in Table 4-12. Note that only storm sewers with a priority of 1 and 2 are shown in Table 4-12. The complete analysis is provided in Appendix B.

The purpose of the storm sewer deficiencies screening was to identify potential deficiencies at a planning level. The hydrologic results calculated in this DBPS are not resolute enough for detailed hydraulic evaluation of storm systems. As a result, a detailed study is recommended to determine the magnitude of the storm sewer deficiencies that were identified and to determine the appropriate plan of action.

4.4.4. Areas of Geomorphic Instability

Areas of geomorphic instability along each of the three tributaries were identified during field work and review of aerial photography. These areas were identified based on observation and are not all inclusive due to access constraints. Two types of geomorphic instability exist within the Falcon Watershed: erosional areas and depositional areas. Erosional areas are reaches where the channel has downcut and become incised. This process generates an excessive sediment load which is transported downstream and increases lateral migration which results in unstable channel banks. Depositional areas are typically found downstream of an erosional area where the excessive sediment that was generated is dispersed across the channel and floodplain. This process reduces the flood capacity within the channel, clogs drainageway crossings, and increases the risk that flood flows will overtop roadways. All observed locations of geomorphic instability are shown on Figure 4-38. These locations are also provided on Figure 4-39 for reference only as they are reflective only of existing conditions.

Table 4-9. Existing Potential Detention Pond Deficiencies

Detention Pond	Tributary	Spillway Elev. (ft)	HEC-RAS 100-yr WSE (ft)	HEC-HMS 100-yr WSE (ft)
Paint Brush Hills Pond A	West (offline)	7,148	N/A	7,149
Woodmen Hills Pond H	Middle (offline)	6976	N/A	6,977
Regional Pond MN	Middle	6,854	6,853	6,855
Paint Brush Hills Pond #4	East	7,134	7,136	7,135
Woodmen Hills Pond #1 South	East	6,954	6,947	6,956
Woodmen Hills Pond #2	East	6,930	6,926	6,932
Woodmen Hills Pond #3	East	6,902	6,903	6,903
Woodmen Hills Pond #4	East	6,860	6,857	6,861

Notes:
[1] Offline ponds were not modeled with HEC-RAS

Table 4-10. Future Potential Detention Pond Deficiencies

Detention Pond	Tributary	Spillway Elev. (ft)	HEC-RAS 100-yr WSE (ft)	HEC-HMS 100-yr WSE (ft)
Paint Brush Hills Pond A	West (offline)	7,148	N/A	7,149
Paint Brush Hills Pond B1	West (offline)	7,158	N/A	7,158
Paint Brush Hills Pond B2	West (offline)	7,148	N/A	7,148
Paint Brush Hills Pond C	West (offline)	7,200	N/A	7,200
Woodmen Hills Pond H	Middle (offline)	6976	N/A	6978
Regional Pond WU	West	6832	6833	6832
Regional Pond MN	Middle	6,854	6,854	6,855
Paint Brush Hills Pond #4	East	7,134	7,136	7,135
Woodmen Hills Pond #1 North	East	6,960	6,962	6,959
Woodmen Hills Pond #1 South	East	6,954	6,948	6,956
Woodmen Hills Pond #2	East	6,930	6,926	6,932
Woodmen Hills Pond #3	East	6,902	6,903	6,903
Woodmen Hills Pond #4	East	6,860	6,857	6,861

Notes:
[1] Offline ponds were not modeled with HEC-RAS

Table 4-11. Drainageway Crossing Deficiencies

Crossing Name	Priority[1]	Tributary	100-yr Flow (cfs)		Location	Size[2]	Existing Deficiency[3]	Future Deficiency[3]
			Existing	Future				
WT 14	1	West	89	89	Burgess Rd.	18" CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
WT 13	1	West	170	170	Pine Park Trl.	30" CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
WT 11	1	West	480	480	Arroya Ln.	12" CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
Pond WU Inlet Structure	1	West	1,017	1,398	Tamlin Rd.	(3) 18" RCP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
WT 6	1	West	910	1,100	Falcon Hwy.	(2) 5.58' x 8.25' Arch CMP	Overtops	Overtops
WT 5	1	West	910	1,100	Meridian Rd.	24" CMP	Overtops	Overtops
WT 5-2	1	West	910	1,100	Meridian Rd.	18" CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
WT 4	1	West	1,300	1,700	W. Condor Rd.	48" CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Freeboard Criteria
WT 1	1	West	1,900	2,406	Blaney Rd.	(2) 36" RCP	Overtops, Does Not Meet Freeboard Criteria	Overtops, Does Not Meet Freeboard Criteria
MT 7	1	Middle	259	360	Owl Ln.	1.75' x 1.25' Elliptical CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
MT 6	1	Middle	760	1,200	Woodmen Rd.	(3) 48" RCP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
MT 6-2	1	Middle	760	1,200	Woodmen Rd.	(3) 48" RCP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
MT 1	1	Middle	820	1,200	Falcon Hwy.	24" CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
ET 31	1	East	280	390	Stapleton Dr.	(2) 6' x 2.5' RCBC	Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
ET 26	1	East	460	580	Rio Secco Ln.	(3) 48" RCP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
ET 13	1	East	380	390	Pinto Pony Rd.	(2) 48" CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
ET 11	1	East	430	450	Falcon Hwy.	(2) 60" RCP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
ET 10	1	East	590	680	N. Condor Rd.	4.67' x 3.17' Arch CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
ET 9	1	East	590	680	Sunset Trl.	48" CMP	Overtops, Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
ET 4	1	East	309	325	Garrett Rd.	4.67' x 3.17' Arch CMP	Does Not Meet Hw/D Criteria	Overtops, Does Not Meet Hw/D Criteria
WT 10	2	West	950	1,100	Woodmen Road	8.75' x 18.92' RCBC	None	Does Not Meet Hw/D Criteria
WT 9	2	West	1,000	1,400	Meridian Rd.	(4) 10' x 6' RCBC	Does Not Meet Freeboard Criteria	Does Not Meet Freeboard Criteria
WT 7-2	2	West	890	1,100	Rail Road	54' Wood Bridge	Does Not Meet Freeboard Criteria	Does Not Meet Freeboard Criteria
WT 7-1	2	West	890	1,100	Hwy. 24	(3) 12' x 6' RCBC	Does Not Meet Freeboard Criteria	Does Not Meet Freeboard Criteria
WT 3	2	West	1,300	1,700	Garrett Rd.	(2) 12' x 7.33' Arch CMP	Does Not Meet Freeboard Criteria	Does Not Meet Freeboard Criteria
MT 5-1	2	Middle	770	1,200	McLaughlin Rd.	27' Steel Bridge	Does Not Meet Freeboard Criteria	Does Not Meet Freeboard Criteria
MT 4	2	Middle	800	1,200	Rail Road	77' Wood Bridge	None	Does Not Meet Freeboard Criteria
MT 3	2	Middle	800	1,200	Hwy. 24	(2) 12' x 6' RCBC	Does Not Meet Freeboard Criteria	Does Not Meet Freeboard Criteria
MT 2	2	Middle	820	1,200	Swingline Rd.	20' x 6.83' RCBC	Does Not Meet Freeboard Criteria	Does Not Meet Freeboard Criteria
ET 32	2	East	150	200	Liberty Grove Dr.	(2) 42" CMP	Does Not Meet Hw/D Criteria	Does Not Meet Hw/D Criteria
ET 30	2	East	460	580	Royal County Down Rd.	72" RCP	Does Not Meet Hw/D Criteria	Does Not Meet Hw/D Criteria
ET 19	2	East	733	733	Eastonville Rd.	72" CMP	Does Not Meet Hw/D Criteria	Does Not Meet Hw/D Criteria
ET 14	2	East	370	390	Hwy. 24	(2) 12' x 4.83' RCBC	Does Not Meet Freeboard Criteria	Does Not Meet Freeboard Criteria

Notes:
1) Priority 1 = Overtopping, Priority 2 = Does Not Meet Hw/D Criteria or Freeboard Criteria
2) Based on field measurements
3) Per DCM page 6-10

Table 4-12. Storm Sewer Deficiencies

Storm Sewer ID[1]	Priority[2]	Location	Size (in)	Capacity (cfs)			Existing 100-yr Flow (cfs)[3]	Existing Deficiency	Future 100-yr Flow (cfs)[3]	Future Deficiency
				Storm Sewer	Street	Total				
DP149763	1	Maybeck View	18	4.8	0.0	5	60	92%	65	93%
DP150714	1	Maybeck View	18	6.0	0.0	6	60	90%	65	91%
DP292284	1	Woodmen Hills Dr.	30	29	16	45	320	86%	320	86%
DP292283	1	Woodmen Hills Dr.	30	41	22	63	320	80%	320	80%
DP292940	1	Mc Laughlin Rd.	24	20	0.0	20	88	77%	90	78%
DP150712	2	Cranston Dr.	30	41	0.0	41	130	68%	160	74%
DP292942	2	Tomkins Rd.	42	45	0.0	45	130	65%	130	65%
DP292201	2	Fort Smith Rd.	18	15	34	49	140	65%	140	65%
DP292290	2	Tompkins Rd.	18	17	38	54	140	60%	140	60%
DP292333	2	McLaughlin Rd.	24	23	22	44	110	60%	110	61%
DP292164	2	Greenough Rd.	18	14	31	45	110	59%	110	60%
DP292345	2	Tompkins Rd.	24	23	0.0	23	53	57%	53	57%
DP149784	2	Londonderry Dr.	18	11	22	33	75	57%	85	62%
DP292151	2	Greenough Rd.	30	32	18	50	110	54%	110	55%
DP292147	2	McClure Rd.	30	29	17	46	100	54%	100	54%
DP292133	2	Midnight Rd.	30	32	19	51	110	54%	110	55%
DP292213	2	Buschborn Rd.	18	14	31	44	92	52%	92	52%
DP292132	2	Midnight Rd.	24	26	27	53	110	52%	110	53%
DP292293	2	Tompkins Rd.	30	32	18	50	100	50%	100	50%
DP292353	2	Woodmen Hills Dr.	36	52	17	68	140	50%	140	50%
DP149767	2	Liberty Grove Dr.	24	34	33	66	130	49%	160	58%

Notes:
1) From County GIS database
2) Priority 1 = 75% to 100% deficient, Priority 2 = 50% to 75% deficient
3) Peak flow calculated by multiplying the peak flow for the encompassing subbasin by the estimated percentage of drainage area contributing to each storm system

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5.0 ALTERNATIVES ANALYSIS

5.1. Introduction

The purpose of the alternatives analysis was to synthesize all of the information gathered and analyzed thus far in this DBPS and evaluate several detention and reach alternatives for the Falcon Watershed. In addition to the previous hydrologic and hydraulic analyses, one public meeting and several project team meetings were conducted to gather input for the alternatives analysis. The outcome of this section is a recommended detention alternative and a reach alternative prioritization to be carried forward to the plan development design phase for further analysis. All backup calculations and data are provided in Appendix C.

5.2. Planning Reach Delineation

Open Channel Reaches

Planning reaches within the Falcon Watershed were delineated based on the environmental factors discussed in Section 2.0, the projected future flows in Section 3.0, and the hydraulic evaluation and deficiency analysis in Section 4.0. All of the open-channel reaches identified through these analyses were evaluated for alternatives as a part of this DBPS.

Storm Systems

The potential storm sewer deficiencies that were identified in Section 4.0 will not be evaluated for alternatives as a part of this DBPS. The hydrologic results calculated in this DBPS are not resolute enough for detailed hydraulic evaluation of storm systems. Therefore, it is recommended that a detailed study be completed for all storm systems that were identified to be potentially deficient.

Spillway Overtopping & Drainageway Crossing Deficiencies

The deficiencies analysis completed in Section 4.0 shows that 13 of the 16 existing detention pond spillways are overtopped and that 33 of the 34 drainageway crossings are deficient. The deficiencies for drainageway crossings range from roadway overtopping to inadequate headwater-to-depth ratios. The deficiencies analysis for both the spillways and drainageway crossings is reflective of future flows without any additional detention ponds or modifications to any of the existing detention ponds.

Deficiencies for existing detention pond spillways and drainageway crossings were not reexamined with the revised peak flows from the detention pond alternatives analysis. These deficiencies were revised and quantified during plan development design after the preferred detention alternative was selected. In general, as peak flows are reduced due to increased detention, spillway and drainageway crossing deficiencies will decrease.

5.3. Evaluation of Detention Alternatives

The two primary issues within the Falcon Watershed are areas of channel instability and flooding. Channel instability consists of both erosion and deposition and is primarily a result of increased channel-forming flows being released into the tributaries, when compared to historical conditions. The channel-forming flow is the discharge that shapes the channel through erosion and sedimentation and is typically associated with more frequently occurring, small storm events. Flooding, on the other hand, typically results from less frequently occurring, large storm events that cause inundation at drainageway crossings, along roads, and at individual properties. As a result, the goals of the detention alternatives for the Falcon Watershed are to:

1. Manage the channel-forming flows to historical conditions where possible
2. Manage the major flood flows to historical conditions where possible

The idea driving these goals is that if the hydrology within the watershed is appropriately managed:

- Many of the stable, relatively "pristine" reaches within the watershed can be preserved,
- Many of the currently impaired reaches within the watershed can be returned to a near pristine condition,
- Overall costs for required channel and infrastructure improvements will be much lower, and
- Flooding will be reduced.

The UDFCD recommends using full spectrum detention to mimic historic peak flows for the full range of storm events, such as the 2-, 5-, 10-, 25-, 50-, and 100-yr. In order to accomplish this, the UDFCD DCM, Vol. 2 recommends using a two-stage outlet structure that consists of the capture and slow release of the Excess Urban Runoff Volume (EURV) over 72 hours in combination with the 100-yr storage volume to effectively manage the full range of flood flows. The EURV approximately represents the difference between the pre-developed and post-developed 2-yr runoff volumes and includes the Water Quality Capture Volume (WQCV). Full spectrum detention provides water quality benefits by:

- Treating pollutant-laden stormwater runoff via settling and infiltration processes
- Managing the channel-forming flow to historical conditions, thereby limiting channel erosion
- Reducing runoff volume via infiltration

Three detention alternatives were evaluated using a combination of existing, planned, and potential detention ponds:

1. Do Nothing Alternative
2. Regional Detention Alternative
3. Sub Regional Detention Alternative

Full spectrum detention was implemented into existing, planned, and potential detention ponds where possible for both the regional and sub regional alternatives. Existing detention ponds are those currently in place and consist of on-site, sub regional, and regional detention ponds. Existing detention ponds can easily be retrofit to incorporate full spectrum detention by the use of low flow restrictor plates, additional grated inlets, additional culverts, and spillway modifications. Planned detention ponds are those ponds that have been designed in other studies, but have not been constructed or funded. Potential detention pond locations were recommended as a part of this DBPS and were sited on County-owned land where possible and only placed on private property if it was determined to be necessary. All potential ponds were placed on-line for the evaluation of these alternatives. On-line ponds shouldn't pose a risk for sediment in-fill in the Falcon Watershed because it is not a high sediment load watershed. Rough grading was performed at each potential location using:

- Approximate pond shape (i.e. triangle, square, elliptical, etc.)
- 4 horizontal to 1 vertical maximum grades

- 10-ft maximum water depth within the estimated pond grading due to jurisdictional dam limitations

The analysis of these three alternatives was developed using the future hydrology model developed in Section 3.0 as the base model. The stage-storage-discharge (SSD) curves developed for the existing detention ponds in Section 3.0 were used for all of the detention ponds in the Do Nothing Alternative. Each of the detention ponds modeled for the Regional and Sub Regional alternative was modeled using a simplified SSD curve with points to represent the pond bottom, EURV/WQCV, 100-yr volume, and spillway overtopping with the following criteria:

- EURV/WQCV
    - Storage and discharge requirements were calculated based on the guidelines outlined in the UDFCD DCM, Vol. 2
    - EURV drain time of 72 hours
    - WQCV drain time of 40 hours
- 100-yr Volume
    - Storage was initially estimated based on the difference between the pre-development and post-development 100-yr hydrographs
    - 100-yr storage was limited to the spillway elevation of the pond
    - 100-yr storage was limited to a 10-ft maximum water depth within the estimated pond grading of proposed ponds due to jurisdictional dam limitations
    - Release rates were greater than historic in some cases due to storage limitations
- Spillway Overtopping
    - Stage and storage calculated at 2 ft above the spillway elevation
    - Release rates were set as the sum of the inflow hydrograph plus the target 100-yr discharge

5.3.1. Do Nothing Alternative

This alternative utilizes all of the existing detention ponds shown in Figure 5-1 without retrofit for full spectrum detention and would require that channel improvements for all of the tributaries be designed for the future peak flows calculated in Section 3.0. This alternative would not provide any additional flood flow attenuation for managing channel-forming flows or flood flows and would put the watershed at risk for continued erosion, deposition, and flooding.

5.3.2. Regional Detention Alternative

This alternative recommends adding 1 additional detention pond at the confluence of each of the major tributaries for a total of 2 new detention ponds as shown on Figure 5-2. Full spectrum detention was incorporated into all existing and proposed detention ponds where applicable for this alternative. However, in some cases different detention configurations were used due to pond volume limitations. The other types of detention pond configurations that were used consist of:

- 100-yr control only – Used in ponds where there was minimal head differential between the EURV or WQCV stage and the 100-yr stage. Recommending a 100-yr control above the EURV/WQCV with minimal head differential may result in an outlet structure configuration that is not feasible to pass the 100-yr flow.
- EURV storage – Used in ponds where available storage volume was limited and the additional volume for the 100-yr flood could not be contained.
- WQCV storage in combination with 100-yr storage - Used in ponds where there was minimal head differential between the EURV stage and the 100-yr stage. The WQCV requires less storage volume and still provides attenuation for the channel forming flows. This combination of control allows for a more feasible outlet structure configuration because it provides more head differential between the WQCV stage and 100-yr stage.

A list of all detention ponds, and the type of outlet control used in each, is provided in Table 5-1.

Table 5-1. Regional Detention Alternative

Detention Pond	Tributary	Outlet Stages	Type of Outlet Control
Paint Brush Hills Pond C	West Tributary	EURV + 100-yr	Full Spectrum
Paint Brush Hills Pond A	West Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr
Paint Brush Hills Pond B1	West Tributary	No Modification	N/A
Paint Brush Hills Pond B2	West Tributary	EURV + 100-yr	Full Spectrum
The Meadows Pond #1	West Tributary	EURV + 100-yr	Full Spectrum
Regional Pond WU	West Tributary	EURV + 100-yr	Full Spectrum
Regional Pond R1	West Tributary	EURV + 100-yr	Full Spectrum
Proposed Regional Pond R2	West Tributary	EURV Only	~2-yr
Woodmen Hills Pond H	Middle Tributary	No Modification	N/A
The Meadows Pond #2	Middle Tributary	EURV + 100-yr	Full Spectrum
Regional pond MN	Middle Tributary	100-yr Only	100-yr
Woodmen Hills Pond #5	Middle Tributary	EURV + 100-yr	Full Spectrum
Paint Brush Hills Pond #4	East Tributary	No Modification	N/A
Woodmen Hills Pond #1 North	East Tributary	EURV + 100-yr	Full Spectrum
Woodmen Hills Pond #1 South	East Tributary	EURV + 100-yr	Full Spectrum
Woodmen Hills Pond #2	East Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr
Woodmen Hills Pond #3	East Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr
Woodmen Hills Pond #4	East Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr

Both Woodmen Hills Pond H and Paint Brush Hills Pond #4 are grossly undersized and both of the spillways currently overtop during the 100-yr storm. As a result, no retrofit solution was provided for these ponds. It is recommended that on-site detention be incorporated upstream of these ponds to reduce flooding at these locations. The drainage area that needs to be mitigated by an EURV or WQCV at these pond locations was accounted for in downstream detention ponds. A detailed analysis and summary for all of the detention ponds in this alternative is provided in Appendix C.

5.3.3. Sub Regional Detention Alternative

This alternative recommends adding 7 additional ponds at points of major hydrologic change along each of the major tributaries as shown on Figure 5-3. Full spectrum detention was incorporated into all existing and proposed detention ponds where applicable for this alternative. However, in some cases other controls were used due to pond volume limitations. A list of all detention ponds, and the type of outlet control used in each, is provided in Table 5-2.

Table 5-2. Sub Regional Detention Alternative

Detention Pond	Tributary	Outlet Stages	Type of Outlet Control
Proposed Sub Regional Pond SR1	West Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr
Paint Brush Hills Pond C	West Tributary	EURV + 100-yr	Full Spectrum
Paint Brush Hills Pond A	West Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr
Paint Brush Hills Pond B1	West Tributary	No Modification	N/A
Paint Brush Hills Pond B2	West Tributary	EURV + 100-yr	Full Spectrum
Proposed Sub Regional Pond SR2	West Tributary	EURV Only	~2-yr
The Meadows Pond #1	West Tributary	EURV + 100-yr	Full Spectrum
Proposed Sub Regional Pond SR3	West Tributary	EURV Only	~2-yr
Regional Pond WU	West Tributary	EURV + 100-yr	Full Spectrum
Proposed Regional Pond R1	West Tributary	EURV + 100-yr	Full Spectrum
Proposed Regional Pond R2	West Tributary	EURV Only	~2-yr
Woodmen Hills Pond H	Middle Tributary	No Modification	N/A
The Meadows Pond #2	Middle Tributary	EURV + 100-yr	Full Spectrum
Proposed Sub Regional Pond SR4	Middle Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr
Regional pond MN	Middle Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr
Woodmen Hills Pond #5	Middle Tributary	EURV + 100-yr	Full Spectrum
Paint Brush Hills Pond #4	East Tributary	No Modification	N/A
Proposed Sub Regional Pond SR6 (previously planned location)	East Tributary	EURV + 100-yr	Full Spectrum
Woodmen Hills Pond #1 North	East Tributary	EURV + 100-yr	Full Spectrum
Woodmen Hills Pond #1 South	East Tributary	EURV Only	~2-yr
Woodmen Hills Pond #2	East Tributary	EURV + 100-yr	Full Spectrum
Woodmen Hills Pond #3	East Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr
Woodmen Hills Pond #4	East Tributary	WQCV + 100-yr	Low Flow (<2-yr) + 100-yr

Both Woodmen Hills Pond H and Paint Brush Hills Pond #4 are grossly undersized and both of the spillways currently overtop during the 100-yr storm. As a result, no retrofit solution was provided for these ponds. It is recommended that on-site detention be incorporated upstream of these ponds to reduce flooding at these locations. The drainage area that needs to be mitigated by an EURV or WQCV at these pond locations was accounted for in downstream detention ponds. A detailed analysis and summary for all of the detention ponds in this alternative is provided in Appendix C.

5.3.4. Hydrologic Results

The hydrologic results for each of the detention alternatives at key locations throughout the Falcon Watershed are shown in Table 5-3. These results reflect all 16 existing, 1 planned, and all potential detention ponds as shown on Figure 5-1 through Figure 5-3. Note that in some cases the reported peak flows for the Regional Detention and Sub Regional Detention alternatives is higher than the Do Nothing alternative. This is because the configuration of the outlet structures for existing detention ponds had to be modified for these alternatives in order to meet the EURV/WQCV discharge rates. This resulted in having to increase the discharge rates for larger floods to meet the storage constraints within the existing detention ponds. In general, the Sub Regional Detention Alternative reduces peak flows the most throughout the Falcon Watershed. A summary of peak flows at the location of each detention pond is provided on Figure 5-2 and Figure 5-3.

Table 5-3. Peak Flows at Points of Interest within the Falcon Watershed for Detention Alternatives

Location	HEC-HMS Element[2]	2-year Peak Flow (cfs)[3]				100-year Peak Flow (cfs)[3]			
		Historical	Do Nothing	Regional Detention	Sub Regional Detention	Historical	Do Nothing	Regional Detention	Sub Regional Detention
West Tributary									
Raygor Rd.	JWT030	6	9	9	9	75	85	85	85
Stapleton Rd.	JWT120	58	85	73	55	750	920	950	710
Woodmen Rd.	JWT210	80	120	97	81	1,000	1,300	1,300	1,000
Hwy. 24	JWT250	84	85	65	64	1,100	1,100	1,200	980
Falcon Hwy.	JWT260	86	86	70	70	1,100	1,100	1,200	1,000
Garrett Rd.	JWT320	110	160	82	80	1,500	1,700	1,700	1,500
East Blaney Rd.	JWT354	110	230	140	140	1,700	2,500	2,400	2,100
Upstream of Bennett Ranch Tributary[1]	JWT374_Outlet	110	230	140	140	1,700	2,500	2,400	2,100
Middle Tributary									
Woodmen Hills Dr.	JMT010	1	1	5	5	57	160	99	99
Woodmen Rd.	JMT070	24	150	150	31	350	1,200	1,200	840
Hwy. 24	JMT106	24	92	140	33	360	1,200	1,100	840
Falcon Hwy.	JMT110	22	94	140	34	360	1,200	1,100	860
Confluence with West Tributary	RMT114	22	94	140	34	360	1,200	1,100	860
East Tributary									
Stapleton Dr.	JET020	20	74	74	9	200	390	390	200
Woodmen Hills Dr.	JET040	19	27	14	10	240	570	620	260
Eastonville Rd.	JET060	19	13	14	13	260	430	510	360
Hwy. 24	JET090	17	26	30	30	260	390	410	300
Pinto Pony Rd.	JET100	17	27	32	32	260	390	410	300
Falcon Hwy.	JET120	17	49	50	50	270	450	470	400
Garrett Rd.	JET160	18	66	67	67	300	710	720	640
Confluence with West Tributary	RET164	18	66	66	66	300	710	720	630

Notes:
[1] Falcon Watershed Outlet
[2] Reference Figure 3-12 and 3-13
[3] Results shown for Do Nothing, Regional Detention, and Sub Regional Detention reflect fully developed conditions

5.3.5. Detention Alternative Comparison

All three of the detention alternatives were compared against each other using the evaluation parameters listed in Table 5-4 in order to determine which detention alternative provides the most benefit to the watershed. Scores range from 1 to 3, where a score of 1 represents the best alternative for any given evaluation parameter and a score of 3 represents the worst alternative for any given evaluation parameter. The scoring system is intended to be relative so that each detention alternative is compared against the other alternatives for each of the evaluation parameters. The lowest total score represents the best alternative.

Table 5-4. Detention Pond Alternative Scoring Matrix

Evaluation Parameter	Do Nothing	Regional Detention	Sub Regional Detention
Detention Pond Construction Cost	1	2	3
Reach Construction Cost	3	2	1
Detention Pond O&M Costs	1	2	3
Reach O&M Costs	3	2	1
Flood Damage Reduction	2	3	1
Channel Stability (Near-Term)	3	2	1
Channel Stability (Long-Term)	3	2	1
Impact Upon Known Environmental Resources	1	2	3
Impact Upon Existing Utilities	1	1	1
Impact Upon Future Utilities	1	1	1
Impact Upon Existing Thoroughfares	1	1	1
Impact Upon Future Thoroughfares	1	1	1
ROW & Property Acquisition	1	2	3
Regulatory Issues	1	1	1
Trails & Open Space	1	2	2
Stormwater Quality	3	2	1
2-yr Flood Control	3	2	1
100-yr Flood Control	2	3	1
Flexibility for Development	1	1	1
Lot Premium	3	2	1
Habitat Improvements	3	2	1
Total	**39**	**38**	**30**

5.3.6. Woodmen Hills Detention Pond #4

Woodmen Hills Detention Pond #4 is currently not operating correctly which has resulted in severe and extensive erosion and numerous locations of flooding downstream of Highway 24. This pond was restudied by Wilson & Company in 2011. The release rates for the restudy of Woodmen Hills Pond #4 published in the report titled *"Pond 4 of the Falcon Area Stormwater Assessment"* (Pond 4 Assessment) (Wilson & Co. 2011) compare well with what was calculated in the Sub Regional Detention Alternative for this DBPS and are shown in Table 5-5. Further, Matrix determined release rates for Pond #4 based on using the more recent inflow hydrograph from this DBPS (discussed below) and the proposed Wilson & Co. SSD curve for comparison.

Table 5-5. Release Rates from Woodmen Hills Detention Pond #4

Source	2-yr Release Rate (cfs)	100-yr Release Rate (cfs)
Pond 4 Assessment (Wilson & Co. 2011)	11	278
Matrix DBPS model	15	260
Matrix DBPS model w/Wilson & Co. SSD curve	10	288

The Pond 4 Assessment identifies Woodmen Hills Pond #1 and Woodmen Hills Pond #2 as being deficient because both of the spillways are overtopped. The redesign of Woodmen Hills Detention Pond #4 assumes that the outlet structures for both of these ponds will be improved so that flows do not overtop the spillway. The Pond 4 Assessment also assumes that the future pond in the northwest corner of Meridian Road and Stapleton Drive will be constructed.

This DBPS shows that the spillways for Woodmen Hills Pond #1 and Woodmen Hills Pond #2 are overtopped. However, it also shows that the spillway for Woodmen Hills Detention Pond #3 is overtopped. This DBPS did not evaluate a future detention pond in the northwest corner of Meridian Road and Stapleton Drive for the Regional Detention Alternative, but did for the Sub Regional Detention Alternative. The Sub Regional Detention Alternative provides solutions to address spillway overtopping for Woodmen Hills Ponds #1, #2, and #3 and provides a potential configuration for the future detention pond in the northwest corner of Meridian Road and Stapleton Drive. As a result, the inflow hydrograph from this DBPS is likely to be different than what was used in the Pond 4 Assessment.

Recommendations

1. It is recommended that the County use the more recent hydrographs developed for the final version of this DBPS for the redesign of Woodmen Hills Detention Pond #4.
2. It is recommended that the County reevaluate the SSD curve based on the outlet configuration proposed in the final redesign for Woodmen Hills Detention Pond #4 in order to evaluate impacts downstream of this pond.
3. It is recommended that the County include drain time constraints for low flows (< 2-yr) over a 40- to 72-hr period as outlined in the UDFCD DCM. Low flow attenuation was discussed in the Pond 4 Assessment, but drain time was not evaluated.

5.3.7. Detention Alternative Conceptual Cost Estimate

Conceptual cost estimates were developed for each of the three detention pond alternatives and are provided in Table 5-6. These cost estimates were developed for comparison purposes only and were refined during plan development design. The cost estimates were based on the following assumptions:

- Retrofit detention costs include the costs to retrofit existing outlet structures for EURV/WQCV control and 100-yr volume control. This cost assumes that the existing outlet structure can be retrofit by utilizing low flow restrictor plates, adding additional grated inlets, or adding additional culverts. Retrofit costs were assumed to be $10,000/ea.

- Construction costs for potential detention ponds are based on $24,500/ac-ft as documented in the Jimmy Camp Creek DBPS - FSD Costs Memo.
- Required pond volume is based on the pond volume up to the 100-yr WSE and does not include the embankment.
- Land requirements for potential ponds are based on a (land area/pond volume) ratio of 0.285 ac/ac-ft as documented in the Jimmy Camp Creek DBPS - FSD Costs Memorandum.
- 15% engineering and construction administration fee
- 20% contingency

Table 5-6. Detention Alternative Cost Summary

Detention Alternative	Detention Cost
No Detention	$ 0
Regional Detention	$ 7,700,000
Sub Regional Detention	$ 10,800,000

The Sub Regional Detention Alternative is the best alternative when compared against the list of evaluation parameters and it provides the most flow reduction throughout the watershed. The preliminary analysis indicates that this alternative is the most expensive detention alternative. The impact on reach alternatives will be discussed later in this section to determine which detention alternative allows for the implementation of the preferred reach alternatives. Final costs are provided in Section 6.

5.4. Evaluation of Reach Alternatives

Alternatives for each of the planning reaches were evaluated using the peak flows calculated for each of the three different detention alternatives in Section 5.3. The result of this process was a recommended alternative for each planning reach that corresponds to the Do Nothing Detention Alternative, Regional Detention Alternative, and Sub Regional Detention Alternative. A total of five different reach alternatives were considered in the screening process and are described below.

5.4.1. Protect In Place

There are several relatively pristine reaches of channel throughout the Falcon Watershed that are currently in a stable condition. These reaches typically consist of a small low-flow channel that is connected to a very wide floodplain which allows for the effective conveyance of all flood flows by dissipating erosive energy over the entire floodplain area. These reaches also provide water quality benefit due to the amount of surface area available for infiltration and the filtering effect of vegetation. Additionally, there are several reaches throughout the Falcon Watershed that have already been improved and appear to be stable. Preserving both of these reach conditions would not require a direct channel improvement cost. However, upstream detention improvements may be required depending on the location of the reach. Reaches had to meet the following criteria in order to fall into this category:

- The reach had to be in a stable condition currently.
- The 2-yr flood flows within the reach had to be at or below historical conditions.

5.4.2. Natural Channel Design

The goal of this reach alternative is to restore the low-flow channel and connect it to the adjacent floodplain. This alternative allows for channel sheer stress to be reduced by allowing flood flows to access the floodplain where erosive energy is dissipated over the entire floodplain area. This reach alternative can be used where mild longitudinal slopes exist and where floodplain sheer stresses are within a range that vegetation can withstand. These reaches also provide water quality benefit due to the amount of surface area available for infiltration, the filtering effect of vegetation, and because they limit channel erosion. The target slope and channel section for this alternative would be maintained through grade control structures. An illustration of this alternative is shown in Figure 5-4. Reaches had to meet the following criteria in order to fall into this category:

- Existing slope of less than or equal to 0.015 ft/ft. This was based on the average slope in channel sections that are currently stable.
- Shear stress at the 2-yr flood stage of less than or equal to 1 lb/ft^2
  - Based on the average shear stress in channel sections that are currently stable
  - Calculated using the 2-yr flood stage from Section 3.0 within the existing channel section

5.4.3. Small Drop Structures

This reach alternative involves hardening the lower portion of the side slopes of the channel cross-section while relying on smaller (< 3 ft) drop structures to maintain a target longitudinal slope. An illustration of this alternative is shown in Figure 5-5. Reaches had to meet the following criteria in order to fall into this category:

- A calculated spacing between drops greater than or equal to 100 ft (assuming 3-ft drops). A closer spacing between drop structures would result in too many structures in a reach.

5.4.4. Large Drop Structures

This reach alternative involves hardening the lower portion of the side slopes of the channel cross-section while relying on larger (6 ft > drop height > 3 ft) drop structures to maintain the stable longitudinal slope. An illustration of this alternative is shown in Figure 5-6. Large drops structures were only used if the spacing required for small drop structures was less than 100 ft.

5.4.5. Fully-Lined Channel

This reach alternative involves lining a portion of the channel cross-section with riprap for the full length of the reach. Riprap should be sized to handle the projected shear stress for the 100-year flood event with limited or no grade control. An illustration of this alternative is shown in Figure 5-7. Fully lined channels are only required where it is determined that large drop structures are not suitable due to spacing or width constraints. Fully-lined channels were not required anywhere in the Falcon Watershed but were considered for reach alternative comparison purposes.

5.4.6. Reach Alternative Comparison

All five of the reach alternatives were compared against each other using the evaluation parameters listed in Table 5-7 in order to help determine which reach alternative provides the most benefit to the watershed. Scores range from 1 to 5 where a score of 1 represents the best alternative for any given evaluation parameter and a score of 5 represents the worst alternative for any given evaluation parameter. The scoring system is intended to be relative so that each reach alternative is compared against the other alternatives for each of the evaluation parameters. The lowest total score represents the best alternative.

Table 5-7. Reach Alternative Scoring Matrix

Evaluation Parameter	Protect In Place	Natural Channel Design	Small Drop Structures	Large Drop Structures	Fully Lined Channel
Reach Construction Cost	1	2	3	4	5
Reach O&M Costs	1	3	3	3	5
Flood Damage Reduction	1	1	3	4	5
Channel Stability (Near-Term)	1	2	3	4	5
Channel Stability (Long-Term)	1	2	3	4	5
Impact Upon Known Environmental Resources	1	2	3	4	5
Impact Upon Existing Utilities	3	3	3	3	3
Impact Upon Future Utilities	3	3	3	3	3
Impact Upon Existing Thoroughfares	3	3	3	3	3
Impact Upon Future Thoroughfares	3	3	3	3	3
ROW & Property Acquisition	1	3	3	3	5
Regulatory Issues	1	3	3	3	5
Trails & Open Space	1	3	3	3	5
Stormwater Quality	1	2	3	4	5
2-yr Flood Control	1	2	3	4	5
100-yr Flood Control	1	2	3	4	5
Flexibility for Development	5	5	3	3	1
Lot Premium	1	2	3	4	5
Habitat Improvements	1	2	3	4	5
Total	**31**	**48**	**57**	**67**	**83**

The Protect In Place reach alternative is the best reach alternative when compared against the list of evaluation parameters. However, it is not possible to implement this reach alternative in all of the planning reaches due to the criteria constraints previously outlined. Therefore, this scoring matrix was used to set the prioritization of how each reach alternative was implemented while adhering to the criteria previously described. Prioritization for the implementation of the five reach alternatives is as follows:

1. Protect In Place
2. Natural Channel Design
3. Small Drop Structures
4. Large Drop Structures
5. Fully Lined Channel

Some other benefits of the Protect In Place and Natural Channel Design alternatives that were not explicitly captured in Table 5-7 are that these alternatives provide aesthetic value, improve channel function, and limit erosion.

The result of this analysis for each of the detention alternatives is shown on Figure 5-1 through Figure 5-3.

5.4.7. Immediate Action Required

There are 5 locations where immediate action is required in order to preserve the existing reach conditions. These locations are at points adjacent to pristine channel reaches, or Natural Channel Design reaches, where current erosion or deposition has been identified. If left unmitigated, the issues at these locations have the potential to propagate and worsen the existing condition. This will require additional reach improvement costs. These locations can be addressed by implementing the recommended reach alternative for the impaired reach at the sites that are identified while improvements for the remainder of the impaired reaches can be constructed at a later date.

5.4.8. Reach Alternative Conceptual Cost Estimate

Conceptual cost estimates were developed for all of the reaches using flows from the three different detention alternatives in Section 5.3 and the reach alternative prioritization outlined above. These cost estimates were developed for comparison purposes only and were refined during plan development design. The cost estimates were based on the following assumptions:

- Natural Channel Design reach cost of $400/LF as documented in the Cottonwood Creek DBPS
- Small Drops Structures reach cost of $900/LF as documented in the Cottonwood Creek DBPS
- Large Drops Structures reach cost of $2,600/LF as documented in the Cottonwood Creek DBPS
- 15% engineering and construction administration fee
- 20% contingency

Table 5-8. Reach Alternative Cost Summary

Detention Alternative	Reach Cost
No Detention	$ 138,000,000
Regional Detention	$ 125,000,000
Sub Regional Detention	$ 111,000,000

5.5. Recommended Alternative

The Sub Regional Detention Alternative is the best alternative when compared against the list of evaluation parameters and it provides the most flow reduction throughout the watershed. This alternative was previously determined to be the most expensive detention alternative. However, this alternative results in the lowest reach improvement cost, using the reach prioritization previously described, and the lowest total cost as shown in Table 5-9. All of the costs developed in this section were for comparison purposes only and based on conservative estimates of required construction costs. Once the recommended alternative was selected, the detention and reach costs were then refined in the plan development design phase.

Table 5-9. Total Cost Summary

Detention Alternative	Detention Cost	Reach Cost	Total Cost
No Detention	$ 0	$ 138,000,000	$ 138,000,000
Regional Detention	$ 7,700,000	$ 125,000,000	$ 133,000,000
Sub Regional Detention	$ 10,800,000	$ 111,000,000	$ 122,000,000

Detention pond spillway and drainageway crossing repair and/or replacement costs were the only cost component that was not evaluated in this section. In general, as peak flows are reduced due to increased detention the quantity of spillway and drainageway crossing deficiencies will decrease. Therefore, it is assumed that the Sub Regional Detention Alternative will result in the lowest repair and/or replacement costs to address these deficiencies. These deficiencies were revised and quantified once the recommended detention alternative was selected.

It is recommended that the Sub Regional Detention Alternative be used in combination with incorporating reach alternatives with the following prioritization:

1. Protect In Place
2. Natural Channel Design
3. Small Drop Structures
4. Large Drop Structures
5. Fully Lined Channel

5.5.1. Utility Coordination

It is anticipated that none of the major utility corridors will be impacted as a result of the recommended alternative. The major utility corridors identified by the County are:

- The Mountain View Electric Association corridor along Woodmen Road to Meridian Road
- The New Star Energy Oil Line which runs north on Meridian Road, from the intersection of Woodmen Road and Meridian Road, to Eastonville Road and then east on Eastonville Road

Figure 5-1. Do Nothing Alternative

Figure 5-2. Regional Detention Alternative

Figure 5-3. Sub Regional Detention Alternative

Figure 5-4. Natural Channel Design

Figure 5-5. Small Drop Structures

Figure 5-6. Large Drop Structures

Figure 5-7. Fully-Lined Channel

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6.0 PLAN DEVELOPMENT DESIGN

6.1. Introduction

The purpose of the plan development design effort was to refine the selected detention and reach alternatives for the Falcon Watershed and finalize proposed infrastructure improvements and associated implementation costs. The recommended detention and reach alternatives, outlined in Section 5.0, were vetted through one public meeting and several project team meetings. The Sub Regional Detention Alternative along with the corresponding reach alternatives were selected to carry forward into plan development. The detention pond and reach components from the selected alternative were analyzed using a more detailed set of criteria to ensure that the recommendation would be feasible for future implementation. The outcome of the selected plan development design is a conceptual set of infrastructure improvements and costs for use in the fee development phase of this DBPS. All backup calculations and data are provided in Appendix D.

6.2. Selected Detention Alternative

The Sub Regional Detention Alternative that was recommended in Section 5.3 was refined by:

- Performing rough grading at each potential location.
- Maximizing storage for ponds based on existing site conditions.
- Modifying the SSD curves to target EURV or WQCV, and 100-yr volume with no spillway overtopping as outlined in Section 5-3. The EURV target outflow was based on releasing the EURV over 72 hours. The WQCV drain time was 40 hours. 100-yr target outflows were historical 100-yr flow where possible given storage constraints; selected as either the existing 100-yr flow or the lowest attainable 100-yr peak flow based on pond limitations. Release rates were greater than historic in some cases due to storage limitations. Storage and discharge requirements were calculated based on the guidelines outlined in the UDFCD DCM, Vol. 2.
- Assessing the hydrologic benefit of each pond.
- Spillway overtopping based on stage and storage calculations at 2 ft above the spillway elevation.

Full spectrum detention was incorporated into all existing and proposed detention ponds where applicable for this alternative. However, in some cases other controls were used due to pond volume limitations. A detailed analysis and summary for all of the detention ponds in the selected alternative are provided in Appendix D.

6.2.1. Detention Pond Classification

The selected detention alternative consists of 23 ponds that fall within 2 different classifications: existing constructed ponds and proposed ponds. All ponds are shown graphically in Figure 6-1.

Existing Constructed Ponds

Existing constructed ponds include PBH C, PBH A, PBH B1, PBH B2, M 1, R WUS, WH H, M 2, R MN, WH 5, PB 4, WH 1N, WH 1S, WH 2, WH 3, and WH 4. These ponds are currently constructed and functioning within the Falcon Watershed. Each of these ponds was evaluated to determine if it could be retrofit to provide a benefit to the selected detention alternative. Table 6-1 shows the proposed modification to the outlet stages of each of the existing constructed ponds.

Table 6-1. Existing Pond Outlet Modifications

Pond	Proposed Outlet Stages
Paintbrush Hills Pond C	EURV + 100-yr
Paintbrush Hills Pond A	WQCV + 100-yr
Paintbrush Hills Pond B1	Existing Configuration
Paintbrush Hills Pond B2	EURV + 100-yr
The Meadows Pond #1	EURV + 100-yr
Regional Pond WU South	EURV + 100-yr
Woodmen Hills Pond H	Existing Configuration
The Meadows Pond #2	EURV + 100-yr
Regional Pond MN	WQCV + 100-yr
Woodmen Hills Pond #5	EURV + 100-yr
Paint Brush Hills Pond #4	Existing Configuration
Woodmen Hills Pond #1 North	100-yr Only
Woodmen Hills Pond #1 South	EURV Only
Woodmen Hills Pond #2	EURV + 100-yr
Woodmen Hills Pond #3	WQCV + 100-yr
Woodmen Hills Pond #4	EURV + 100-yr

Both Woodmen Hills Pond H and Paint Brush Hills Pond #4 are grossly undersized and both of the spillways currently overtop during the 100-yr storm. As a result, no retrofit solution was provided for these ponds. It is recommended that on-site detention be incorporated upstream of these ponds to reduce flooding at these locations. The drainage area that needs to be mitigated by an EURV or WQCV at these pond locations was accounted for in downstream detention ponds.

Proposed Ponds

Proposed ponds include ponds SR 1, SR 2, SR 3, SR 4, R 1, SR 6, and R 2. These ponds are not constructed or planned for and are recommended as a part of the selected detention alternative. Table 6-2 shows the hydraulic configurations for the proposed ponds.

Table 6-2. Proposed Pond Outlet Configurations

Pond	Outlet Stages
Sub Regional Pond SR1	WQCV + 100-yr
Sub Regional Pond SR2	EURV Only
Sub Regional Pond SR3	EURV Only
Sub Regional Pond SR4	WQCV + 100-yr
Regional Pond R1	EURV + 100-yr
Sub Regional Pond SR6	EURV + 100-yr
Regional Pond R2	EURV Only

6.2.2. Hydrologic Results

The hydrologic results for the selected detention alternative are shown in Table 6-3. These results reflect all 23 ponds shown in Figure 6-1.

Table 6-3. Selected Detention Alternative Results

Location	HEC-HMS Element	Sub Regional Peak Flow (cfs)	
		2-year	100-year
West Tributary			
Raygor Rd.	JWT030	9	85
Stapleton Rd.	JWT120	55	710
Woodmen Rd.	JWT210	81	1,000
Hwy. 24	JWT250	64	980
Falcon Hwy.	JWT260	70	1,000
Garrett Rd.	JWT320	80	1,500
East Blaney Rd.	JWT354	140	2,200
Upstream of Bennett Ranch Tributary	JWT374_Outlet	140	2,200
Middle Tributary			
Woodmen Hills Dr.	JMT010	5	99
Woodmen Rd.	JMT070	31	840
Hwy. 24	JMT106	33	840
Falcon Hwy.	JMT110	34	860
Confluence with West Tributary	RMT114	34	860
East Tributary			
Stapleton Dr.	JET020	9	200
Woodmen Hills Dr.	JET040	10	260
Eastonville Rd.	JET060	13	360
Hwy. 24	JET090	31	300
Pinto Pony Rd.	JET100	32	300
Falcon Hwy.	JET120	50	400
Garrett Rd.	JET160	67	640
Confluence with West Tributary	RET164	66	630

6.2.3. Detention Pond Sizes & Cost Estimate

The detention ponds sizes and costs estimate as a result of selected detention alternative are provided in Table 6-4. Assumptions that were used in developing the detention pond cost estimate are as follows:

- Land requirement for proposed ponds is based on proposed rough grading and the corresponding footprint at the spillway stage.
- Construction cost based on $24,500/ac-ft as documented in the Jimmy Camp Creek DBPS - FSD Costs Memo. Engineering costs were removed from construction cost and added later to the subtotal.
- Land cost was estimated as $50,000/ac based on the current (2013) El Paso County Parks land value of $46,954/ac.
- Improvement cost was estimated at $20,000 per modified pond to retrofit existing outlet structures for EURV/WQCV and 100-yr flood control. Not all existing ponds were retrofit.

Table 6-4. Detention Pond Cost Estimate

Pond	Pond Volume (ac-ft)	Land Requirement (ac)	Construction Cost ($)	Land Cost ($)	Improvement Cost ($)	Total Cost ($)
Paint Brush Hills Pond #4	1.34	-	$ -	$ -	$ -	$ -
Paint Brush Hills Pond A	2.62	-	$ -	$ -	$ 20,000	$ 20,000
Paint Brush Hills Pond B1	9.17	-	$ -	$ -	$ -	$ -
Paint Brush Hills Pond B2	12.09	-	$ -	$ -	$ 20,000	$ 20,000
Paint Brush Hills Pond C	6.77	-	$ -	$ -	$ 20,000	$ 20,000
Regional Pond MN	7.53	-	$ -	$ -	$ 20,000	$ 20,000
Regional Pond R1	25.00	18.8	$ 532,609	$ 940,420	$ -	$ 1,473,028
Regional Pond R2	3.13	5.1	$ 66,634	$ 255,974	$ -	$ 322,608
Regional Pond WU South	39.54	-	$ -	$ -	$ 20,000	$ 20,000
Sub Regional Pond SR1	11.03	3.4	$ 234,987	$ 170,782	$ -	$ 405,769
Sub Regional Pond SR2	2.05	5.2	$ 43,674	$ 257,529	$ -	$ 301,203
Sub Regional Pond SR3	1.03	0.6	$ 21,943	$ 27,609	$ -	$ 49,552
Sub Regional Pond SR4	19.37	20.5	$ 412,665	$ 1,022,834	$ -	$ 1,435,500
Sub Regional Pond SR6	11.82	6.7	$ 251,817	$ 334,260	$ -	$ 586,078
The Meadows Pond #1	3.25	-	$ -	$ -	$ 20,000	$ 20,000
The Meadows Pond #2	7.94	-	$ -	$ -	$ 20,000	$ 20,000
Woodmen Hills Pond #1 North	7.13	-	$ -	$ -	$ 20,000	$ 20,000
Woodmen Hills Pond #1 South	8.78	-	$ -	$ -	$ 20,000	$ 20,000
Woodmen Hills Pond #2	9.18	-	$ -	$ -	$ 20,000	$ 20,000
Woodmen Hills Pond #3	8.35	-	$ -	$ -	$ 20,000	$ 20,000
Woodmen Hills Pond #4	40.45	-	$ -	$ -	$ 240,000	$ 240,000
Woodmen Hills Pond #5	4.10	-	$ -	$ -	$ 20,000	$ 20,000
Woodmen Hills Pond H	2.66	-	$ -	$ -	$ -	$ -
Subtotal					$ 5,053,738	
Engineering/ Construction Admin. (15%)					$ 758,061	
Contingency (20%)					$ 1,010,748	
Total					**$ 6,822,546**	

Additional costs as a percentage of the subtotal construction cost include Engineering/Construction Administration (15%), and Contingency (20%). Detailed quantities and cost estimates are provided in Appendix D.

6.2.4. Detention Pond Phasing Priority

Detention pond construction or modification should be phased so that detention ponds located at the upper end of tributaries are constructed first and detention ponds located on the main stem are constructed last. This method of phasing helps reduce sediment issues that may be caused by construction activities if upstream ponds are developed after ponds on the main stem. In addition to pond location, consideration must also be given to the timing of new development. Detention ponds should generally be constructed or modified along with upstream development with an interim condition in place to mitigate the increased sediment load caused by construction.

Table 6-5 lists the phasing priority for each of the existing and proposed ponds. A phasing priority of "1" means the pond should be constructed or modified immediately or as soon as upstream/adjacent development begins. Higher phasing priority numbers indicate more upstream detention ponds must be built prior to construction of the pond in question.

Table 6-5. Detention Pond Phasing Priority

Pond	Phasing Priority	Constraint
Paint Brush Hills Pond #4	2	None
Paint Brush Hills Pond A	1	Modify after PBH-C
Paint Brush Hills Pond B1	1	None
Paint Brush Hills Pond B2	1	Modify after PBH-B1
Paint Brush Hills Pond C	1	Modify after SR1
Regional Pond MN	3	None
Regional Pond R1	4	Construct after R-WU, R-MN, and WH5
Regional Pond R2	4	Construct after R1 and WH4
Regional Pond WU South	3	Modify after SR3
Sub Regional Pond SR1	1	None
Sub Regional Pond SR2	2	Construct after PBH-A and PBH-B2
Sub Regional Pond SR3	3	Construct after SR2 and M1
Sub Regional Pond SR4	3	Construct after M2 and WH-H
Sub Regional Pond SR6	2	Construct after PBH4
The Meadows Pond #1	2	None
The Meadows Pond #2	2	None
Woodmen Hills Pond #1 North	3	Construct after SR6
Woodmen Hills Pond #1 South	3	Construct after WH1n
Woodmen Hills Pond #2	3	Construct after WH1s
Woodmen Hills Pond #3	3	Construct after WH2
Woodmen Hills Pond #4	4	Construct after WH3
Woodmen Hills Pond #5	3	None
Woodmen Hills Pond H	2	None

6.3. Selected Reach Alternatives

The selected reach alternatives, as defined in Section 5-4, were refined using the flows reported in Section 6.2. Additionally, all bridge and culvert crossings were evaluated as a part of the selected reach alternatives. A summary of the selected reach alternatives is provided graphically in Figure 6-1.

6.3.1. Reach Evaluation

A summary of the reach screening results is provided in Table 6-6.

Table 6-6. Selected Reach Alternatives

Alternative	Length (ft)
Natural Channel Design	13,216
Protect in Place	64,325
Roadside Ditch Improvement	7,519
Small Drop Structures w/Toe Protection	50,751
Total	**135,811**

6.3.2. Bridge & Culvert Crossing Evaluation

All of the bridge and culvert crossings on the main stem of the creek were evaluated for adherence to DCM criteria. Bridge and culvert crossings were analyzed using the 100-year peak flow from the selected detention alternative. The culvert and bridge design criteria listed in the DCM, Pg. 6-10 was used to evaluate the adequacy of each crossing. The results of the evaluation are provided in Table 6-7.

Table 6-7. Existing Bridge and Culvert Crossing Evaluation

Crossing	Location	Q100 (cfs)	Structure Class[1]	Existing Size	Within Criteria[2]	Reason
WT 14	Burgess Rd.	89	Culvert	1.5'dia	No	Overtops, Does Not Meet Hw/D
WT 13	Pine Park Trl.	89	Culvert	2.5'dia	No	Overtops, Does Not Meet Hw/D
WT 11	Arroya Ln	480	Culvert	1'dia	No	Overtops, Does Not Meet Hw/D
WT 10	Woodmen Rd.	1,000	Culvert	8.75'x 18.92'	Yes	
WT 9	Meridian Rd.	1,100	Bridge	(4) 6'x 10'	No	Does Not Meet Freeboard
Pond WU Inlet	Tamlin Rd.	1,100	Culvert	(3) 1.5'dia	No	Overtops, Does Not Meet Hw/D
WT 7-2	Rail Road	970	Bridge	7.41'x 54'	Yes	
WT 7-1	Hwy. 24	970	Bridge	(3) 6'x 12'	No	Does Not Meet Freeboard
WT 6	Falcon Hwy.	1,000	Culvert	(2) 5.58'x 8.25'	No	Overtops
WT 5	Meridian Rd.	1,100	Culvert	2'dia	No	Does Not Meet Hw/D
WT 5-2	Meridian Rd.	1,100	Culvert	1.5'dia	No	Overtops, Does Not Meet Hw/D
WT 4	W. Condor Rd.	1500	Bridge	4'dia	No	Overtops, Does Not Meet Freeboard
WT 3	Garrett Rd.	1,500	Bridge	(3) 7.33'x 12'	No	Does Not Meet Freeboard
WT 1	Blaney Rd.	2,200	Bridge	(2) 3'dia	No	Overtops, Does Not Meet Freeboard
MT 7	Owl Ln.	299	Culvert	1.25'x 1.75'	No	Overtops, Does Not Meet Hw/D
MT 6	Woodmen Rd.	840	Culvert	(3) 4'dia	No	Overtops, Does Not Meet Hw/D
MT 6-2	Woodmen Rd.	840	Culvert	(3) 4'dia	No	Overtops, Does Not Meet Hw/D
MT 5-1	McLaughlin Rd.	820	Bridge	5.22'x 27'	No	Does Not Meet Freeboard
MT 4	Rail Road	840	Bridge	9.17'x 77'	Yes	
MT 3	Hwy. 24	840	Bridge	(2) 6'x 12'	No	Does Not Meet Freeboard
MT 2	Swingline Rd.	860	Bridge	6.83'x 20'	No	Does Not Meet Freeboard
MT 1	Falcon Hwy.	860	Culvert	2'dia	No	Overtops, Does Not Meet Hw/D
ET 32	Liberty Grove Dr.	200	Culvert	(2) 3.5'dia	No	Does Not Meet Hw/D
ET 31	Stapleton Dr.	200	Culvert	(2) 2.5'x 6'	No	Overtops, Does Not Meet Hw/D
ET 30	Royal County Down Rd.	270	Culvert	6'dia	Yes	
ET 26	Rio Secco Ln.	270	Culvert	(3) 4'dia	No	Overtops, Does Not Meet Hw/D
ET 19	Eastonville Rd.	530	Culvert	6'dia	No	Does Not Meet Hw/D
ET 15	Rail Road	300	Bridge	6.5' x 67'	No	Does Not Meet Freeboard
ET 14	Hwy. 24	300	Bridge	(2) 4.83'x 12'	No	Does Not Meet Freeboard
ET 13	Pinto Pony Rd.	300	Culvert	(2) 4'dia	No	Overtops, Does Not Meet Hw/D
ET 11	Falcon Hwy.	400	Culvert	(2) 5'dia	No	Overtops, Does Not Meet Hw/D
ET 10	N. Condor Rd.	590	Culvert	3.17'x 4.67'	No	Overtops, Does Not Meet Hw/D
ET 9	Sunset Trl.	590	Culvert	4'dia	No	Overtops, Does Not Meet Hw/D
ET 4	Garrett Rd.	640	Culvert	3.17'x 4.67'	No	Overtops, Does Not Meet Hw/D

Notes:
[1]According to the Drainage Criteria Manual

6.3.3. Plans & Profiles

Sheets 6-2 through 6-50 provide more detailed plan and profile views of selected reach improvements for each planning reach. These conceptual plans show stream centerline, detention ponds and associated data, proposed grade control structures, drainageway crossings and proposed improvements, and the approximate 100-yr floodplain along with existing infrastructure such as roadways and storm sewers. Hydraulic grade lines shown on the profile, representing the WSE for 5- and 100-year storm events, were generated using HEC-RAS along the main stem of each major tributary.

Sheets 6-51 through 6-56 provide typical details and section views of proposed reach grade control structures, detention pond profiles, and proposed roadside ditch improvements.

6.3.4. Reach Quantities & Cost Estimate

The assumptions and methods used to calculate the quantities and costs for each alternative category listed in Table 6-6 and defined in Section 5.4 are provided in the following sections. Additional costs as a percentage of the subtotal construction cost include Engineering/Construction Administration (15%) and Contingency (20%). Detailed quantities and cost estimates are provided in Appendix D.

Roadside Ditch Sizing

The quantities for this reach alternative include the infrastructure necessary to provide sufficient capacity for roadside ditches only. The required roadside ditch sizes were assumed to have the same slope and roughness as the infrastructure that is being replaced. The quantities and costs for all infrastructure sizing reaches are provided in Table 6-8.

Table 6-8. Roadside Ditch Cost Estimate

Reach	Length (ft)	Q100 (cfs)	Total Cost ($)
RWT344	1,379	250	$ 167,006
RWT354	16	2,200	$ 23,544
RET140	4,052	85	$ 295,914
RET164	2,072	630	$ 132,703
		Subtotal	$ 619,166
		Engineering/Construction Admin. (15%)	$ 92,875
		Contingency (20%)	$ 123,833
		Total	**$ 835,874**

Natural Channel Design

The quantities for this reach alternative include the number of structures per reach. Natural channel design costs were developed with the following assumptions:

- The crest width for a natural channel drop structure is the channel width associated with the low flow (bankfull) event as defined in the DCM update Section 3.1.1.1.
- Natural channel structures were spaced at increments of 7 times the low flow channel width.
- Cost per structure based on $24,400 per structure plus $420 times the width of the low flow channel.

The quantities and costs for all natural channel design reaches are provided in Table 6-9.

Table 6-9. Natural Channel Design Reaches Cost Estimate

Reach	Length	Number of Structures	Cost
RET120	1,379	2	$ 72,798
RET154	2,357	14	$ 468,927
RET156	942	2	$ 73,722
RWT094	2,145	7	$ 1,474,717
RWT122	518	2	$ 424,187
RWT150	3,741	24	$ 765,482
RWT210_upstream	2,132	16	$ 593,011
		Subtotal	$ 2,291,521
		Engineering/Construction Admin. (15%)	$ 343,728
		Contingency (20%)	$ 548,304
	Total		**$ 3,093,554**

Small Drop Structures

The quantities for this reach alternative include earthwork, rip rap toe protection, vegetation, and small (3ft vertical) drop structures. Note that small drop structures span the low flow channel width. Small drop structure reach costs were developed with the following assumptions:

- Earthwork is required to fill the existing degraded channel area to approximate the original section. Earthwork was estimated to cost $15 per cubic yard.
- Revegetation is required to cover the area equal to the earthwork area. Revegetation was estimated to cost $0.50 per square foot.
- Small drop structures are 3ft vertical with a 3ft key depth for a 6ft total height. The cost for small drop structures is estimated using a regression equation developed for this DBPS and is a function of their total height of 6ft and the low flow channel width. The average cost per small drop structure is about $208,000.
- Small drop structures are to be spaced by assuming that the existing channel slope degrades to a design slope less than 0.4 percent and the total drop structure height (6ft) is utilized.

The quantities and costs for all small drop structure reaches are provided in Table 6-10.

Table 6-10. Small Drop Structure Reaches Cost Estimate

Reach	Length	Cost ($)
RET020	1,915	$ 1,169,444
RET030	5,042	$ 1,405,908
RET040	1,820	$ 1,073,275
RET100	1,791	$ 1,342,120
RET110	2,751	$ 1,055,516
RET152	2,030	$ 1,081,390
RET162	3,256	$ 656,460
RMT050	1,568	$ 814,189
RMT062	5,688	$ 2,381,127
RMT064	3,358	$ 1,231,110
RMT102	1,021	$ 636,082
RMT104	874	$ 186,349
RMT106	226	$ 212,322
RMT112	3,372	$ 1,276,142
RMT114	1,667	$ 853,693
RWT054	2,497	$ 1,414,531
RWT080	3,494	$ 2,345,153
RWT092	626	$ 414,434
RWT124_upstream	1,246	$ 640,054
RWT174	1,871	$ 606,335
RWT234	2,129	$ 976,863
RWT296	1,134	$ 223,458
RWT372	1,377	$ 947,221
Subtotal		$ 22,943,176
Engineering/Construction Admin. (15%)		$ 3,441,476
	Contingency (20%)	$ 4,588,635
	Total	**$ 30,973,288**

Bridge and Culvert Crossing Replacements

The proposed size for crossing replacements includes the infrastructure necessary to provide the bridge or culvert with sufficient capacity to adhere to DCM criteria. Costs were estimated using a regression equation developed for this DBPS that was based on 2012 UDFCD master plan costs. Note that several crossings (e.g., WT 5-2, WT 4, WT 1, and MT 1) require such a large number of cells to comply with criteria that the proposed configurations are likely impractical. These locations may necessitate consideration of a more comprehensive capital improvement project including raising the roadway profile to achieve feasibility. The quantities and costs for all crossing replacements are provided in Table 6-11.

Table 6-11. Crossing Replacement Cost Estimate

Crossing	Location	Q100 (cfs)	Proposed Size	Length	Total Cost
WT 14	Burgess Rd.	89	5’	66	$ 31,585
WT 13	Pine Park Trl.	89	5’	53	$ 28,525
Pond WU Inlet Structure	Tamlin Rd.	1,110	(8) 6’ x 12’	74	$ 658,410
WT 6	Falcon Hwy.	1,000	(5) 6’ x 12’	43	$ 249,775
WT 5	Meridian Rd.	1,100	3’	43	$ 8,651
WT 5-2	Meridian Rd.	1,100	(25) 3’ x 10’	43	$ 718,121
WT 4	W. Condor Rd.	1,500	(11) 5’ x 12’	48	$ 528,324
WT 3	Garrett Rd.	1,500	(3) 9’ x 12’	46	$ 218,292
WT 1	Blaney Rd.	2,200	(16) 5’ x 12’	40	$ 636,648
MT 7	Owl Ln.	299	(9) 2’ x 4’	58	$ 207,465
MT 6	Woodmen Rd.	840	(3) 5’	200	$ 166,177
MT 6-2	Woodmen Rd.	840	(3) 5’	220	$ 181,365
MT 5-1	McLaughlin Rd.	820	(3) 7’ x 12’	48	$ 191,098
MT 2	Swingline Rd.	840	(3) 8’ x 12’	83	$ 343,147
MT 1	Falcon Hwy.	860	(11) 4’ x 12’	45	$ 433,032
ET 31	Stapleton Dr.	200	(2) 4’ x 12’	302	$ 525,026
ET 19	Eastonville Rd.	530	7’ x 10’	39	$ 63,340
ET 13	Pinto Pony Rd.	300	(2) 6’ x 8’	50	$ 113,991
ET 11	Falcon Hwy.	400	(2) 6’ x 8’	40	$ 84,348
ET 10	N. Condor Rd.	590	(3) 7’ x 10’	44	$ 162,656
ET 9	Sunset Trl.	490	(2) 6’ x 8’	40	$ 84,102
ET 4	Garrett Rd.	640	(2) 5’ x 8’	61	$ 106,060
				Subtotal	$ 5,740,139
				Engineering/Construction Admin. (15%)	$ 861,021
				Contingency (20%)	$ 1,148,028
				Total	**$ 7,749,187**

No crossing improvements were necessary at WT 10, WT 7-2, MT 4, or ET 30 since the hydraulic condition at these locations were within criteria as noted in Table 6-7. Crossings WT 7-1, MT 3, and ET 14 were not resized because they are CDOT structures. Crossing WT 11 was not resized because it is located under a private drive. Other crossings, including WT 9, ET 32, ET 26, and ET 15, were not resized because the degree of criteria exceedance was so minor that they did not warrant replacement.

6.3.5. Immediate Action Required

There are 6 locations where immediate action is required in order to preserve the existing reach conditions as shown in Figure 6-1. These locations are at points adjacent to pristine channel reaches, or Natural Channel Design reaches, where current erosion or deposition has been identified. If left unmitigated, the issues at these locations have the potential to propagate and worsen the existing condition, thereby necessitating additional reach improvement costs. These locations can be addressed by implementing the recommended reach alternative for the impaired reach at the sites that are identified while improvements for the remainder of the impaired reaches can be constructed at a later date.

6.3.6. Protect In Place

There are several relatively pristine reaches of channel throughout the Falcon Watershed that are currently in a stable condition. Additionally, there are several reaches throughout the Falcon Watershed that have already been improved and appear to be stable. Preserving both of these reach conditions would not require a direct reach improvement cost. However, upstream detention improvements may be required depending on the location of the reach.

6.3.7. Reach Phasing Priority

Reach construction should be phased so that planned upstream detention ponds are constructed prior to reach construction. This method of phasing protects the reach alternatives from being damaged as a result of higher than designed for flows being released into the reach. A phasing priority of 1 means the reach can be constructed. Higher phasing priority numbers indicate more upstream detention ponds should be built prior to construction of the reach in question. The phasing priority for each of the reaches is provided in Appendix D.

6.4. Cost Summary

Costs for all detention ponds, reach improvements, bridge and culvert replacements, and roadside ditches are summarized in Table 6-12.

Table 6-12. Cost Summary

Alternative	Cost[1]
Detention Ponds	$ 6,822,546
Roadside Ditches	$ 835,874
Reaches[2]	$ 34,066,842
Bridge & Culvert Crossings	$ 7,749,187
Total	**$ 49,474,449**

Notes:
[1]Includes all construction and additional costs
[2]Reaches includes both Natural Channel Design and Small Drop Structure reaches

Figure 6-1. Selected Plan

Sheet 6-2 to Sheet 6-19. Falcon DBPS Conceptual Plan West Tributary

Sheet 6-20 to Sheet 6-25. Falcon DBPS Conceptual Plan Middle Tributary

Sheet 6-26 to Sheet 6-38. Falcon DBPS Conceptual Plan East Tributary

Sheet 6-39 to Sheet 6-50. Falcon DBPS Conceptual Plan Small Tributaries

Sheet 6-51. Typical Natural Channel Cross-Sections

Sheet 6-52. Typical Rock Cross Vane Details

Sheet 6-53. Typical Riffle Cross Sections

Sheet 6-54. Typical Grouted Sloping (GSB) Boulder Drop Structure

Sheet 6-55. Typical Profile of Detention Basin

Sheet 6-56. Typical Roadside Ditch Improvements

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7.0 FEE DEVELOPMENT

7.1. Introduction

The objective of the fee development exercise was to determine the equitable share of drainage improvement costs that a developer is responsible for paying to El Paso County if they wish to plat a property. This fee is a function of the total cost for the selected plan outlined in Section 6 and will be used by the County to pay for drainage improvements that are necessary as a result of development. The product of this calculation is a unit fee (cost/impervious acre) that is a one-time charge to the developer based on the number of impervious acres within the platted property.

7.2. Developable Land

The Falcon Watershed has a total area of 6,847 acres. The entirety of the watershed is within the County with 1,969 acres unplatted, according to the GIS dataset received from the County. This dataset also includes unplatted areas that can't be developed because of specific land use designations. Table 7-1 provides a summary of land classifications in the Falcon Watershed. A complete summary of unplatted area land use is provided in Appendix E.

Table 7-1. Land Classification

Classification	Area (acres)
Platted	3,670
Unplatted	1,969
Other	1,208
Total	**6,847**

The projected impervious acreage within unplatted areas totals 645.58 acres. A summary of land classification within the Falcon Watershed is provided in Figure 7-3.

7.3. Fee Calculation & County Cost

The total cost for the Selected Plan was separated into a Development Fee, County Cost, Metropolitan District Cost, and Drainage and Bridge Funds. A description of how the aforementioned were defined is as follows:

- **County Cost –** Drainage improvement costs that are the responsibility of the County as shown in Figure 7-1.
- **Metropolitan District Cost –** Drainage improvement costs that are the responsibility of a metropolitan district as shown in Figure 7-2.
- **Development Fee –** All drainage improvement costs that are directly associated with new development.
- **Drainage and Bridge Funds –** The balance of drainage and bridge funds as of August 2015 was $584,134 and $510,777, respectively, with a liability of $300,000 cost for this DBPS (an additional contract amendment increased the cost of this DBPS to $339,088).

The anticipated reimbursements due for work completed in the Falcon Watershed are approximately equivalent to the available drainage and bridge funds. As a result, reimbursements were not included in the fee calculation. Drainage improvements that are required as a result of new development are listed in Appendix E.

The costs apportioned to County and metropolitan district drainage improvements are provided in Table 7-2 and Table 7-3. The bridge improvement fees shown in Table 7-2 and Table 7-3 were determined by classification of the crossing as either a bridge or a culvert. This classification was based on the DCM criteria.

Table 7-2. County Cost

Drainage Improvements	$ 24,051,349
Bridge Improvements	$ 2,887,437
Total Cost	**$ 26,938,786**

Table 7-3. Metropolitan District Cost

Drainage Improvements	$ 3,972,407
Bridge Improvements	$ 1,855,620
Total Cost	**$ 5,828,027**

The development cost and corresponding fee calculations based on impervious acreage are provided in Table 7-4 and 7-5.

Table 7-4. Development Drainage Cost and Fee

Drainage Improvements	$ 14,649,163
DBPS Cost	$ 339,088
Total Cost	**$ 14,988,251**
Drainage Fee (per imp. ac.)	**$ 23,217**

Table 7-5. Development Bridge Cost and Fee

Bridge Improvements	$ 2,058,474
Total Cost	**$ 2,058,474**
Bridge Fee (per imp. ac.)	**$ 3,189**

Figure 7-1. County Cost Improvements

Figure 7-2. Metro District Cost Improvements

Figure 7-3. Developable Unplatted Area

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8.0 REFERENCES

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Appendix A. Hydrologic Analysis

Appendix B. Hydraulic Analysis

Appendix C. Alternatives Analysis

Appendix D. Plan Development

Appendix E. Fee Development