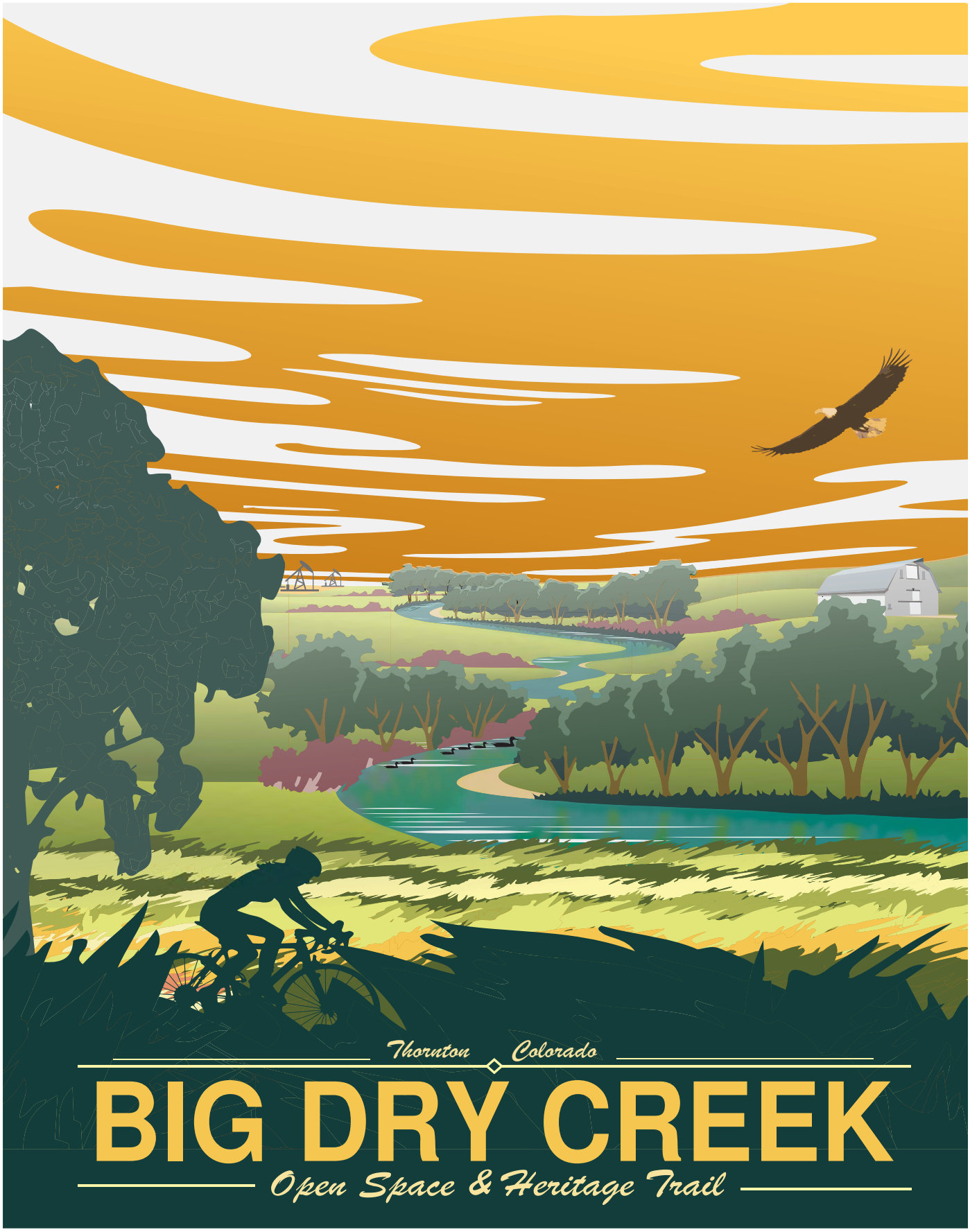

Big Dry Creek Recreation & Floodplain Restoration Master Plan

City of Thornton

February, 2018

City of Thornton

ADAMS COUNTY
COLORADO

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Panoramic photograph of Big Dry Creek in Thornton

Partnerships and Collaborative Input

Throughout the entire project, a variety of agencies, departments and groups were engaged to provide feedback and input into the Master Plan. This collaborative input ensured that the Master Plan recommendations are achievable, reasonable and positioned for success. Valuable input from the public sector was given by:

- Adams County
- Big Dry Creek Watershed Association
- Colorado State University Civil and Environmental Engineering Departments
- Urban Drainage and Flood Control District
- Oil and natural gas companies operating within the corridor
- Great Outdoors Colorado
- Multiple city of Thornton departments and Boards, including:
  - Community Services Department
  - Infrastructure Department
  - Parks and Open Space Advisory Commission (POSAC)

Table of Contents

Primary Maps and Figures

Appendices *(under separate cover)*

Glossary of Commonly Used Terms:

Alluvial soil	A fine-grained fertile soil deposited by water flowing over flood plains or in river bed
Alluvium	A deposit of clay, silt, sand and gravel left by flowing streams in a river valley or delta, typically producing fertile soil
Avulsion	The sudden change in the course of a river channel (often during a flood), potentially causing the separation of land from one property and its attachment to another
Bank Stabilization	The process of using creek engineering strategies to prevent bank erosion within a channel
Bankfull	The water level, or stage, at which a stream, river or lake is at the top of its banks and any further rise would result in water moving into the floodplain
Bankfull discharge	Flow rate within a channel when water is just about to spill out of the channel banks and into the adjacent floodplain
Baseflow	The portion of streamflow that does not come from storm events. In Big Dry Creek, the main sources of Baseflow are groundwater and Wastewater Treatment Plant discharges
Benthic macroinvertebrates	Small animals living among stones, logs, sediments and aquatic plants on the bottom of streams, rivers and lakes. They are large enough to be seen with the naked eye (macro) and have no backbone (invertebrate)
Best Management Practice	A practice or combination of practices determined to be effective and practicable, often in relation to preventing water pollution and/or improving water quality
Channel incision	The process of downcutting into a stream channel leading to a decrease in the channel bed elevation
Channel reach	General term for a length of a stream or river, usually suggesting a level, uninterrupted stretch
Cut bank	A nearly vertical cliff produced by erosion of the banks of a stream
Deposition	Sediment settling out of moving water and being added to the stream bed, bank, or floodplain
Diversion	The physical removal of water from a stream or lake via an engineered structure. Often used to divert water for irrigation, municipal, industrial, or storage purposes
Downcutting	A geological process by hydraulic action that deepens the channel of a stream by removing material from the stream's bed (also see channel incision)
Entrenched	A river that is confined to a canyon or gorge, and in most cases, it is relatively narrow with very little or no floodplain. It often has meanders already developed into landscapes. This is also used to describe incised streams that have become disconnected from their floodplains

Ephemeral channel	A stream or part of a stream that flows only as a result of precipitation and receives little or no flow from groundwater
Equilibrium	A channel in which erosion and deposition are balanced, resulting in little or no change in channel shape over time
Erosion	The movement of soil or rock by wind, water, or other natural processes
Fish ladder	A series of pools built like steps to enable fish to bypass a dam, drop structure or other barrier in the stream
Floodplain	An area of low-lying ground adjacent to a river, formed mainly of river sediments and subject to flooding
Flow regime	The pattern and variability in the amount of water that travels through a waterway in response to precipitation, evapotranspiration and drainage basin characteristics
Fluvial erosion	Erosion caused by flowing water in a stream or river
Fluvial geomorphology	The study of rivers and streams and the deposits and landforms created by them
Freeboard	The height distance between a set water elevation (such as the 100 year flood elevation) and the bottom of a structures (such as a bridge)
Geomorphic	Relating to the form of the landscape and other natural features of the earth's surface
Grade control	A natural or engineered structure on the channel bed which locally prevents bed erosion, creating a stable channel slope (or "grade")
Headcut	An erosional feature of some streams where an abrupt vertical drop in the stream bed occurs (also known as a knickpoint)
Heritage Trail	The Heritage Trail system is a series of loop trails that traverse culturally-significant zones within the city of Thornton and create special educational and interpretive experiences for users, each with a distinct historical, cultural, or environmental theme
Hydrology	The branch of science concerned with the properties of the earth's water, especially its movement in relation to land
Impervious	A material that does not allow fluid to pass through it (e.g., concrete)
Incised	When a river or stream has a cut vertically downward through its bed, and has lost connection with its floodplain
Interstitial spaces	Small spaces or gaps between two larger objects; for example, the small spaces between grains of sand or gravel
Lateral channel migration	The geomorphological process by which a stream channel moves laterally across the landscape due to water eroding the bank on one side of the stream (usually balanced by sediment deposition on the opposite bank)

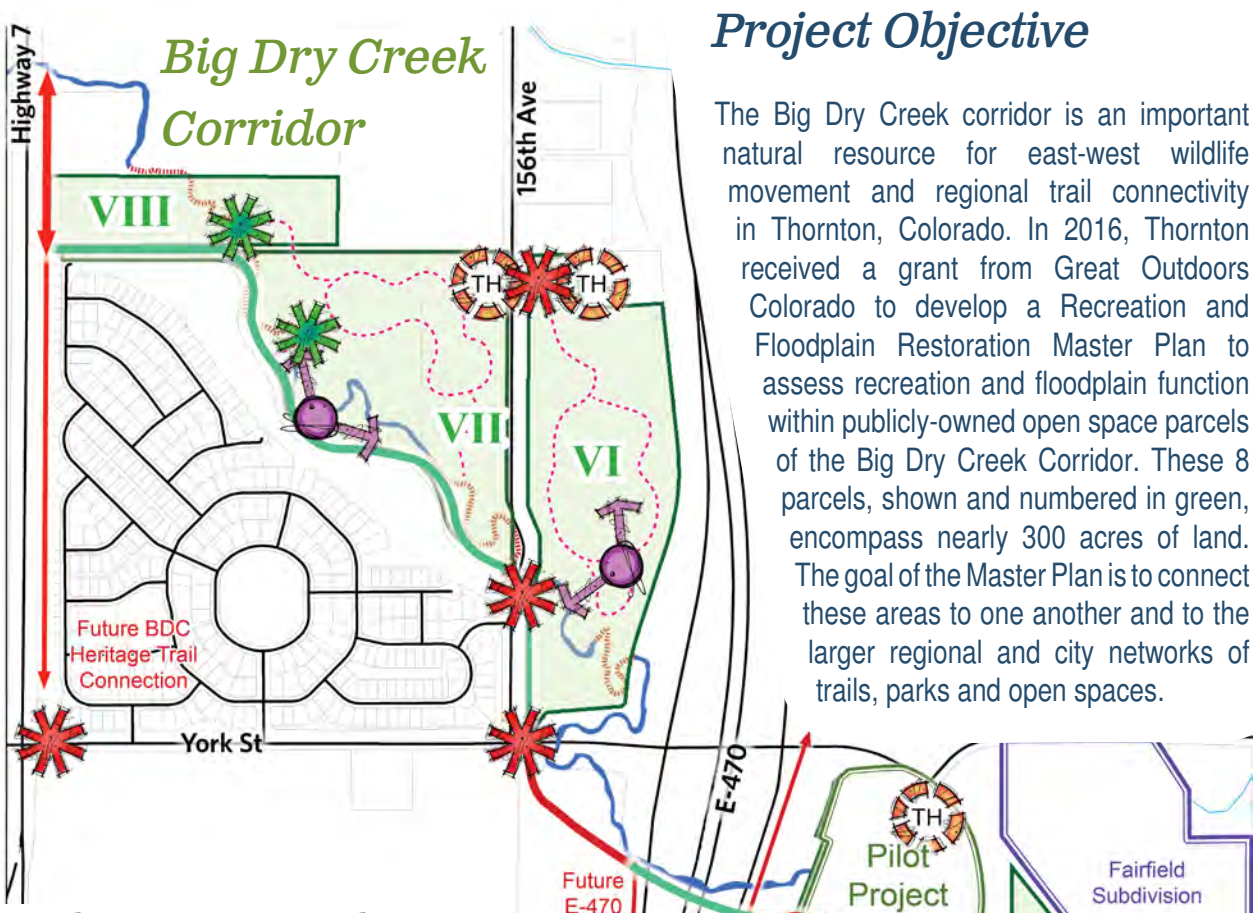
Low flow	See ***Baseflow***
Mass wasting	Also known as slope movement or mass movement; the downhill movement of soil and rock fragments induced by gravity; this is the process causing stream bank collapse or failure
Meander	A twist, turn or curve in an active channel of a river, stream or creek. See ***Oxbow*** for the historical/past curves of a river
Meander belt	An identified boundary on both sides of a stream which run parallel with a stream or river. A stream will naturally laterally migrate within this boundary from time to time, especially during a flood
Meander bends	Curves formed in the path of a stream caused by water velocities eroding the stream's outer banks and widening its valley
Nonpoint source pollution	Pollution that occurs as a result of precipitation moving over and through the ground, absorbing and assimilating any pollutants it comes into contact with and eventually running off into a stream
Outfall	The place where an irrigation ditch, drain or sewer pipe empties into a water body
Oxbow	A naturally abandoned or cutoff portion of a historic meander bend; while a meander is part of an active channel, an oxbow is the non-active area remaining after a meander is cut off from the channel
Planform aspects	The outline of an object viewed from above
Plugs (plants)	Individual wetland or riparian plants that are established by a professional wetland plant nursery and installed in predetermined areas along a stream or wetland to expedite plant establishment
Point source pollution	A specific identifiable location or point where pollutants are discharged into a water body
Return flows	A portion of water previously diverted from a stream for irrigation or other uses which travels back to the same or a different body of water via ground or surface water pathways
Revetment	Armoring, such as to protect something
Rheotactic salmonids	Fish of the Salmon family (i.e. salmon, trout, char and whitefish) that generally turn to face into an oncoming current
Riparian	Relating to or situated on the banks of a river
Scour	The result of swiftly moving water eroding soil, causing a hole or depression in the stream bed

Shear Stress	A force that causes layers or parts to slide upon each other in opposite directions; for example, moving water imparts a shear stress on a river's bed and banks
Sinuosity	A ratio of stream length following curvature of stream between two points to straight-line distance between the same two points. A higher ratio indicates greater sinuosity
Sloughing	An outer layer or covering that is shed or removed
Stream restoration	A large variety of ecological, physical, spatial and management measures and practices aimed at restoring the natural state and functioning of a stream or river system in support of biodiversity, recreation, flood management and landscape development
Thalweg	A line drawn to join the lowest points along the entire length of a streambed or valley in its downward slope, defining its deepest channel
Toe of bank	The bottom of a stream bank where the bank meets the baseflow water level of a channel
Velocity	The speed of something in a given direction
Wetland sod mats	Similar to grass sod, wetland sod mats are comprised of wetland plants grown hydroponically on a coir erosion control mat which then, when installed, maximizes root growth for immediate anchoring and improved soil cohesion
Wetland	Land consisting of marshes or swamps; saturated land
Width-to-depth ratio	The ratio of the bankfull surface width to the mean depth of the bankfull channel. The width/depth ratio is key to understanding the distribution of available energy within a channel, and the ability of various discharges occurring within the channel to move sediment
WWTP effluent	Treated liquid waste or sewage from a wastewater treatment plant that is discharged into a body of water
Xeric	Plant community characterized by, relating to or requiring only a small amount of moisture

Common Acronyms:

ADCO – Adams County
BDC – Big Dry Creek
BMP – Best Management Practice
CDPHE – Colorado Department of Public Health & Environment
CDPS – Colorado Department of Public Safety
CFS – Cubic Feet per Second
CLOMR – Conditional Letter of Map Revision
EPA – Environmental Protection Agency
FEMA – Federal Emergency Management Agency
HOA – Homeowners Association
MPD – Major Drainageway Plan
POSAC – Parks and Open Space Advisory Commission (city of Thornton)
TSS – Total Suspended Solids
UDFCD – Urban Drainage and Flood Control District
USDCM – Urban Storm Drainage Criteria Manual
WWTP – Wastewater Treatment Plant

Executive Summary



Project Objective

The Big Dry Creek corridor is an important natural resource for east-west wildlife movement and regional trail connectivity in Thornton, Colorado. In 2016, Thornton received a grant from Great Outdoors Colorado to develop a Recreation and Floodplain Restoration Master Plan to assess recreation and floodplain function within publicly-owned open space parcels of the Big Dry Creek Corridor. These 8 parcels, shown and numbered in green, encompass nearly 300 acres of land. The goal of the Master Plan is to connect these areas to one another and to the larger regional and city networks of trails, parks and open spaces.

Master Plan Approach

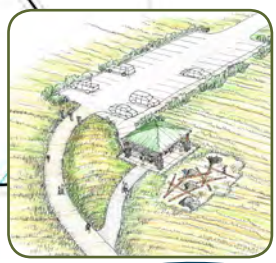
The approach for this Master Plan is to balance recreation and infrastructure improvement with floodplain restoration and long term environmental health to establish a holistic vision for Big Dry Creek through Thornton. The Master Plan vision will improve the environment along the Big Dry Creek corridor and connect open space visitors to increased recreational opportunities within this unique open space pearl.

Master Plan Recommendations

The Master Plan recommendations have been separated into three overall categories:

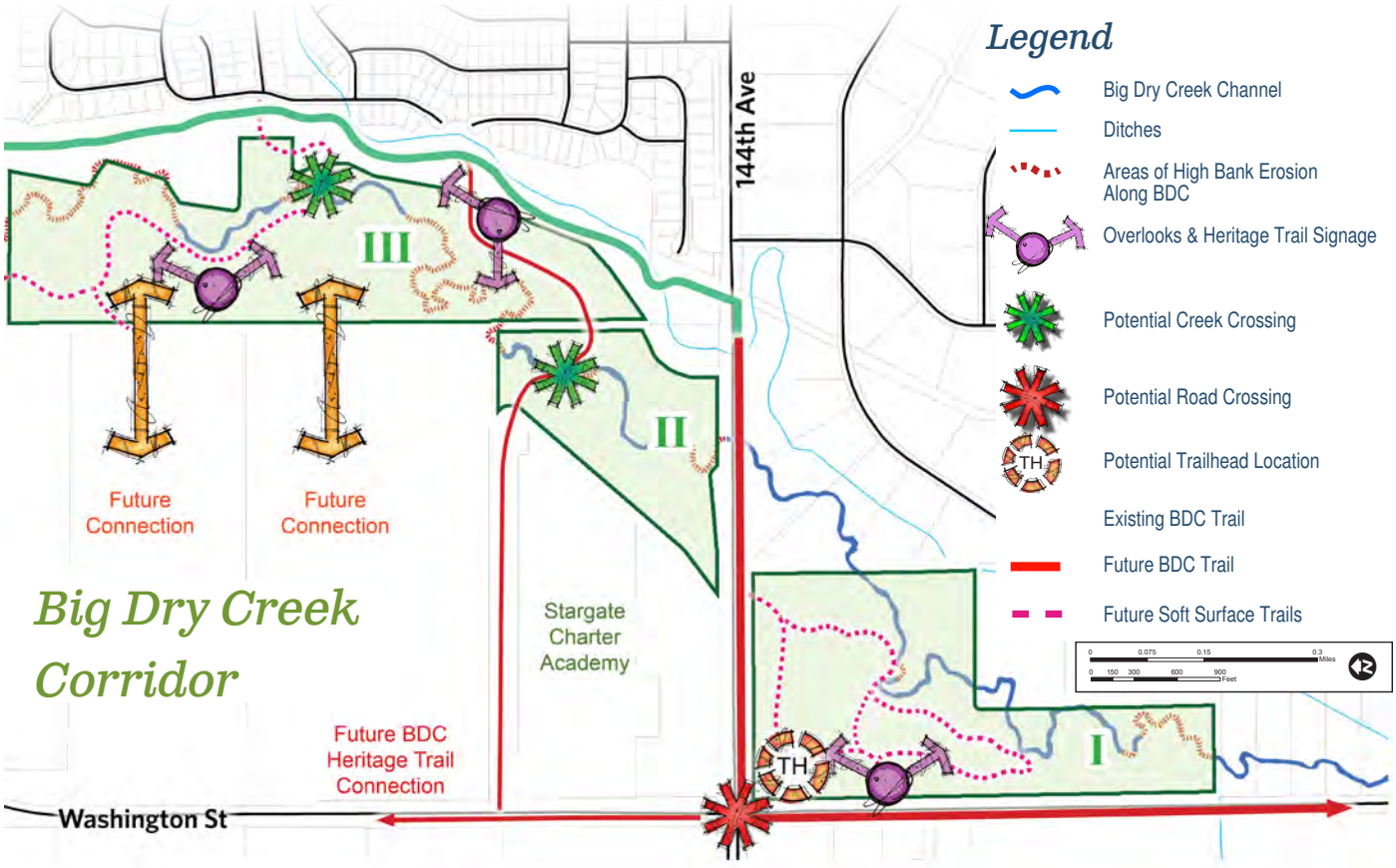
- > Recreation and Infrastructure
- > Floodplain Restoration
- > Environmental Treatment

Through assessment and evaluation, each category can relate to and impact the other categories to achieve a well-rounded improvement project. The Master Plan recommends that each future improvement project encompasses as many categories as possible.



Master Plan Goals

1. Investigate and assess the Big Dry Creek corridor from **multiple angles**.
2. Develop a Master Plan that will achieve a **sustainable balance** in the Big Dry Creek corridor by improving floodplain resiliency, channel stability, water quality, recreational opportunities, trail connections, wildlife habitat and ecosystem health.
3. Create an **implementation toolbox** that can be used to design and build improvements throughout the corridor.
4. Identify an impactful and achievable floodplain restoration **Pilot Project** to be built on city of Thornton property following the Master Plan goals. Funds for passive recreation aspects of the Pilot Project should be pursued in an effort to create a multi-purpose project.
5. Develop and build public momentum for improvements in the corridor in order to make Big Dry Creek an **open space pearl**, similar to the South Platte River and Niver Creek through Thornton.
6. Preserve and enhance the **floodplain** along the corridor to provide natural beneficial functions to the stream system, areas of passive recreation and wildlife habitat.
7. Develop open space uses compatible with infrequent flood inundation, respecting FEMA and city of Thornton restrictions in the **floodway**.
8. Develop solutions for **stream stabilization** that reflect the existing (semi-natural) hydrology of the stream and recognize the potential for channel evolution over time.

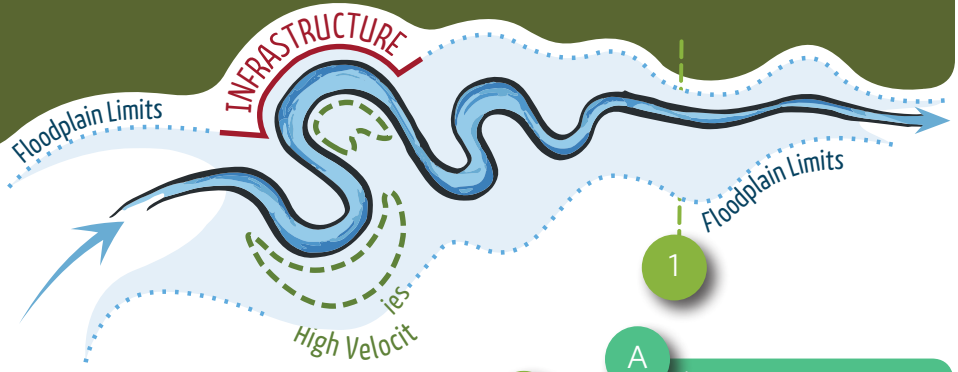


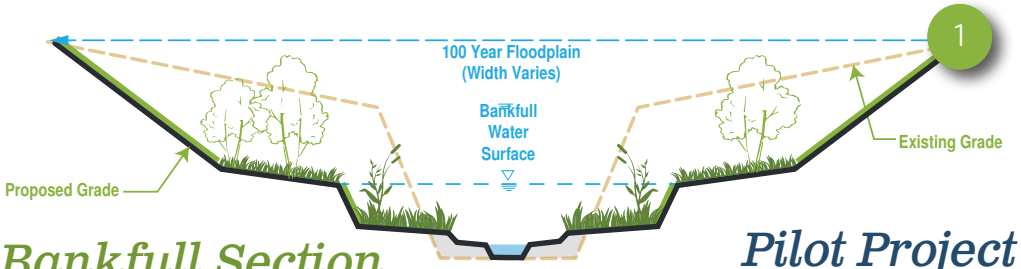
Floodplain Restoration Toolbox

A 'toolbox' approach was taken for the Master Plan to identify general strategies and techniques for the restoration and management of Big Dry Creek. The Toolbox enables the users of the Master Plan to develop a conceptual restoration approach for a variety of potential deficiencies along Big Dry Creek and adapt each technique to the individual conditions of a specific project. The Toolbox was separated into the following categories to address any issue that may be encountered on Big Dry Creek:

1. Floodplain Reconnection and Restoration
2. Bank Stabilization
3. Channel Complexity
4. Grade Control

The restored creek channel will vary in function, form and ecology based on the site specific issues which exist at a given location.

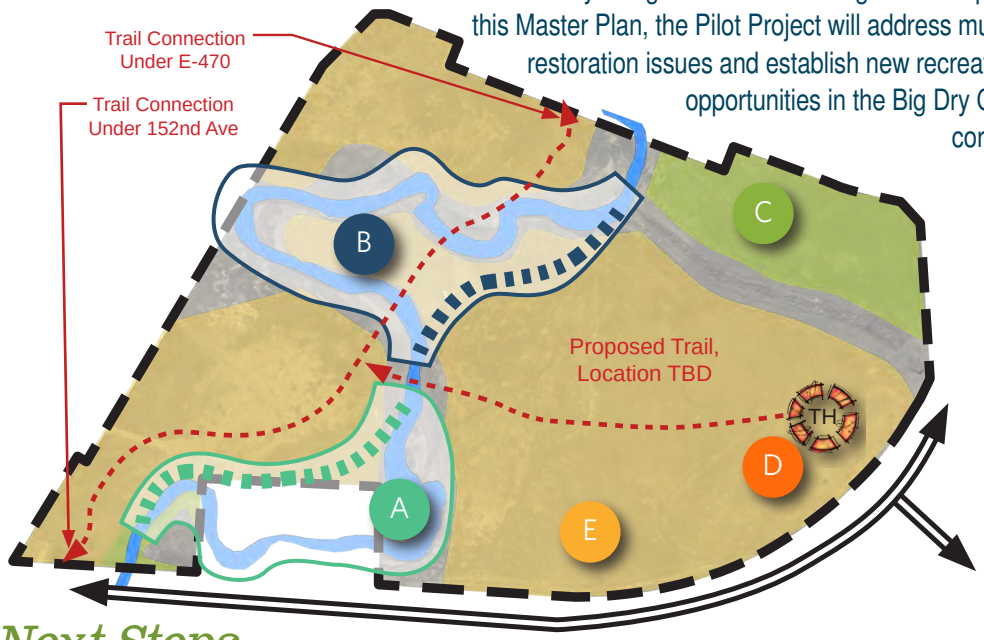




Bankfull Section

Pilot Project

The Big Dry Creek Pilot Project will set the example of restoration in the corridor. By using the Toolbox strategies developed in this Master Plan, the Pilot Project will address multiple restoration issues and establish new recreational opportunities in the Big Dry Creek corridor.



A

Issues
- Lateral Migration
- Erosion
- Habitat degradation

Improvement Strategies
- Off channel wetlands
- Bank stabilizations
- Grade Control
- Revegetation

B

Issues
- Lateral Migration
- Erosion

Improvement Strategies
- Channel Realignment
- Bank Stabilization
- Grade Control
- Revegetation

C

Invasive Weeds including:
- Curly Dock
- Musk Thistle
- Russian Olive
- Kochia

Weed management and revegetation

D

Potential Trailhead Location:
- Paved/unpaved parking
- 36,000 SF Max

E

Heavily populated Prairie Dog habitat with short low grasses throughout

Opportunity to increase vegetation and biodiversity

Next Steps

The next step in the Big Dry Creek Recreation & Floodplain Restoration Master Plan will be to design and construct the Pilot Project. This project will help build momentum for future projects in the corridor and help the city of Thornton apply for grants to help fund future projects.

Chapter 1 - Project Introduction

Chapter Summary

Chapter 1 provides a brief overview of the project and defines objectives, goals, partnerships and collaborative efforts during the course of the project. Project goals were developed at the beginning of the master planning through public input and were modified and improved throughout the project. Subsequent chapters discuss background information, existing conditions, plan recommendations, prioritization, pilot projects and the master plan process. Additional information and details from the process are listed in the Appendices, found under a separate cover.

Project Objective

Thornton's Parks and Open Space Master Plan identifies the Big Dry Creek corridor as an important natural resource for east-west wildlife movement and regional trail connectivity in Thornton. In 2016, the city of Thornton received a grant from Great Outdoors Colorado (GOCO) for $75,000 to develop a Big Dry Creek Recreation and Floodplain Restoration Master Plan (Master Plan). Through a partnership with Adams County, the Master Plan will assess recreation and floodplain function within publicly-owned (city of Thornton and Adams County) open space parcels of the Big Dry Creek corridor. These parcels (the project area) encompass almost 300 acres and have been acquired through city of Thornton and Adams County funds. The Master Plan has created the framework for these areas to be connected both to each other and to the larger regional and city networks of trails, parks and open spaces. In the 2012 update, the city of Thornton's Parks and Open Space Master Plan identified the Big Dry Creek corridor as one of the most important areas of natural vegetation in Thornton, and recommended the extension/completion of the Big Dry Creek Trail as a top priority in the coming years.

A reach of Big Dry Creek running through city of Thornton open space

Big Dry Creek with the historic Big Dry Creek barn

The Big Dry Creek watershed originates in unincorporated Jefferson County near the mouth of Coal Creek Canyon at an elevation of approximately 8,000 feet above sea level. The total drainage area is approximately 110 square miles. Below Standley Lake, Big Dry Creek flows in a northeasterly direction approximately 33 miles to its confluence with the South Platte River near Fort Lupton in Weld County. Thornton's stretch of Big Dry Creek (the project area) is about 6 miles long, beginning at I-25 and flowing northeast to the Adams County line at East 168th Avenue. These 6 miles of creek are influenced and defined by a number of different factors. While these factors certainly overlap and interact, they can generally be separated into two overall categories as described below:

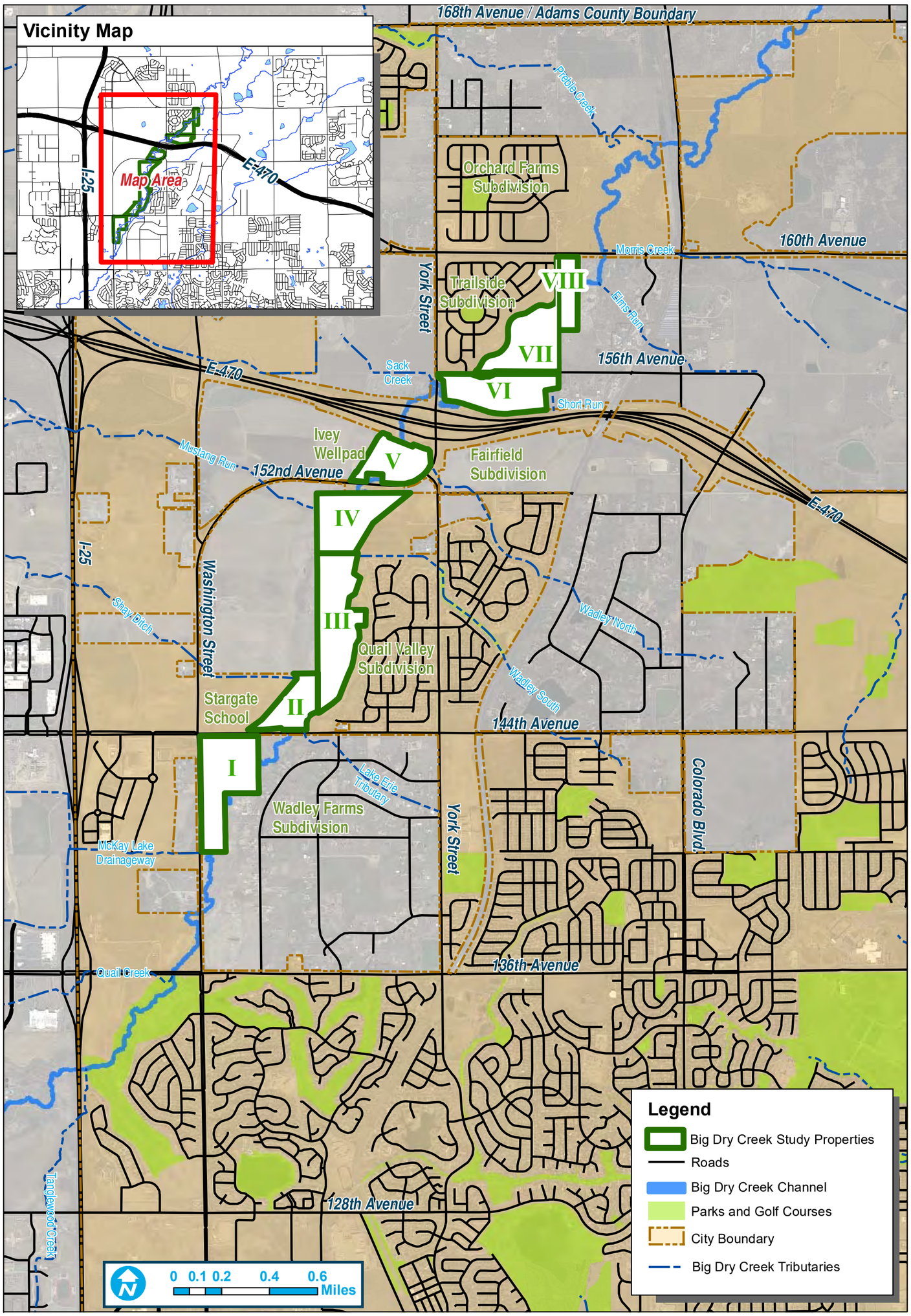
Recreation & Infrastructure:

- Adjacent and nearby developments
- Oil and natural gas extraction
- Regional and local trails
- Adjacent neighborhoods and communities
- Current and future traffic patterns

Floodplain Restoration and Environmental:

- Floodplains and floodways
- A modified hydrology largely dependent on Standley Lake and wastewater treatment plant releases
- Bank stability and erosion
- Wildlife including prairie dogs, owls, hawks, smaller birds, coyotes, insects and small aquatic organisms
- Ecosystems ranging from riparian to wetland to upland
- Current and future utilities and drainage outfalls

The key guiding principle used for approaching this Master Plan is that these factors all relate to each other and must be planned for holistically. In order to successfully plan for this complex riparian corridor, the project team (consisting of the city of Thornton, Adams County and the consultants) examined the varied factors within each section of the corridor, as well as how they all interact and connect with each other.



Big Dry Creek Master Plan Area Map

Project Goals

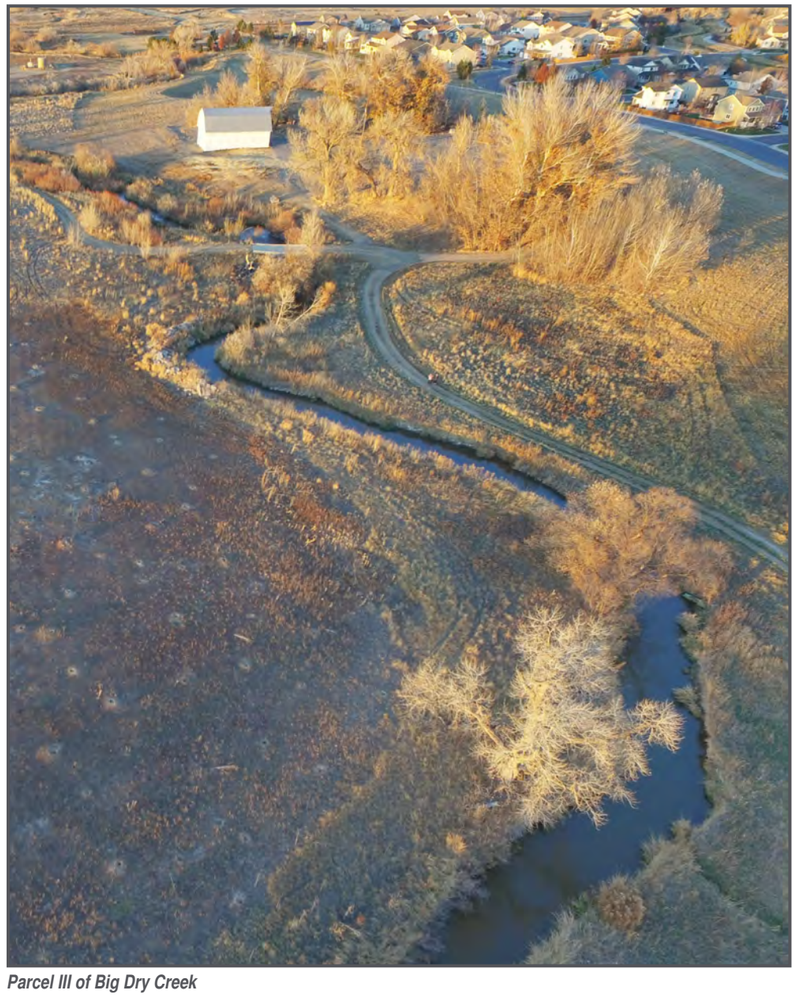
Goals serve as the long-term vision of the project, but also as its guiding principles. In order to develop a successful and long-lasting Master Plan that meets the objectives described on page 2, the following project goals were developed:

1 Investigate and assess the Big Dry Creek corridor from **multiple angles**.

2 Develop a Master Plan that will achieve a **sustainable balance** in the Big Dry Creek corridor by improving floodplain resiliency, channel stability, water quality, recreational opportunities, trail connections, wildlife habitat and ecosystem health.

3 Create an **implementation toolbox** that can be used to design and build improvements throughout the corridor.

4 Identify an impactful and achievable floodplain restoration **pilot project** to be built on city of Thornton property following the Master Plan goals. Funds for passive recreation aspects of the pilot project should be pursued in an effort to create a multi-purpose project.



Parcel III of Big Dry Creek

5 Develop and build public momentum for improvements in the corridor in order to make Big Dry Creek an **open space pearl**, similar to the South Platte River and Niver Creek through Thornton.

6 Preserve and enhance the **floodplain** along the corridor to provide natural beneficial functions to the stream system, passive recreation, wildlife habitat and other considerations.

7 Develop open space uses compatible with infrequent flood inundation, respecting FEMA and city of Thornton restrictions in the **floodway**.

8 Develop solutions for **stream stabilization** that reflect the existing (semi-natural) hydrology of the stream and recognize the potential for channel evolution over time.

Chapter 2 - Background

Chapter Summary

While Chapter 1 provides a brief overview of the project, this chapter provides an in-depth look at the background and history of Big Dry Creek from a variety of viewpoints. As part of the master planning process, the project team reviewed many existing planning and design documents which are summarized in the following pages. This chapter also discusses the existing and historical hydrology and hydraulics of Big Dry Creek. Understanding this is a key to properly planning for the corridor's future.

Background Documents

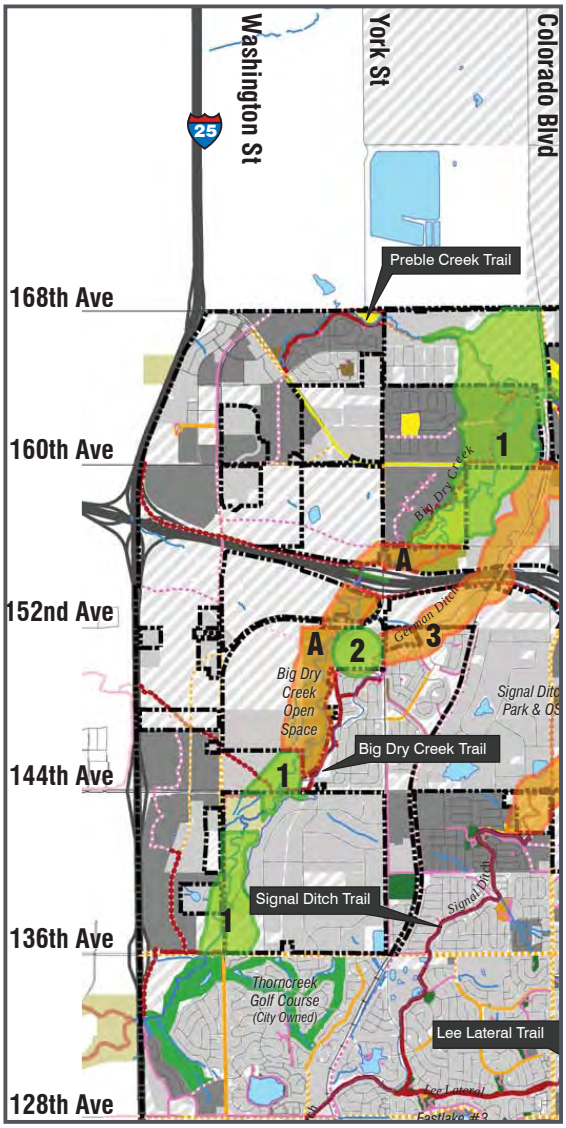
The project team was given access to a wealth of GIS data, past planning documents, current/on-going design plans and conservation easement documents. This 'bank' of background information was reviewed thoroughly to ensure that the Master Plan did not repeat work that has already been done, as well as to create thoughtful recommendations and designs that are supported by past efforts. Below is a brief summary of the most important documents, and how they relate to the Big Dry Creek Master Plan.

City of Thornton Parks and Open Space Master Plan

Thornton's Parks and Open Space Master Plan was developed following the 1997 0.25% sales and use tax increase, the formation of the Parks and Open Space Advisory Commission (POSAC) in 1998 and a $22.4 million bond issued in 2000 to finance the acquisition of 116 acres of open space, 5.5 miles of trails and 53 acres of parkland. This bond also supported the development of other recreational facilities within Thornton. The Parks and Open Space Master Plan was developed to establish a vision ***'in which parks, recreation facilities and open space are linked by a citywide trail system to form a "string of pearls." The "pearls" include opportunities for both active and passive forms of recreation.'***

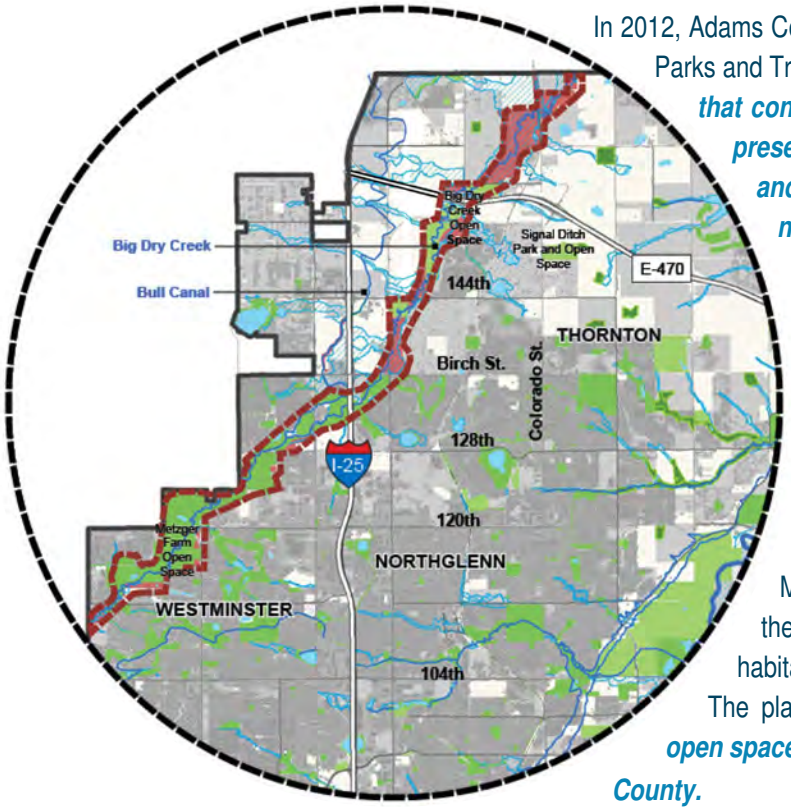
The Parks and Open Space Master Plan identified key "pearls" of parks, recreation facilities and open spaces that should be connected by trail corridors. The South Platte River, Niver Creek and Big Dry Creek are three riparian corridors identified as ***'the most important areas of natural vegetation'***. Both the South Platte River and Niver Creek have already been developed, leaving Big Dry Creek as a connection for Thornton to implement. Extending the Big Dry Creek trail as a part of the larger Heritage Trail Plan is recommended as a key missing segment that should be completed by 2025. The Heritage Trail Plan suggests wildlife along with oil and gas development as the theming elements for the Big Dry Creek Heritage Trail.

The Parks and Open Space Master Plan also noted crucial wildlife species that either currently live within, or could live within the Big Dry Creek corridor. These species, listed in order of endangered/threatened status (most endangered listed first), include bald eagles, black-tailed prairie dogs, swift foxes, ferruginous hawks, peregrine falcons, coyotes, red foxes, white pelicans and great blue herons. There are many other raptor, owl and songbird species that live in the corridor as well. Big Dry Creek is also home to three special-concern non-game fish species-the brassy minnow, common shiner and plains killifish (aka plains top minnow).



Thornton's 2012 Parks and Open Space Master Plan Update showing areas '1' and 'A' as Big Dry Creek opportunity sites.

Adams County Open Space, Parks and Trails Master Plan (2012)



In 2012, Adams County produced an update to their 1998 Open Space, Parks and Trails Master Plan to ***'promote an open space system that conserves agricultural lands throughout the County; preserves and enhances important wildlife habitats and corridors; and protects and improves important natural and scenic resources such as wetlands, floodplains, and unique land forms.'*** Within the Adams County Master Plan, Big Dry Creek is one of eleven main areas identified. To the west of Thornton, Westminster has completed significant trail and floodplain improvements along Big Dry Creek. It is recommended that Thornton's improvements connect to these now existing facilities. Similar to the Thornton 2012 update to the Parks and Open Space Master Plan, this Adams County Master Plan identifies the importance and value of existing vegetation, wildlife habitat and ecosystems within the Big Dry Creek corridor. The plan states that ***'completing the gaps in parks and open space acquisition is a high priority for Thornton and the County.***

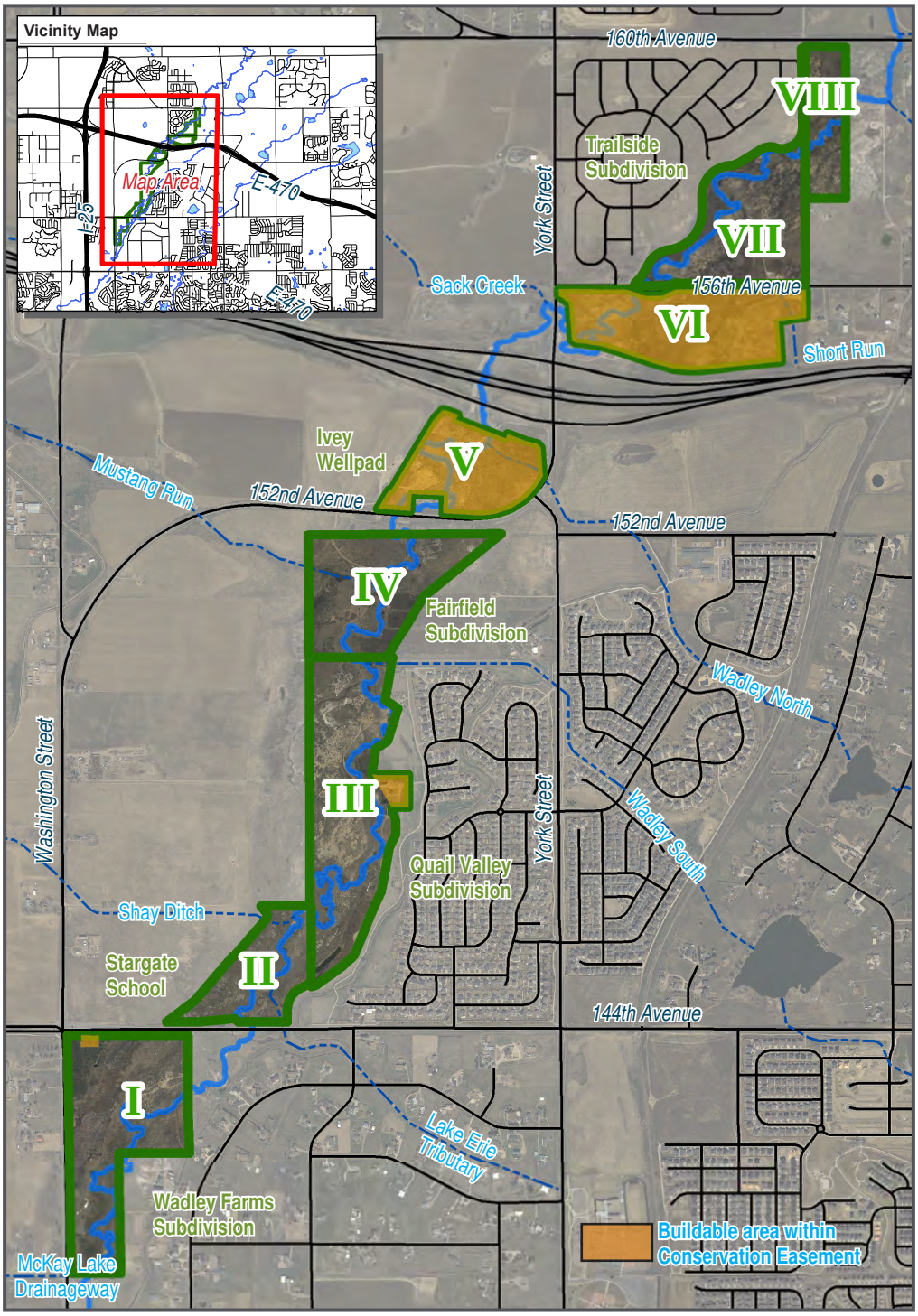
Map 11 within the Adams County Open Space, Parks and Trails Master Plan (2012) discusses the importance of the Big Dry Creek corridor as a recreational and environmental asset.

Thornton's Big Dry Creek Trail will connect to Westminster's Big Dry Creek Trail (photo credit: http://www.ci.westminster.co.us)

Conservation Easements/History of Land Acquisition

Thornton and Adams County have partnered to create a string of eight open space parcels encompassing almost 300 acres (see Big Dry Creek Corridor Properties Map below). Some of these parcels have conservation easements that allow trails and unenclosed structures, with only the Big Dry Creek Trail allowed to be paved. Detailed descriptions of these conservation easements can be found in "Appendix B: Conservation Easements". Some of the parcels also have specific definitions for the type and location of parking areas, trailheads and enclosed structures such as restrooms.

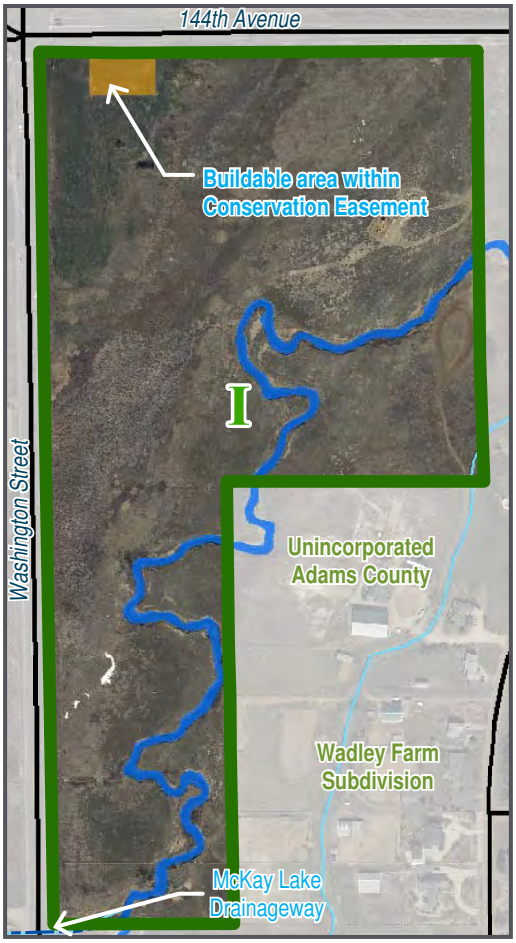
Big Dry Creek Corridor Properties Map



Map showing the eight study parcels for the Big Dry Creek Master Plan and areas within each parcel that allow building improvements, per the Conservation Easements

Parcel I (south of 144th Avenue and east of Washington Street) is comprised of a 35.9 acre parcel acquired by Adams County in 2010, and an additional 12.89 acre parcel acquired in 2012. The entire area, totaling 48.79 acres, has a conservation easement deeded to the city of Westminster (2014) that limits recreation to passive uses and designates a location in the northwest of the property for the future construction of a vehicle parking lot not to exceed 8,000 square feet. The parking area could accommodate 18 cars and one restroom facility that should not exceed 500 square feet. There is currently a well site with an access road on the parcel.

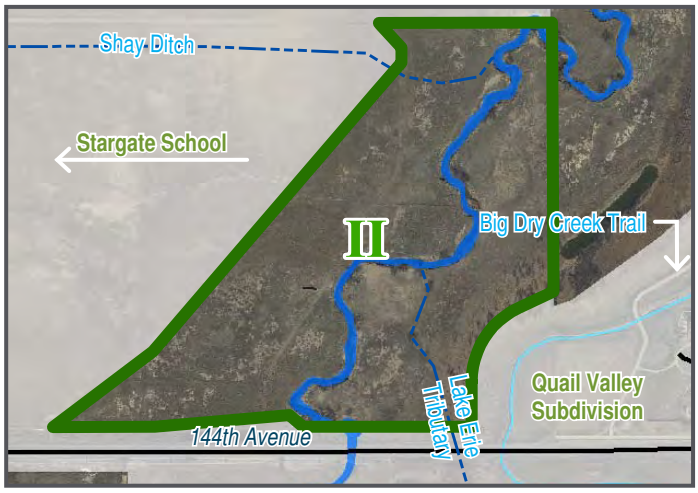
Photograph of Parcel I (owned by Adams County)



Parcel I (owned by Adams County)

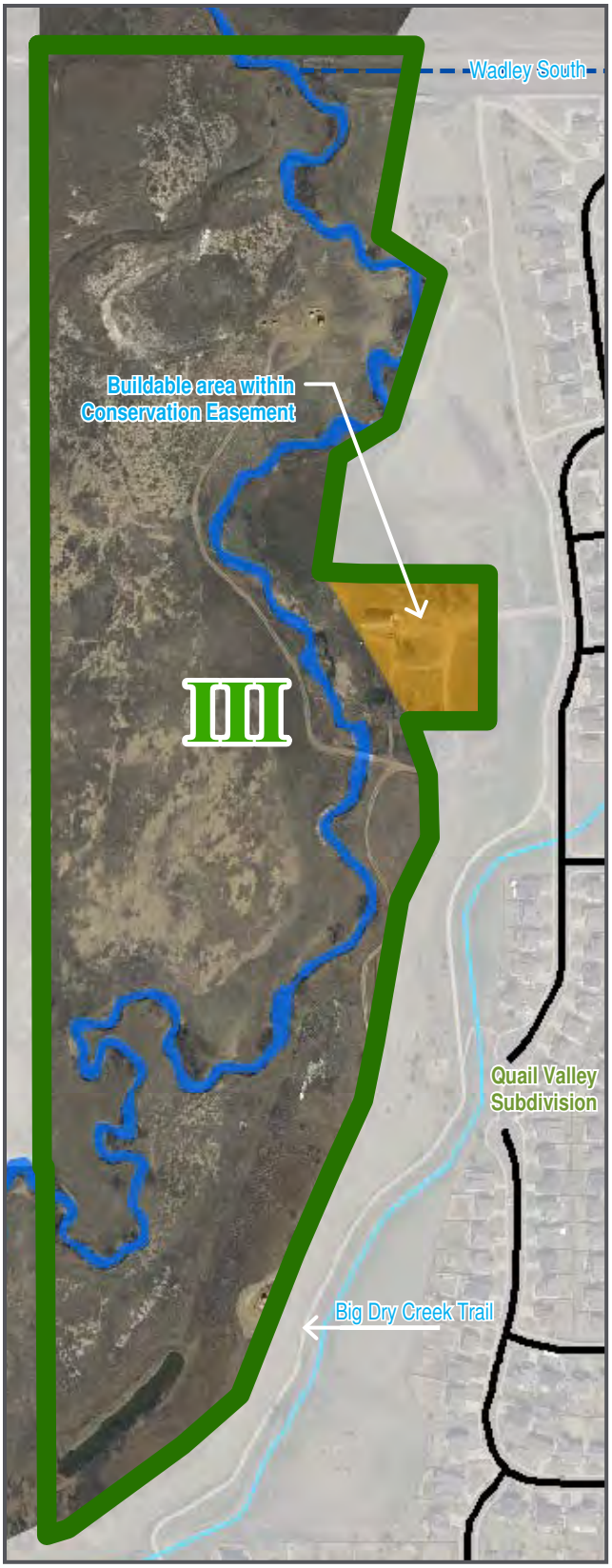
The following parcels (Parcels II-VIII) will be owned by Thornton.

Parcel II (north of 144th Avenue) is comprised of 24 acres that was undergoing final paperwork to be deeded to Thornton at the time this Master Plan was written. The Stargate School purchased a large parcel where they have built their school buildings. The eastern portion of their property is within the floodplain and they agreed to deed the floodplain portion of their property to the city of Thornton.



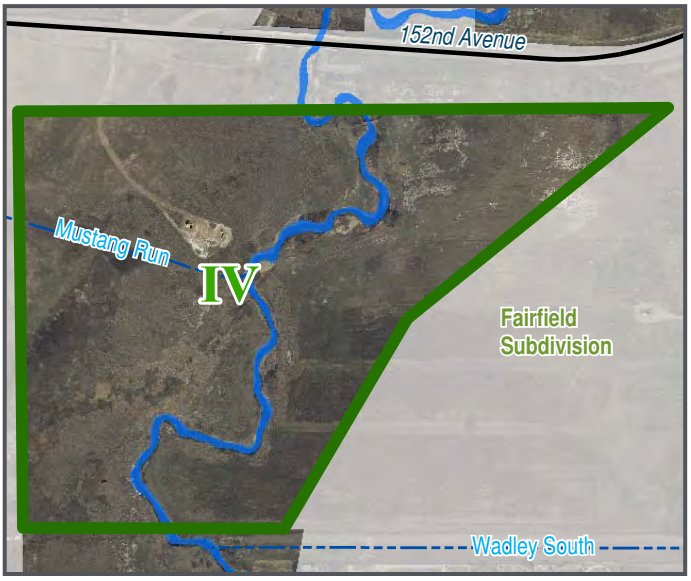
Parcel II (owned by city of Thornton)

Photograph of Parcel II (owned by city of Thornton)



Parcel III (owned by city of Thornton)

Parcel III (north of 144th Avenue, west of Quail Valley Subdivision) is comprised of 59.59 acres and was acquired by the city of Thornton in 2011. This property is the largest of the Big Dry Creek parcels and includes the historic Big Dry Creek Barn built in 1923. The conservation easement defines a 2.3 acre building area (surrounding the barn) which Thornton is allowed to construct new structures and parking areas within. This site contains two well sites and access roads.

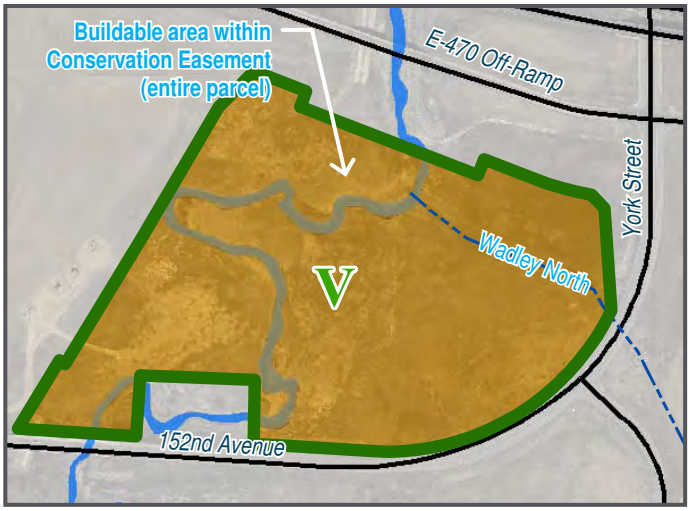


Parcel IV (owned by city of Thornton)

Parcel IV (directly north of Parcel III and south of 152nd Avenue) is comprised of 41 acres and was acquired by Thornton in 2006 with no conservation easement. Currently, there is one well structure and an access road on the property and the lessee retained ingress and egress rights to the well site.

Photograph of Parcel IV

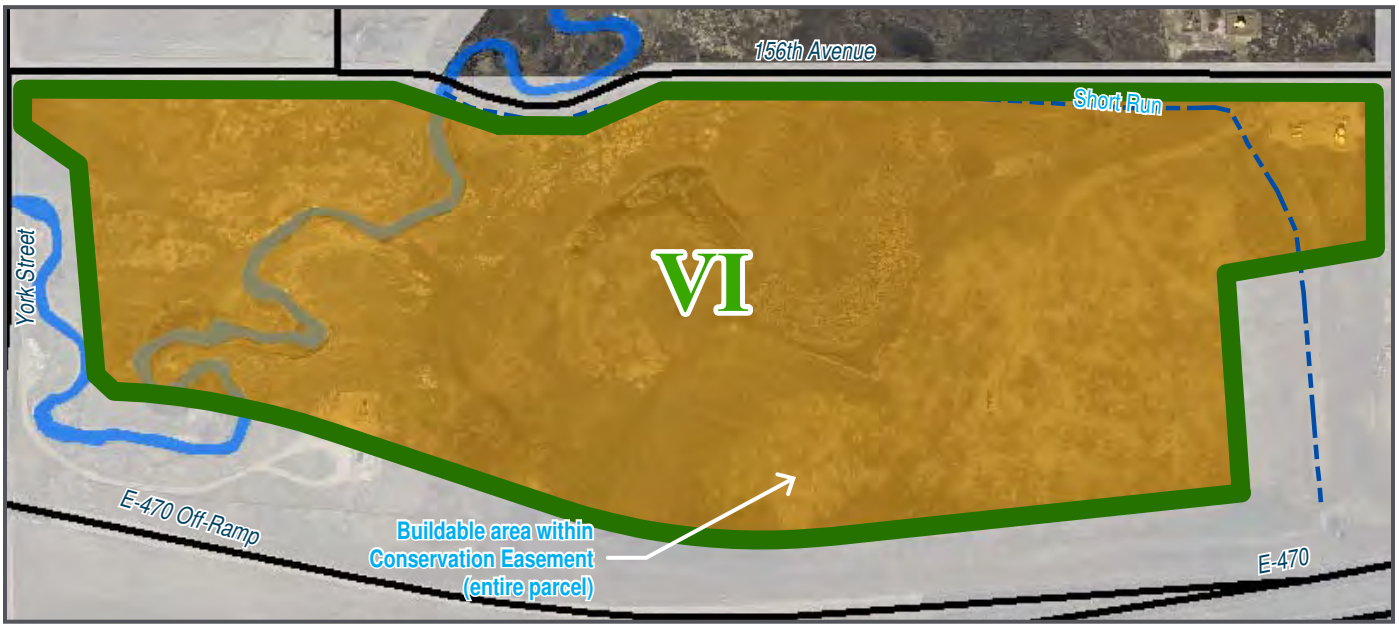
Parcel V (between 152nd Avenue and E-470) is comprised of 25.54 acres and was acquired by the city of Thornton in 2009. The conservation easement allows a future lighted or unlighted parking lot and trailhead that shall not exceed 3% of the total area of the property. The property is subject to a Directional Drilling Agreement, although the lessee provided an estoppal certificate certifying that it would not conduct additional surface drilling. The parcel is surrounded by roads on all but the west side, providing good vehicular access and visibility. The intersection of York Street and 152nd Avenue has been identified as the most likely place to enter the site with future vehicular traffic.



Parcel V (owned by city of Thornton)

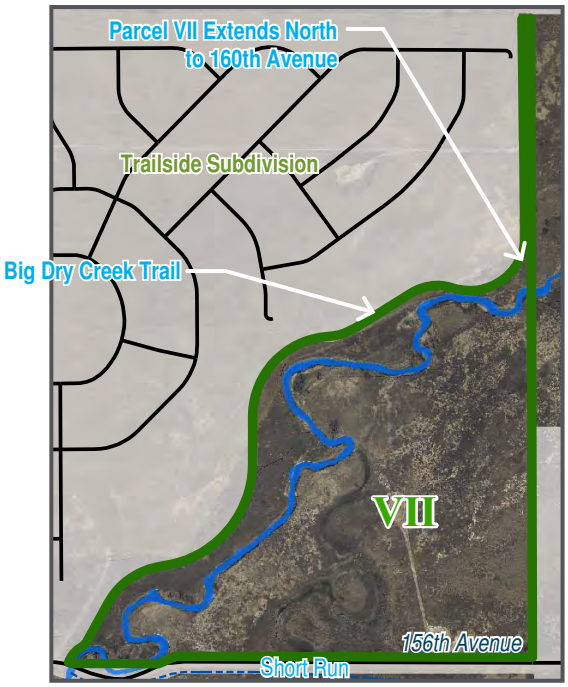
Aerial photograph of Parcel V looking north with E-470 in the background

Parcel VI (east of York Street and south of 156th Avenue) is comprised of 44.08 acres and was acquired by Thornton in 2011. The conservation easement allows for the construction and maintenance of a future lighted parking lot and trailhead ***'sized consistently with the uses expressed'*** in the conservation easement. Currently, there is one and one half well structures (second well site falls partially on Thornton property and partially in E-470 right-of-way) and an access road on the property.



Parcel VI (owned by city of Thornton)

Parcel VII (east of York Street and north of 156th Avenue) is actually three separate parcels totaling 134 acres that were deeded by Trailside Subdivision to the city of Thornton in 2014. This site does not contain any conservation easement restrictions but has a 25' sanitary sewer easement on a portion of the parcel. Currently, this site does contain a well site and access drive. The Big Dry Creek Trail separates the parcel from Trailside Subdivision.



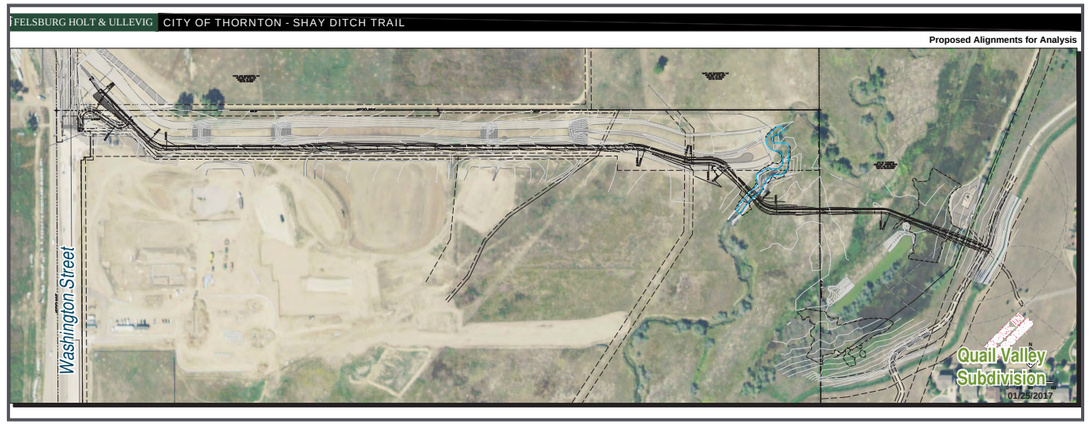
Parcel VII (owned by city of Thornton)

Parcel VIII (owned by city of Thornton)

Parcel VIII In 2016, the city acquired Parcel VIII, a 16 acre parcel that became the final addition to the current Big Dry Creek open space. This parcel has a 40' utility easement and a 30' sanitary sewer easement running through the northwest corner. No conservation easement is in place on this parcel.

Shay Ditch Trail

During the master planning process, Thornton was involved in discussions with the Stargate School about building a trail through Parcel II of the Big Dry Creek corridor. This trail would connect Washington Street to the existing Big Dry Creek trail that runs along the western edge of the Quail Valley Subdivision. The trail is planned to be constructed in late 2017. The project will include one crossing of Big Dry Creek.



Shay Ditch Trail layout through Parcel II (plan courtesy of city of Thornton and Felsburg Holt & Ullevig)

Adjacent Neighborhoods and Plans

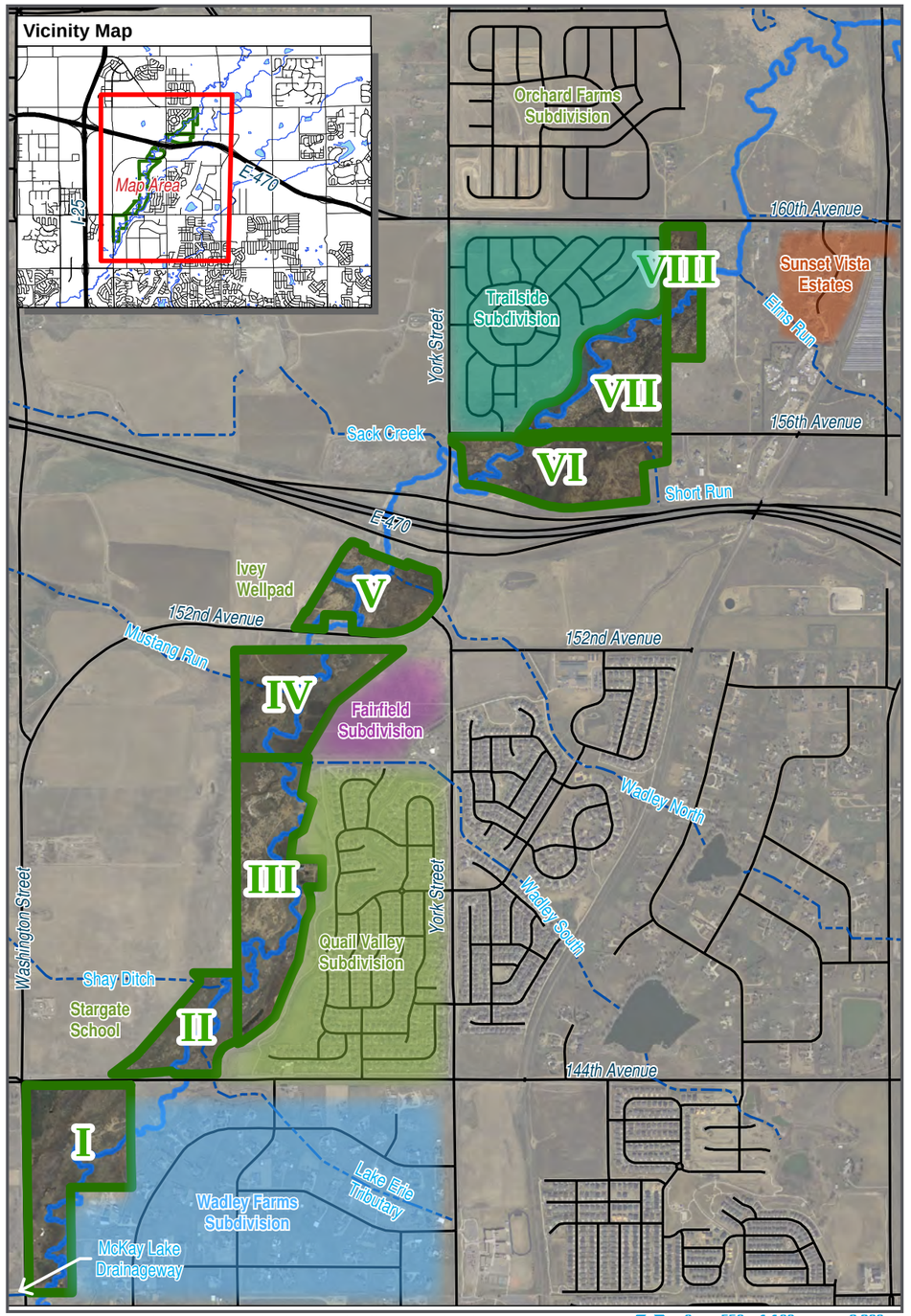
There are a number of existing and future neighborhoods along the Big Dry Creek corridor through Thornton. Directly to the east of Parcel I lies **Wadley Farms Subdivision**, an Adams County neighborhood with larger lots and a more rural character.

The **Quail Valley Subdivision** sits east of Parcels II and III and is a more suburban area with smaller lot sizes, paved roads and sidewalks. Quail Valley Subdivision owns a significant buffer between the Big Dry Creek open space and the neighborhood which is used for open space natural areas. Public access to the Big Dry Creek Trail is provided via a public trail easement through the buffer.

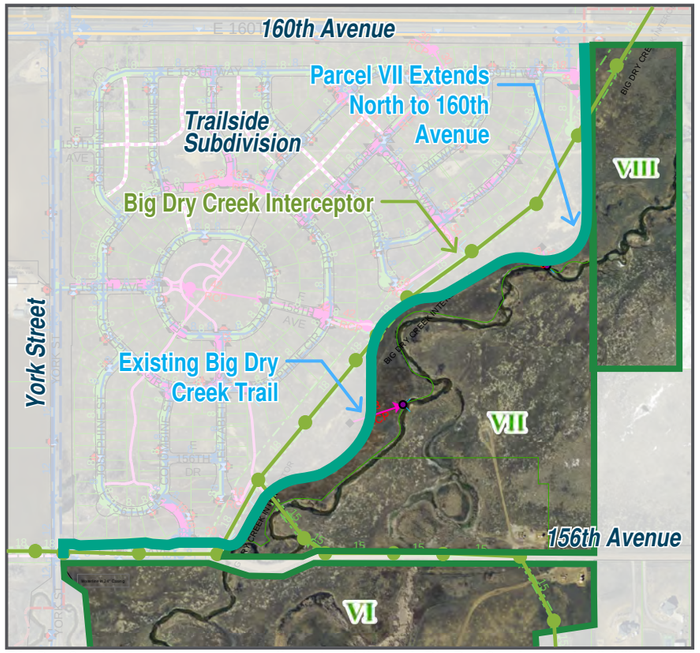
East of Parcel IV is a new residential development that is currently under construction at the time of this Master Plan. The **Fairfield Subdivision** is an approved 107 lot residential neighborhood that includes approximately 9.4 acres of park open space, mostly situated along the property line shared with Big Dry Creek Parcel IV. The subdivision's developer is required to build a portion of the Big Dry Creek Trail that will connect to the existing Big Dry Creek Trail in the Quail Valley Subdivision and connect to parcel IV.

Northwest of Parcels VII and VIII is the **Trailside Subdivision**, which is similar in character to Quail Valley Subdivision. This subdivision is also installing numerous trail connections to the Big Dry Creek open space in Parcel VII. At the time of this Master Plan, the subdivision is mostly built on the southern end near East 156th Avenue and the northern portion near Highway 7 is under construction. As part of this development, the developer is required to improve the 156th Avenue bridge over Big Dry Creek. Toolbox strategies found in this Master Plan have been provided to the developer.

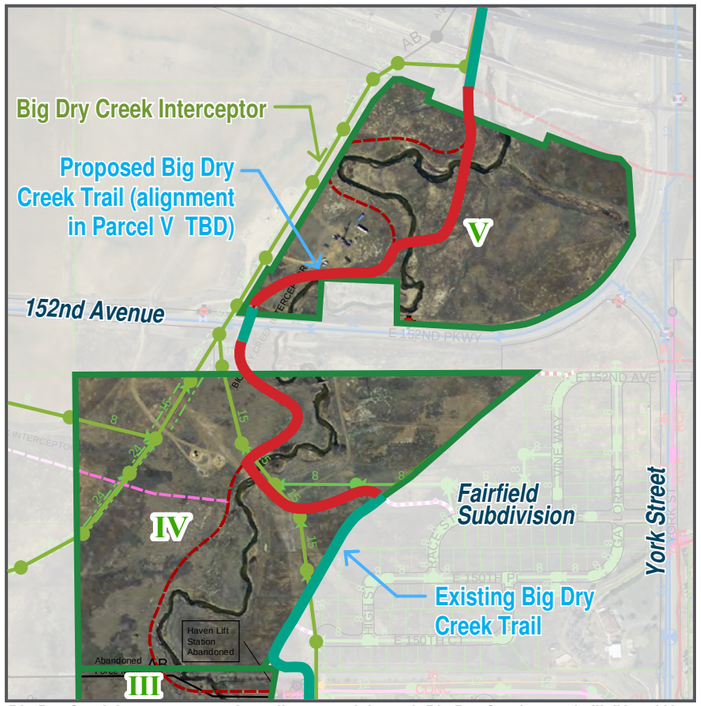
The **Sunset Vista Estates Neighborhood** rests on the southwest corner of 160th Avenue and Colorado Boulevard in unincorporated Adams County. The HOA owns an open space parcel that is just over 6 acres. Residents have expressed an interest in creating connections from this property to the Big Dry Creek open space (Parcel VIII). There are two privately owned parcels between Parcel VIII and the HOA parcel, therefore the trail would either need to run along the south side of 160th Avenue, or Thornton would have to acquire easements or land through the two privately owned parcels. Big Dry Creek does run through both of these parcels.



Map showing the eight study parcels for the Big Dry Creek Master Plan and nearby neighborhoods/developments



Big Dry Creek Interceptor running adjacent and through Big Dry Creek parcels VI, VII and VIII



Big Dry Creek Interceptor running adjacent and through Big Dry Creek parcels III, IV and V

Utility Plans

There are a number of utilities that exist near Big Dry Creek, although the most prominent is the city of Thornton's Big Dry Creek sanitary sewer interceptor line that generally runs parallel to Big Dry Creek. This sewer does cross under Big Dry Creek in certain locations and care needs to be taken that no future improvements to the creek or open space areas negatively impact the sewer line. It is also city of Thornton policy to provide access to manholes. As such, care should be taken when determining the final alignment for the Big Dry Creek Trail, as well as secondary trails. There is also a lift station (pump) that is being expanded near Big Dry Creek, although it is north of Highway 7 and is outside of the project limits of the Master Plan.

Thorncreek Golf Course - Big Dry Creek Stabilization

Currently, Thornton and the Urban Drainage and Flood Control District (UDFCD) are leading a channel improvement project for a portion of Big Dry Creek through the Thorncreek Golf Course, located southeast of the intersection of I-25 and East 136th Avenue, upstream of the Master Plan project area. As part of this project, approximately 2,200 linear feet of Big Dry Creek is being restored using various bank and grade stabilization approaches. The proposed channel generally consists of a 7 foot deep trapezoidal channel with an 18 foot (+) bottom width and 3H:1V side slopes.

The 30% design level construction drawings indicate the following channel improvements are being considered for this reach:

- A design channel slope of approximately 0.001 ft/ft.
- Installation of a grade control drop structure located at the downstream end of the project.
- Installation of various bank stabilization measures including bank shaping and planting, geotextile stabilization seeded with riparian plant communities, and buried riprap toe stabilization extending 2 to 4 feet up the bank.
- Portions of the channel will also include a single or stacked boulder wall to provide a stabilized low flow channel.
- As part of this project the existing channel bottom will be filled and raised between 2 and 5 feet.

The channel improvements proposed at Thorncreek Golf Course generally agree with the recommendations provided in this Master Plan. The general concept of raising the incised channel to reconnect with the floodplain is being implemented as a part of the Thorncreek Golf Course Project. Zero-rise floodplain/floodway requirements may limit the extent that this can be accomplished in some areas, especially when proximate to structures.

Big Dry Creek Major Drainageway Plan Conceptual Design Report

The 2012 "Big Dry Creek Major Drainageway Plan Conceptual Design" report[1] provides a summary of recommendations for minimizing stormwater and flood-related damages to drainageways, public infrastructure, and private property from headwaters of Big Dry Creek (Standley Lake) to the Weld County, CO line. For the purposes of this Big Dry Creek Recreation and Floodplain Restoration Master Plan, this document was primarily used to help target and categorize channel reaches into low, medium, and high priority channel restoration reaches. This documentation was also reviewed to identify specific channel crossing, or outfall improvement projects that should be considered as part of this Master Plan.

1 WWE, 2012. Big Dry Creek Major Drainageway Plan Conceptual Design Report. Prepared for Urban Drainage and Flood Control District, Denver CO. Prepared by: Wright Water Engineers, Inc. Denver, CO. Available: http://udfcd.org/

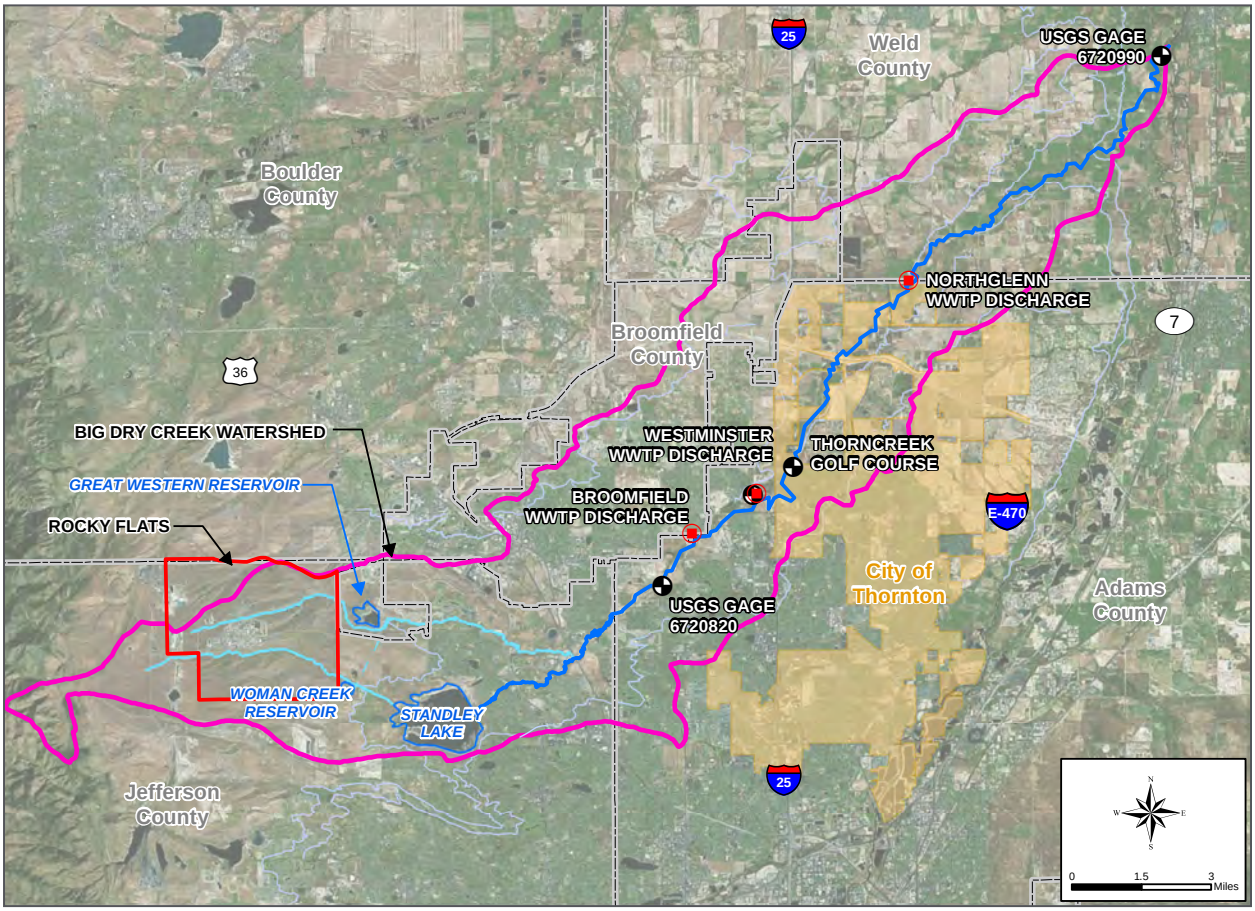
Flood Hazard Area Delineation (FHAD) – Big Dry Creek

The 2012 "Flood Hazard Area Delineation Big Dry Creek" report[1] provides the results of a hydrologic and hydraulic update to the Big Dry Creek watershed from headwaters of Big Dry Creek (Standley Lake) to the Weld County, CO line. This document was developed using a compilation of existing data, detailed field work, and hydrologic and hydraulic modeling which consolidated and updated multiple drainage master planning efforts from the previous 30 years for the Big Dry Creek watershed. For the purposes of this Big Dry Creek Recreation and Floodplain Restoration Master Plan, the hydraulic model, developed as part of the FHAD, was used to evaluate fluctuating baseflow depths to help determine minimum bank stabilization heights within this Master Plan's project area.

Big Dry Creek Annual Water Quality Summary for 2015

The "Big Dry Creek Annual Water Quality for 2015" report, prepared by Wright Water Engineers, Inc. in 2015 for the Big Dry Creek Watershed Association, is a summary of findings from the 2015 monitoring program focusing on the comparison of annual data to stream standards, biological monitoring, annual flow conditions, and targeted discussions regarding E. coli, metals, and nutrients in Big Dry Creek. The water quality information, found in Chapter 3 (Existing Conditions), is primarily based on the analysis provided in this document. The water quality report also provides a detailed summary of the measured hydrologic influences on Big Dry Creek (wastewater treatment plant discharge and water rights diversions) which are considered in many of the hydrologic calculations performed in support of this Master Plan.

1 WWE, 2012. Flood Hazard Area Delineation Big Dry Creek. Prepared for Urban Drainage and Flood Control District, Denver CO. Prepared by: Wright Water Engineers, Inc. Denver, CO. Available: http://udfcd.org/



Big Dry Creek Watershed Map (map credit: Big Dry Creek Watershed Association)

Hydrologic and Hydraulic History of Big Dry Creek

Starting at Standley Lake in Jefferson County, Big Dry Creek is approximately 33 miles long flowing north and east through portions of Adams and Broomfield Counties, and eventually into Weld County until its confluence with the South Platte River. Historically, Big Dry Creek was an ephemeral channel (only conveying water during and for a short duration after rainfall events) which conveyed surface runoff and shallow groundwater flow from its watershed to the South Platte River. Prior to the construction of Standley Lake between 1907 and 1912, Big Dry Creek was a naturally meandering stream originating in the foothills near the mouth of Coal Creek Canyon and terminating at the confluence with the South Platte River near Fort Lupton. Originally, Standley Lake was constructed on Big Dry Creek as part of the Farmers Reservoir and Irrigation Company (FRICO) water storage system for agricultural users.

The Big Dry Creek Watershed Association (BDCWA) was founded in 1997 by partners including the city and county of Broomfield, city of Northglenn, city of Westminster and the U.S. Department of Energy Rocky Flats Environmental Technology Site (Rocky Flats), with support from the U.S. Environmental Protection Agency (EPA). The initial focus of this association was monitoring treated wastewater discharges into the stream from municipal wastewater treatment facilities. In 2004 the group formalized the association as a nonprofit corporation and added Adams County and Weld County to the Association's Board of Directors.

"The mission of the Big Dry Creek Watershed Association is to develop a sound scientific understanding of water quality, flow, aquatic life, and habitat conditions in the Big Dry Creek watershed for the purposes of: (1) environmentally responsible decision-making with regard to land and stream uses and (2) identifying measures to improve and protect stream conditions. The goals of the Watershed Association include three broad categories: (1) public education and involvement, (2) monitoring and study, and (3) protecting, preserving and restoring water quality, aquatic life, and habitat" (BDCWA, 2017).

Modified Hydrology & Channel Evolution of Big Dry Creek

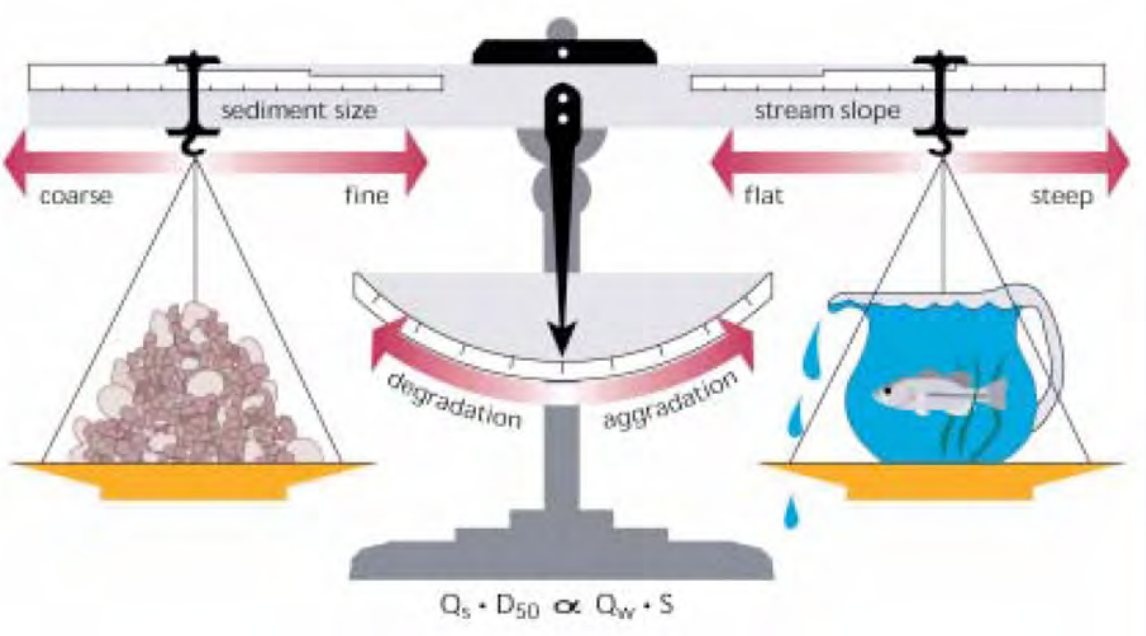
Similar to other rivers and streams along Colorado's Front Range, Big Dry Creek is being significantly impacted by alteration to the flow regime from land use change, wastewater treatment plant discharges, and irrigation return flows released from Standley Lake. In response to this alteration, the channel has undergone a series of changes. First, there has been widespread incision, or channel bed erosion, which has resulted in a deeper, more confined channel. However, incision has slowed or halted in many areas due to a number of artificial or natural grade controls which are relatively resistant to further erosion. These include unintentional grade controls such as bridges and culverts as well as structures designed specifically to prevent further erosion. Additionally, in some places (including the project area) the channel has incised through the alluvial soil material and has encountered a naturally occurring clay layer which is more resistant to erosion than the sand/fine gravel bed material. As the bed has become more erosion resistant, the channel has begun to adjust primarily through bank erosion and lateral migration.

As a result of the hydrologic changes experienced by Big Dry Creek, including maintaining a steady baseflow of water throughout the year from irrigation releases from Standley Lake as well as wastewater treatment plant effluent, a channel evolution has occurred as the drainageway seeks a new quasi-equilibrium to stabilize itself. The time scale for this adjustment is unknown due to a number of factors. First, continued urbanization in the watershed may further modify the hydrology which would initiate further channel changes. Second, increases or decreases in the upstream sediment supply (either from channel erosion or adjacent surface runoff erosion) could either hasten or delay the return of the channel to a quasi-equilibrium state.

> The best outcome for a stream to be considered generally stable is a quasi-equilibrium state. A stream in quasi-equilibrium tends to fluctuate from one side of the theoretical true equilibrium point to the other, due to the dynamic nature of flows and sediment in a stream system.

The graphic below provides a visual depiction of Lane's Stable Channel concept. This graphic shows a balancing scale with the primary factors affecting a channels quasi-equilibrium:

1. Sediment Load
2. Water Discharge
3. Sediment Size (or channel bed material size)
4. Stream Slope



Lane's Stable Channel Concept (USFISRWG, 1998 and Lane, 1955)

This graphic shows a balanced scale, indicating that the channel is in a quasi-equilibrium. However, as these factors change, the scale can be used to evaluate what will happen to the streams stability.

For example, as a result of the hydrologic changes to Big Dry Creek, the water discharge (volume and average rate) has increased or gotten "heavier" while the other factors remain more or less constant. This tips the scale towards degradation. Because the water discharge side of the scale has increased, to shift conditions back toward equilibrium, the sediment load transported also must increase. The increased sediment load comes from erosion of the channel bed and banks, and this leads to the eroding, incised channel that Big Dry Creek is today.

As a result of this incision, high flows are now contained within the channel rather than accessing the floodplain. This has increased the erosive power of these flows and resulted in excess erosion of the channel banks. Furthermore, as the banks become steeper and taller as a result of this erosion, they become unstable and collapse contributing large blocks of soil into the channel. This bank erosion has resulted in channel widening and large channel meander bends. This continued erosion contributes significant loads of sediment to the stream. Much of this sediment is being deposited in the lower reaches of Big Dry Creek, near its confluence with the South Platte. However, there is no evidence of significant deposition in the Master Plan area, suggesting that erosion will continue until the channel has "balanced the scales."

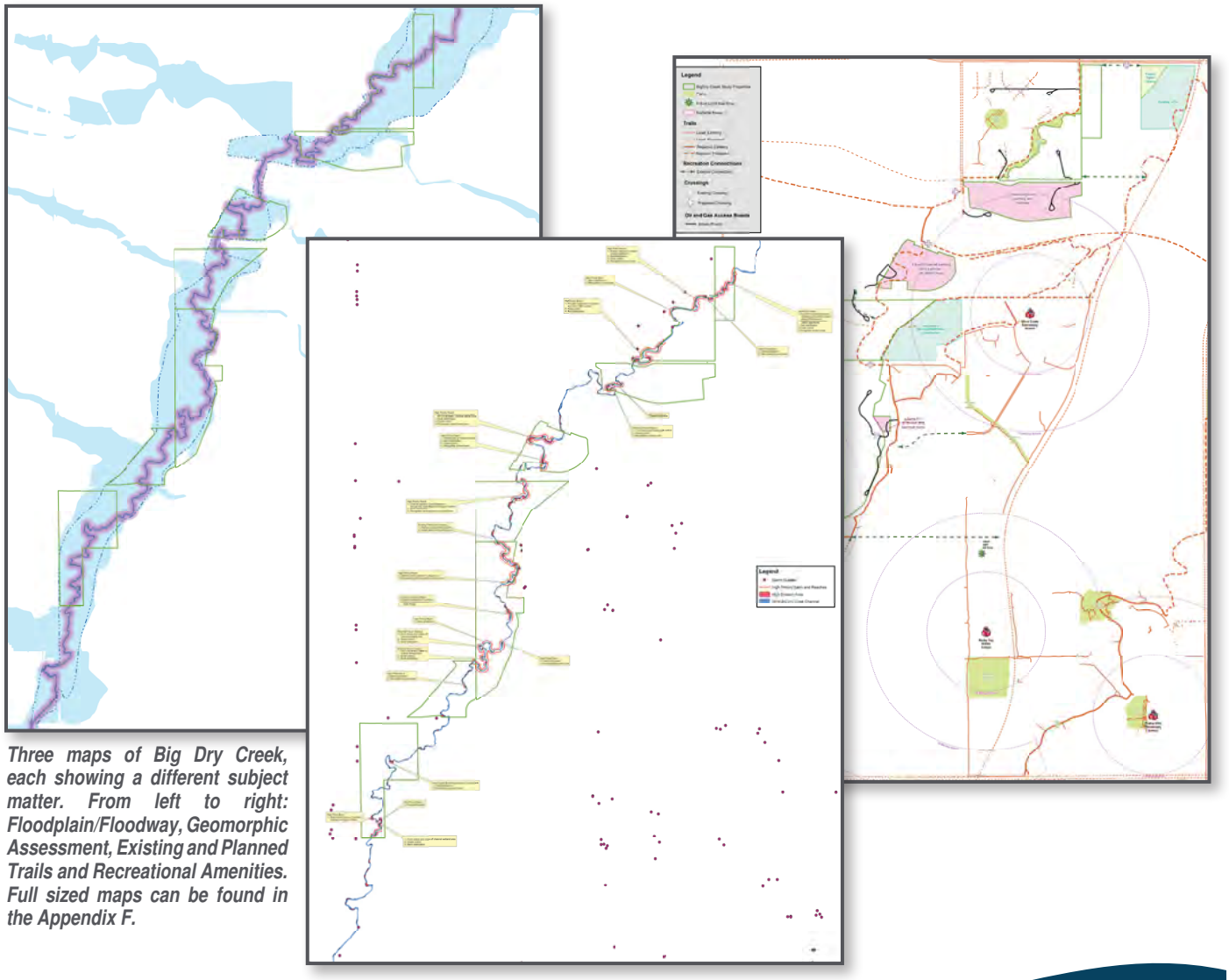
One of the primary goals of this Big Dry Creek Recreation and Floodplain Restoration Master Plan is to provide recommended approaches, and design information to move Big Dry Creek into a quasi-equilibrium state by either reconnecting it with its historic floodplain or regrading channel cross sections to establish an internal terraced floodplain with stable stream banks.

Chapter 3 - Existing Conditions

Chapter Summary and Master Plan Organization

The Big Dry Creek Recreation and Floodplain Restoration Master Plan has been organized to present a cohesive picture of the entire 6 mile project area while providing recommendations to address specific issues relating to hydrologic and hydraulic conditions, geomorphic characteristics, recreational amenities, environmental conditions and oil and gas exploration. As these issues are interconnected and function as part of a larger system that cannot be properly assessed on an individual parcel basis, the Master Plan is organized primarily by subject matter (hydraulics, recreation, environmental, etc.) and secondarily by parcel. In this way, each specific issue is discussed both in terms of the overall corridor and the individual parcels. In addition to providing subject specific information, both Chapter 3 (Existing Conditions) and Chapter 4 (Plan Recommendations) provide a matrix that summarizes the main points of all of the categories for all of the parcels on a single page. The Existing Conditions by Parcel Matrix can be seen on the facing page.

It is the intention that by organizing the Master Plan by subject matter first, an emphasis will be placed on planning and designing projects from a corridor-wide perspective rather than a localized parcel-wide perspective. Any changes or impacts to Big Dry Creek are sure to cause upstream and downstream effects and this approach will limit these negative effects. In addition to considering the entire corridor, future projects must also take into account how the varying subject matters will impact each other. For example, a trail project could very likely have impacts on the hydraulic, environmental, water quality and/or geomorphic conditions within the corridor. It is imperative for the overall health of the corridor that the city of Thornton, Adams County, private developers, oil/gas operators and public users of the open spaces recognize the importance of interconnected corridor-wide planning.

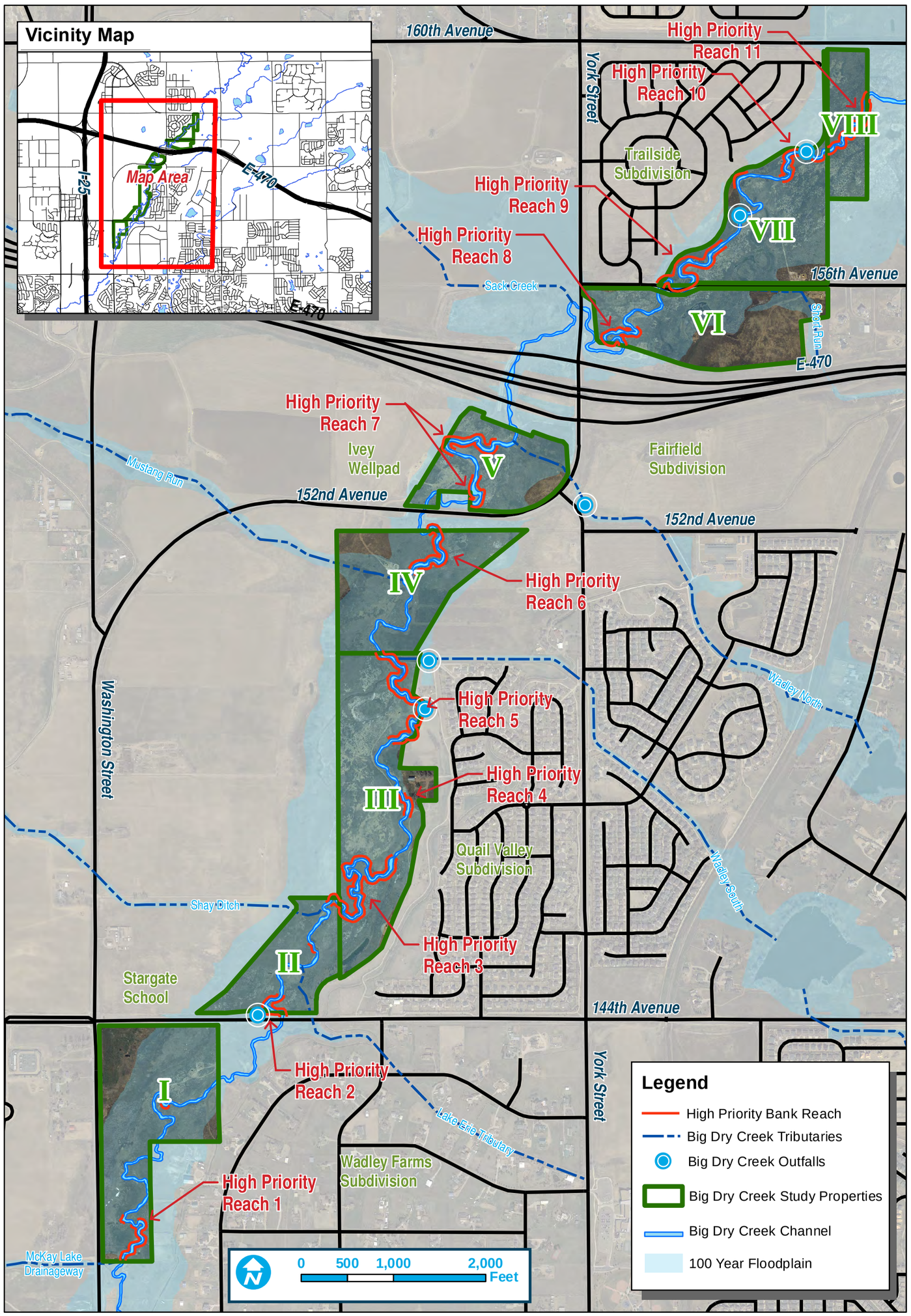


Three maps of Big Dry Creek, each showing a different subject matter. From left to right: Floodplain/Floodway, Geomorphic Assessment, Existing and Planned Trails and Recreational Amenities. Full sized maps can be found in the Appendix F.

Existing Conditions by Parcel Matrix

	Geomorphic Conditions	Oil and Gas	Environmental Conditions	Recreational Amenities
Parcel I **Adams County** **48.79 Acres**	> **Bed Material:** Sand > **Cut Banks:** Mostly 5-10' tall, up to 15' tall > **Tributaries:** McKay Lake Drainageway > **Issues:** Bank erosion, disconnected floodplain	> Existing oil/gas well and access road on northeastern portion of the parcel.	> Grassy uplands, riparian vegetation along Big Dry Creek. > 1/3 of parcel is wetlands, mostly in southern portion of the parcel. > Prairie dogs are overpopulated. > Some invasive plants in northeast portion of parcel.	> No existing trails or access points.
Parcel II **Thornton** **24 Acres**	> **Bed Material:** Sand > **Cut Banks:** Mostly 5-6' tall, up to 10' tall > **Tributaries:** Shay Ditch, Lake Erie Tributary > **Issues:** Bank erosion, disconnected floodplain, heavy meanders that threaten infrastructure/property boundaries	> None	> Grassy uplands, patchy weedy and bare areas, some riparian vegetation along banks. > Large linear wetland along the east side of the parcel. > Prairie dog habitat on the western portion of the parcel.	> Shay Ditch Trail is currently being designed to go through this parcel.
Parcel III **Thornton** **59.29 Acres**	> **Bed Material:** Sand > **Cut Banks:** Mostly 4-5' tall, up to 10' tall > **Tributaries:** Wadley South Drainageway > **Issues:** Bank erosion, disconnected floodplain, heavy meanders that threaten infrastructure/property boundaries, weakening bridge abutments, blown out crossing/culverts	> Two existing oil/gas wells and access roads; one in the southeast portion of the parcel, one in the northeast portion. > Existing oil/gas access bridge in need of the repair near the Big Dry Creek Barn.	> Parcel includes some great examples of healthy diverse ecosystems in upland, riparian and wetland areas. > Parcel also contains degraded upland and riparian areas. > Upland degraded areas are overpopulated by prairie dogs. > Invasive plants in southern portion of the parcel and slightly northwest of the Big Dry Creek Barn.	> Existing oil/gas access roads and bridges are widely used for walking and dog walking. > The Big Dry Creek Trail is just to the east of this parcel. > Big Dry Creek Barn is in this parcel.
Parcel IV **Thornton** **41 Acres**	> **Bed Material:** Sand > **Cut Banks:** Mostly 5-6' tall, up to 10' tall > **Tributaries:** Mustang Run > **Issues:** Bank erosion, disconnected floodplain, blown out crossing/culverts	> Existing oil/gas well with access road from 152nd Avenue. > Well is relatively close to Big Dry Creek channel.	> Generally well vegetated uplands with appropriate prairie dog populations. > Parcel includes some stretches of riparian vegetation along Big Dry Creek. > Many Russian olive trees in this parcel.	> The Fairfield Subdivision has installed part of the Big Dry Creek Trail along the eastern property line of this parcel. > There is an existing pedestrian bridge that is not in safe or usable condition near the northern edge of the parcel. > Trail has been paved under 152nd Avenue.
Parcel V **Thornton** **25.54 Acres**	> **Bed Material:** Sand > **Cut Banks:** Mostly 5-6' tall, up to 10' tall > **Tributaries:** Wadley North Drainageway > **Issues:** Bank erosion, disconnected floodplain, heavy meanders that threaten infrastructure/property boundaries	> Existing oil/gas access road crosses the property, although the wells are on the Adams County property to the west. > The Ivey Wellpad is planned to be built on the Adams County property to the west.	> Uplands are heavily browsed by prairie dogs and degraded. > Portions of Big Dry Creek have excellent riparian shrubs, grasses and other herbaceous plant growth. > Russian olives and other invasive species are present.	> Trail has been paved both under 152nd Avenue and under E-470.
Parcel VI **Thornton** **44.08 Acres**	> **Bed Material:** Sand > **Cut Banks:** Mostly 3-4' tall, up to 10' tall > **Tributaries:** Short Run Outfall > **Issues:** Bank erosion, disconnected floodplain, heavy meanders that threaten infrastructure/property boundaries	> Existing oil/gas well in a portion of the southwestern portion of the parcel. > Access road is being eroded by Big Dry Creek on E-470 ROW. > Existing oil/gas well and access road in the northeastern portion of the parcel, away from Big Dry Creek.	> Marginal upland areas. > Excellent oxbow wetland areas. > Some Russian olives and invasive species.	> No existing trails or access points.
Parcel VII **Thornton** **34 Acres**	> **Bed Material:** Sand > **Cut Banks:** Mostly 5-6' tall, up to 10' tall > **Tributaries:** None > **Issues:** Bank erosion, disconnected floodplain, heavy meanders that threaten infrastructure/property boundaries	> Existing oil/gas well and access road in the southeastern portion of the parcel, generally away from Big Dry Creek.	> Uplands have many weeds with invasive plants along northwestern border of parcel. > Creek banks have healthy stretches of riparian vegetation. > Well established oxbow wetlands in the southern portion of the parcel.	> The Trailside Subdivision has installed a portion of the Big Dry Creek Trail along the western side of the parcel.
Parcel VIII **Thornton** **16 Acres**	> **Bed Material:** Sand > **Cut Banks:** Mostly 4-5' tall, up to 6' tall > **Tributaries:** None > **Issues:** Bank erosion, disconnected floodplain, heavy entrenchment	> None	> Moderately established upland with active prairie dog colonies. > Some riparian areas have good terracing in terms of vegetation. > Some small wetlands exist along the channel.	> The Trailside Subdivision has installed a portion of the Big Dry Creek Trail along the western side of the parcel.

Big Dry Creek Existing Hydrologic and Hydraulic Conditions Map



Hydrologic and Hydraulic Conditions

During precipitation events, Big Dry Creek conveys elevated stormflows beyond what it historically received as precipitation because of the increased runoff from the urbanizing watershed. Due to changes in hydraulic regime associated with increased runoff, wastewater return flows and irrigation releases from Standley Lake, bank erosion is a common problem along many portions of Big Dry Creek.

The following language from the UDFCD 2012 FHAD[1] describes the erosion process currently occurring in Big Dry Creek:

> ***Bank erosion is a common problem in the Big Dry Creek watershed as a result of naturally occurring erosion-prone soils and stream characteristics. The "flashy," variable flows that occur in the watershed in response to storm events cause increased bank erosion by preventing the stream from reaching a state of equilibrium. Banks dry out at low flows, while at high flows water moves into the pore spaces in the soil, reducing the pore space tension, and the soil becomes less cohesive and erosion prone[2]. In order to balance the sediment transport capacity of the high flow, sediment is removed from the banks of the stream. In reality, Big Dry Creek is never really dry due to wastewater return flows (post-treatment water returned directly to the stream from wastewater treatment facilities) and irrigation releases from reservoirs to the creek. Variability of these base flows, which cause the water surface in the creek to rise and fall, contribute to bank erosion due to water surface fluctuations and the fact that much of the water that comprises baseflows is "sediment hungry" since the releases/discharges to the creek typically have very low sediment levels. As sediment is removed from the bank, surface erosion, undercutting and sloughing (streambank erosion) can occur. As the flow recedes, the banks dry again, and the cycle repeats itself.***

Vertical cut bank on Big Dry Creek

Rubble and cut banks on Big Dry Creek

The 2012 FHAD and associated Major Drainageway Plan (MDP)[3] used revised hydrologic and hydraulic models to develop updated floodplain and floodway delineations for Big Dry Creek. It also incorporated the effects of revised development patterns in the watershed including existing and future impervious areas and effects of regional stormwater detention practices.

The reach of Big Dry Creek downstream of the Broomfield wastewater treatment plant (WWTP) and as it travels through the master planning area, can be characterized as a plains stream type and includes shifting channels, eroding banks, overhanging grasses with few trees, and primarily sand and silt in the streambed.

1 WWE, 2012. Flood Hazard Area Delineation Big Dry Creek. Prepared for Urban Drainage and Flood Control District, Denver CO. Prepared by: Wright Water Engineers, Inc. Denver, CO. Available: http://udfcd.org/
2 Bledsoe, 2001; full citation in FHAD (footnote 1, this page)
3 WWE, 2012. Big Dry Creek Major Drainageway Plan Conceptual Design Report. Prepared for Urban Drainage and Flood Control District, Denver CO. Prepared by: Wright Water Engineers, Inc. Denver, CO. Available: http://udfcd.org/

Geomorphic Characteristics of Big Dry Creek

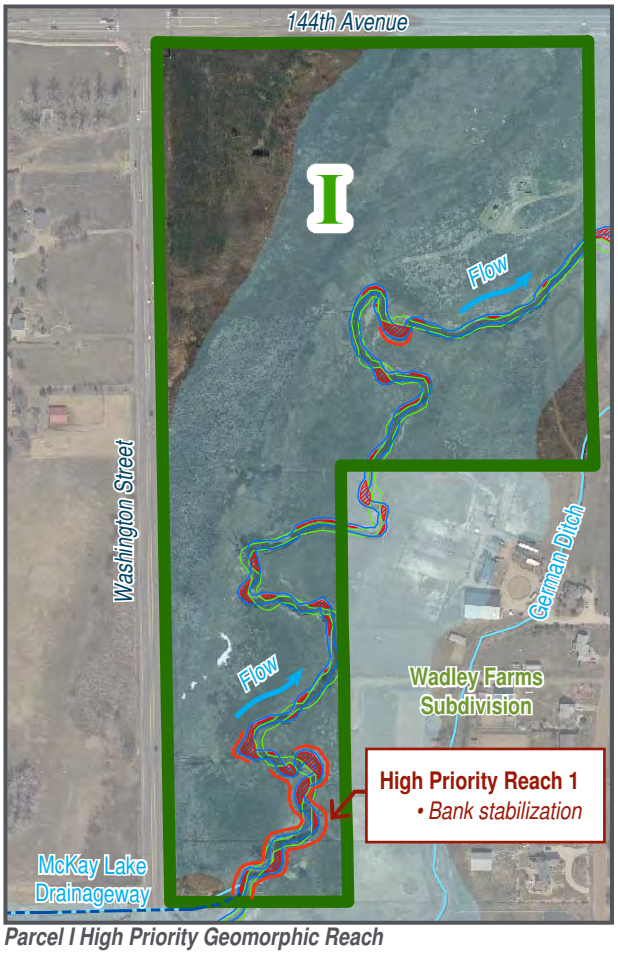
This Big Dry Creek Recreation and Floodplain Restoration Master Plan focuses on eight specific Big Dry Creek open space parcels owned by Adams County and the city of Thornton. "Appendix G: Recommended Channel Cross Sections by Parcel" provides a series of figures which illustrate typical existing channel cross-sections for the specific channel reach of Big Dry Creek associated with each project parcel. A brief description of the channel reach by parcel is provided on the following pages.

Parcel I Geomorphology: The channel within this reach is located on Adams County open space, and runs for 4,621 linear feet. The 48.79 acres of Parcel I include a highly meandering channel with a sandy bottom and brush and trees on the channel banks. Cut banks range from 5 to 15 feet high, with the majority of the channel banks being in the 5 to 10 foot range.

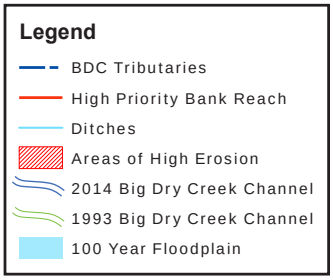
One tributary, the McKay Lake Drainageway, flows into Big Dry Creek immediately upstream of the southern parcel boundary. The German Ditch diverts water from the creek immediately upstream of the southern parcel boundary.

Many of the areas downstream of 136th Avenue have existing agricultural land uses that may involve livestock with access to the creek. Livestock access to the creek is contrary to the goals of reducing erosion and water quality objectives because livestock cause bank erosion when they access the stream. Livestock is also a potential source of E. coli. Limiting livestock access to the creek should be considered within the open space parcel.

High Priority Reach 1 begins immediately downstream of the southern parcel boundary where there is significant mass wasting, or sloughing, of channel banks. The channel has migrated laterally to a significant degree and is at risk of forming an oxbow in at least one location. If the channel forms this oxbow there is a high potential that a headcut will form, resulting in further incision and bank instability upstream of the parcel. There is also a highly active erosional bank in the center of the parcel. Over time, this could migrate towards the upstream reach of the channel, cutting off the meander and causing a need for grade control.

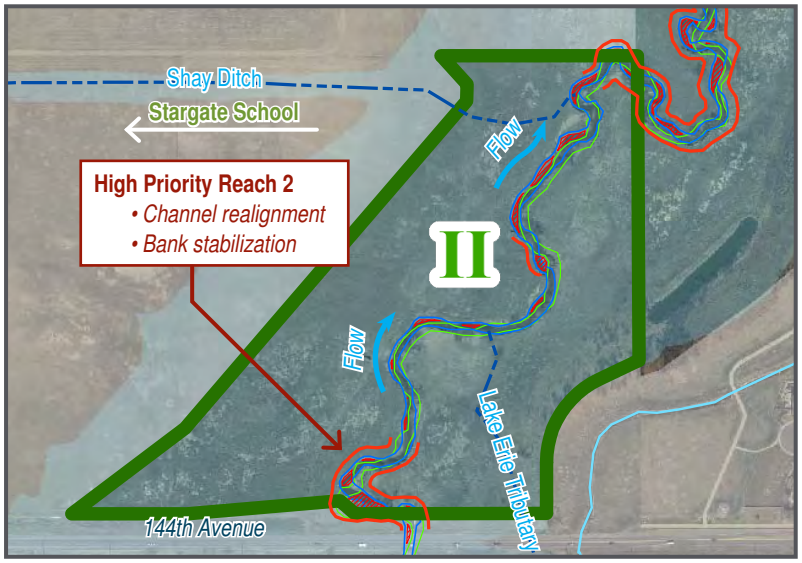


Parcel I High Priority Geomorphic Reach



Two localized drainages were identified entering this parcel reach. At each of these confluences, there is a high degree of bank erosion and stabilization needed to prevent further erosion of the channel.

Outer bend bank erosion and inner bend sedimentation in Parcel I



Parcel II High Priority Geomorphic Reach

Legend

- BDC Tributaries
- High Priority Bank Reach
- Ditches
- Areas of High Erosion
- 2014 Big Dry Creek Channel
- 1993 Big Dry Creek Channel
- 100 Year Floodplain

Parcel II Geomorphology: Big Dry Creek runs for 2,227 linear feet in theis parcel, and the channel bottom in Parcel II is sandy with mostly grasses and some shrubs along the bank. Channel cut banks range from 4 to 10 feet high, with the majority of the channel banks being in the 5 to 6 foot range.

In this approximately 33 acre parcel, two tributaries, Shay Ditch and Lake Erie Tributary, drain into Big Dry Creek near the southern and central area of this parcel, respectively. The city of Thornton is in the process of design and construction for a concrete trail to be installed through this parcel along a rerouted Shay Ditch, including a crossing over Big Dry Creek. The crossing is intended to become inundated during large flows.

A long reach of Big Dry Creek, High Priority Reach 2, was identified within Parcel II during the field visit. Immediately downstream of 144th Avenue (the southern boundary of this parcel), Big Dry Creek makes a sharp and immediate turn to the west. As a result there is a high degree of bank instability in this area.

The channel should be realigned downstream of the 144th Avenue crossing to improve crossing hydraulics. Another high priority reach begins on the northern edge of Parcel II and continues into Parcel III. Since this reach is shared between Parcels II and III, it will be discussed in more detail under Parcel III.

Cut bank on the outside bend of Big Dry Creek in Parcel II; sloughed sediment from the bank can be seen at the base of the creek

Riparian vegetation growing into sloughed sediment in Parcel II

Parcel III Geomorphology: The channel within this reach is located on 59.29 acres of city of Thornton open space, and runs for 4,878 linear feet. The channel bottom is sandy, with grasses, trees and shrubs on the channel banks. Channel cut banks range from 3 to 10 feet high, with the majority of the channel banks being in the 4 to 5 foot range.

One tributary, Wadley South, drains into Big Dry Creek from the east near the northern extent of this parcel.

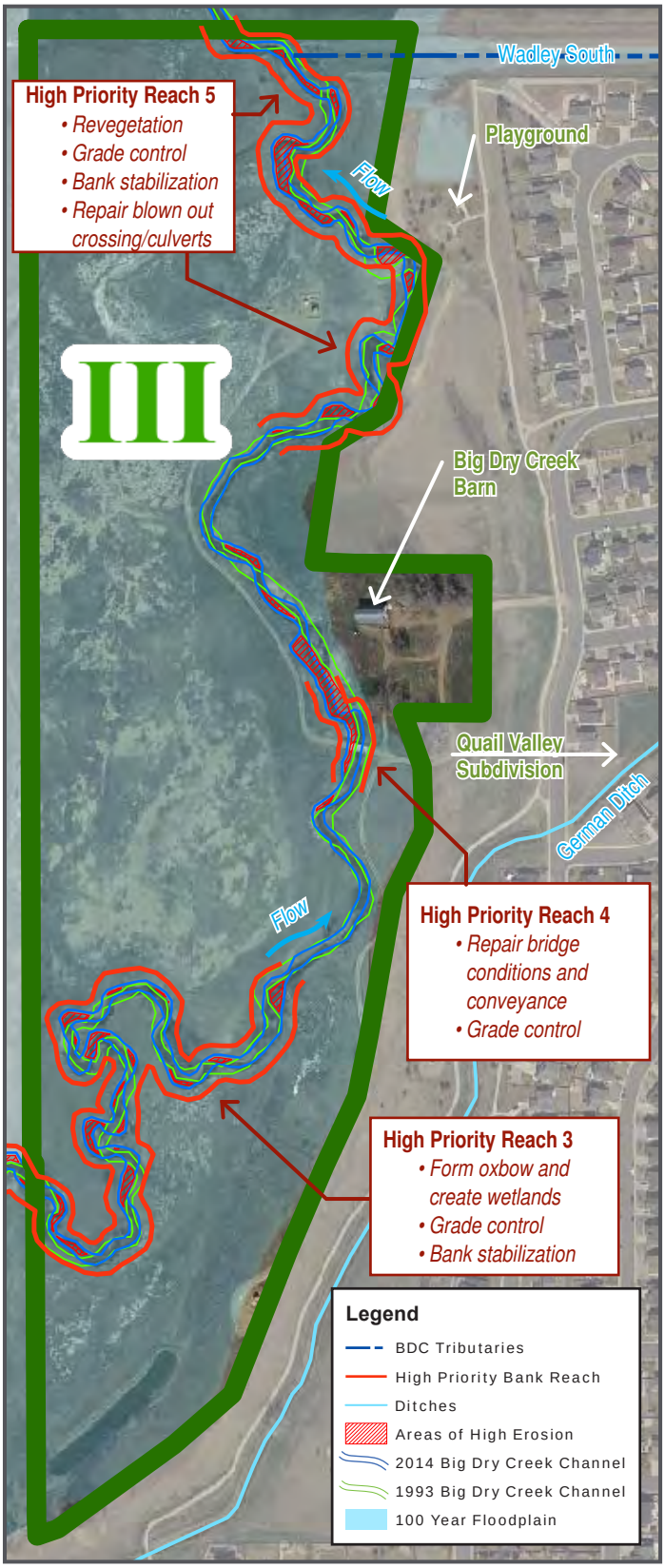
Three high priority reaches were identified during the field visit. High Priority Reach 3 begins immediately downstream of the western parcel boundary where there is significant mass wasting of channel banks. The channel has migrated laterally to a significant degree and is at risk of forming an oxbow in at least two locations. If the channel forms these oxbows there is a high potential that a headcut will form, resulting in further incision and bank instability upstream of the parcel.

High Priority Reach 4 is associated with an existing deteriorated bridge crossing owned and maintained by the oil/gas operator. The embankments around the bridge are eroded and a large scour pool has formed downstream of the bridge. Repairs to the bridge embankments are needed as well as hydraulic capacity and conveyance improvements.

High Priority Reach 5 is near an adjacent HOA -owned playground in the northern portion of the parcel. Some improvements have been made in this reach, however, it is evident that the public accesses the stream in this location via a steep and eroded bank. This activity along an unstable bank is causing additional bank erosion in this area. There is also a failed culvert crossing which appears to be currently serving as a grade control for the channel. In the event these culverts are completely washed out, there is the potential for a headcut to form and migrate upstream. These culverts should be removed and grade control measures should be implemented.

Failed culvert crossing within High Priority Reach 5 in Parcel III

Riparian vegetation and Russian olive trees growing along the banks of Big Dry Creek in Parcel III

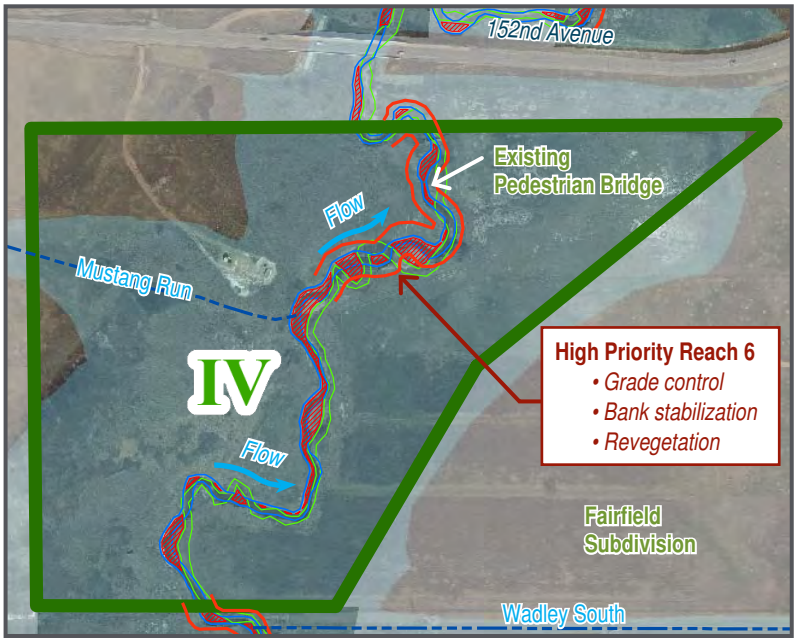


Parcel III High Priority Geomorphic Reaches

Parcel IV Geomorphology: The channel within this reach is located on 41 acres of city of Thornton open space, and runs for 2,393 linear feet. The channel bottom is sandy with mostly grasses, brush and a few trees along the channel bank. Channel cut banks range from 5 to 10 feet high, with the majority of the channel banks being in the 5 to 6 foot range.

One tributary, Mustang Run, drains into Big Dry Creek from the west near the middle of this parcel.

High Priority Reach 6 begins about halfway through the parcel area where there is significant mass wasting of channel banks. The majority of the bank erosion is occurring on the outside of channel bends. Outside channel bends are in need of stabilization while the inside banks on these bends are in need of revegetation. The channel appears to have steepened through this reach based on field observations which were consistent with a historical channel imagery comparison. Grade control should be considered in this area to help prevent further channel incision.



Parcel IV High Priority Geomorphic Reach

Sharp bend on Big Dry Creek in Parcel IV

Small outfall pipe draining into Big Dry Creek in Parcel IV

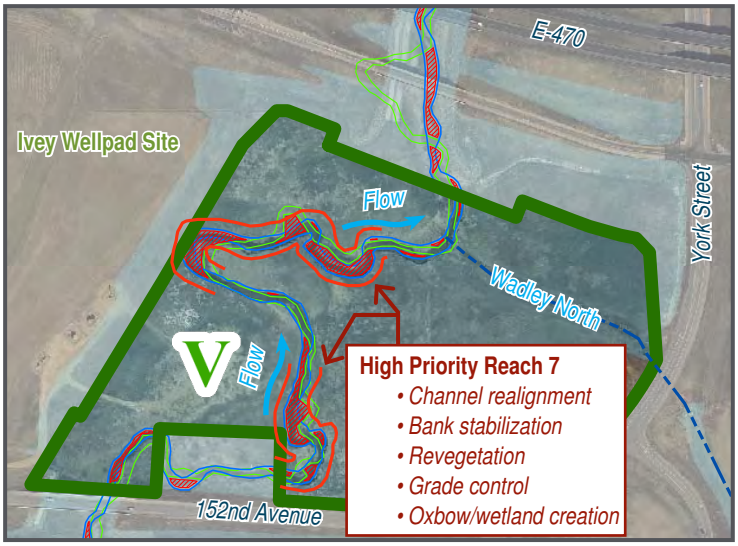
Erosion on outer bank of Big Dry Creek Parcel IV

Parcel V Geomorphology: The channel within this reach is located on 25.54 acres of city of Thornton open space, and runs for 1,847 linear feet. This parcel is bounded by 152nd Avenue to the south, York Street on the east and Highway E-470 on the north. The channel is winding with a sandy bottom with mostly grasses, brush and a few trees along the channel bank. Channel cut banks ranged from 5 to 10 feet high, with the majority of the channel banks being in the 5 to 6 foot range.

Wadley North drains into Big Dry Creek from the east near the northern extent of this parcel.

Two high priority reaches were identified during the field visit and have been combined as High Priority Reach 7. The first portion of this reach begins immediately downstream of the southern parcel boundary. The channel makes an immediate turn to the east after crossing under 152nd Avenue, leaves the open space parcel boundary and then re-enters the open space parcel. The channel is migrating to the south in this area, threatening the integrity of 152nd Avenue. If possible, re-routing the channel in this area through the open space parcel would be beneficial. After the existing channel re-enters the open space parcel there is significant mass wasting of channel banks on the outside of channel bends. Outside channel bends are in need of stabilization while the inside bank on these bends are in need of revegetation.

The second portion of this reach is a result of excessive lateral channel migration to the west. The channel is beginning to migrate off of the open space parcel towards existing and future oil and gas wells. Outside channel bends need to be stabilized to keep the channel within the open space boundary. The inside bank on these bends are in need of revegetation.



Parcel V High Priority Geomorphic Reach

Legend
- BDC Tributaries
- High Priority Bank Reach
- Ditches
- Areas of High Erosion
- 2014 Big Dry Creek Channel
- 1993 Big Dry Creek Channel
- 100 Year Floodplain

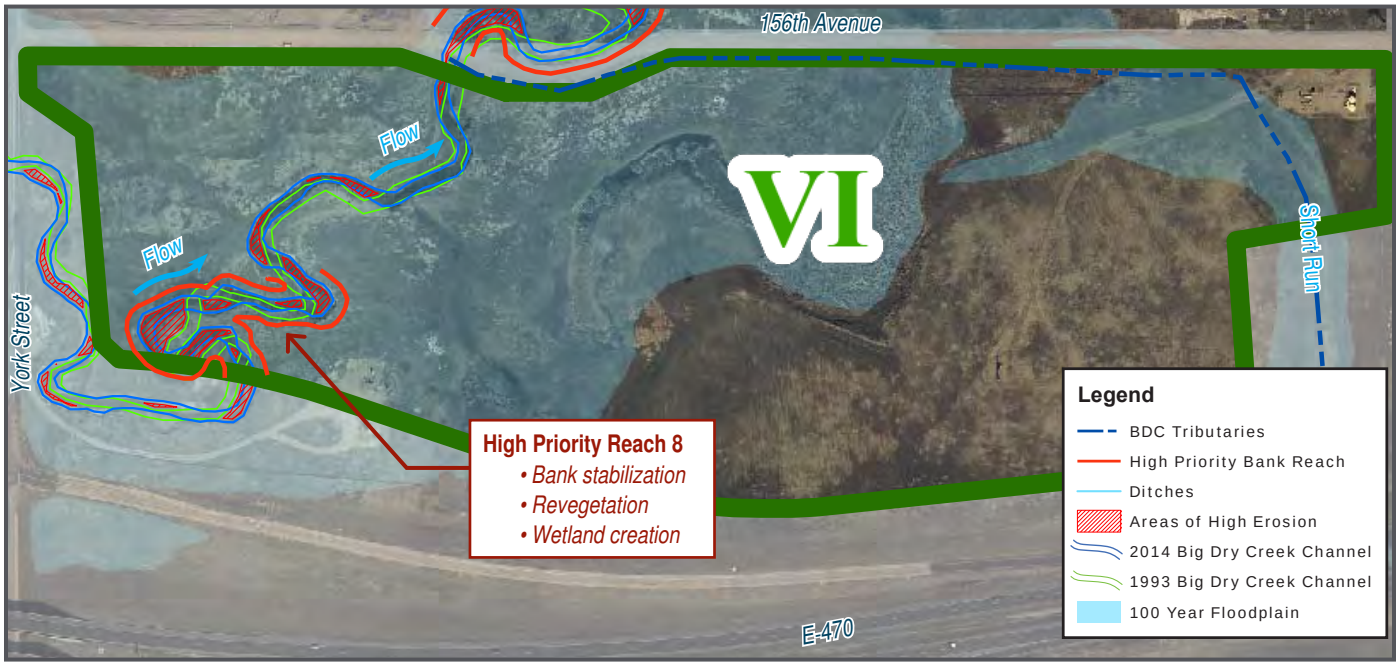
Aerial image of high priority reach in Parcel V

Vegetation on inner bank in Parcel V; vertical cut bank on outer bank

Inner bank in Parcel V that would benefit from revegetation

Parcel VI Geomorphology: The channel within this reach is located on 44.08 acres of city of Thornton open space, and runs for 1,324 linear feet. There are two oil and gas wellpads within this parcel boundary. The channel within this reach is winding with a sandy bottom and primarily grasses with some shrubs along the banks. Channel cut banks ranged from 3 to 10 feet high, with the majority of the channel banks being in the 3 to 4 foot range.

The Short Run Outfall enters Big Dry Creek from the east just downstream from this parcel.



Parcel VI High Priority Geomorphic Reach

One high priority reach, High Priority Reach 8, was identified during the field visit. A portion of the channel just outside the parcel area boundary is threatening an existing wellpad access road. If possible, re-routing the channel in this area through the open space parcel area would be beneficial. Within the parcel area boundary there is significant mass wasting or deterioration of channel banks. The channel has migrated laterally to a significant degree and is at risk of forming an oxbow in at least one location. If the channel forms this oxbow, there is a high potential that a headcut will form, resulting in further incision and bank instability upstream of the parcel.

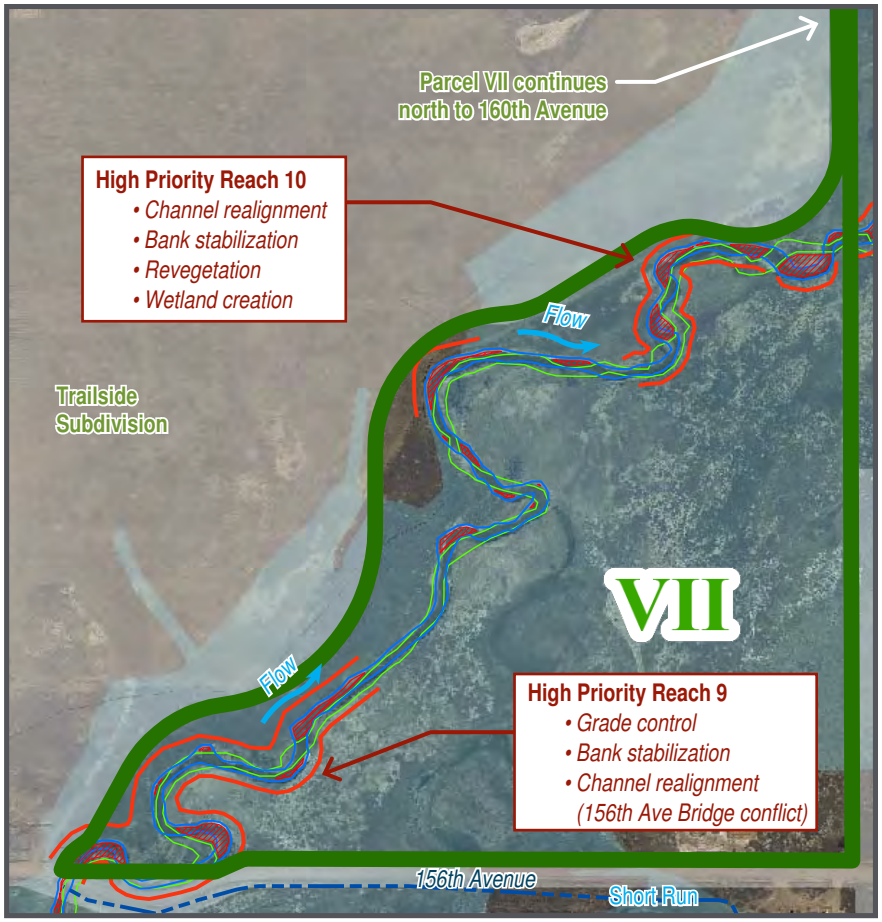
Bank slough and sedimentation with vegetation in Parcel VI

Project team inspecting outer cut banks in Parcel VI

Parcel VII Geomorphology: The channel within this reach is located within 34 acres of city of Thornton open space, and runs for 3,302 linear feet. The channel is winding with a sandy bottom and grasses and shrubs along the banks. Channel cut banks range from 5 to 10 feet high, with the majority of the channel banks being in the 5 to 6 foot range.

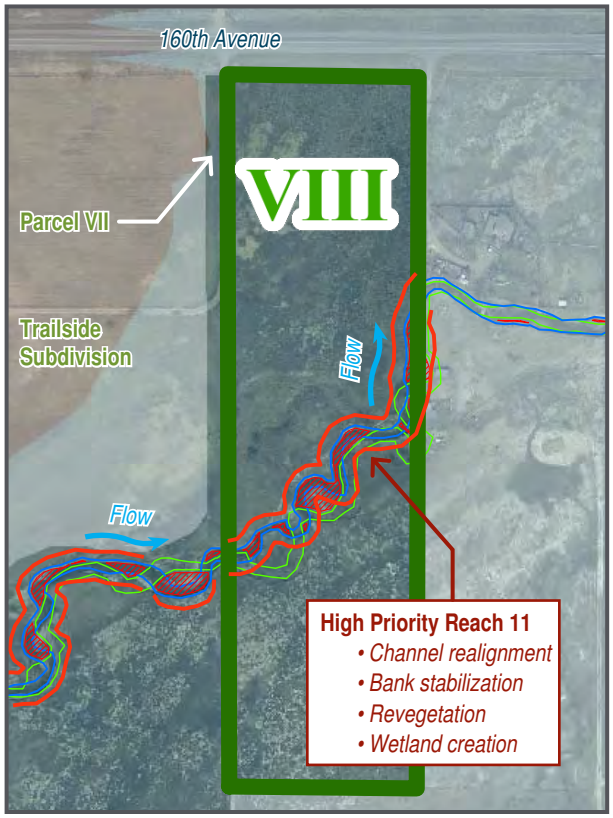
Two high priority reaches, 9 and 10, were identified during the field visit. High Priority Reach 9 begins immediately downstream of the southern parcel boundary. The channel makes an immediate turn to the east and then south after crossing under 156th Avenue. The channel is threatening the integrity of 156th Avenue and should be rerouted to avoid future destabilization of the road.

High Priority Reach 10 is a result of lateral channel migration. The majority of the bank erosion is occurring on the outside of channel bends. Outside channel bends are in need of stabilization while the inside bank on these bends are in need of revegetation.



Parcel VII High Priority Geomorphic Reaches

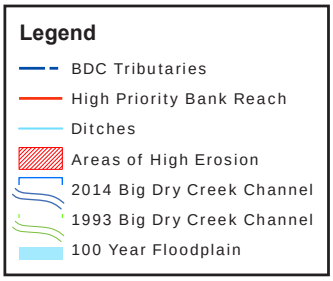
Erosion and sloughed banks in Parcel VII



Parcel VIII High Priority Geomorphic Reach

Parcel VIII Geomorphology: The channel within this reach is located on 16 acres of city of Thornton open space, and runs for 784 linear feet. The channel is winding with a sandy bottom and grasses along the banks. Channel cut banks ranged from 3 to 6 feet high, with the majority of the channel banks being in the 4 to 5 foot range.

The full extent of the Big Dry Creek channel within this parcel boundary is considered a high priority (High Priority Reach 11). Lateral channel migration is highly active in this area and is threatening the integrity of two buildings located just outside and east of the parcel boundary. If possible, re-routing the channel through the central portion of the open space parcel area would be beneficial.



Outer cut banks in Parcel VIII

Meander Belt Width Analysis

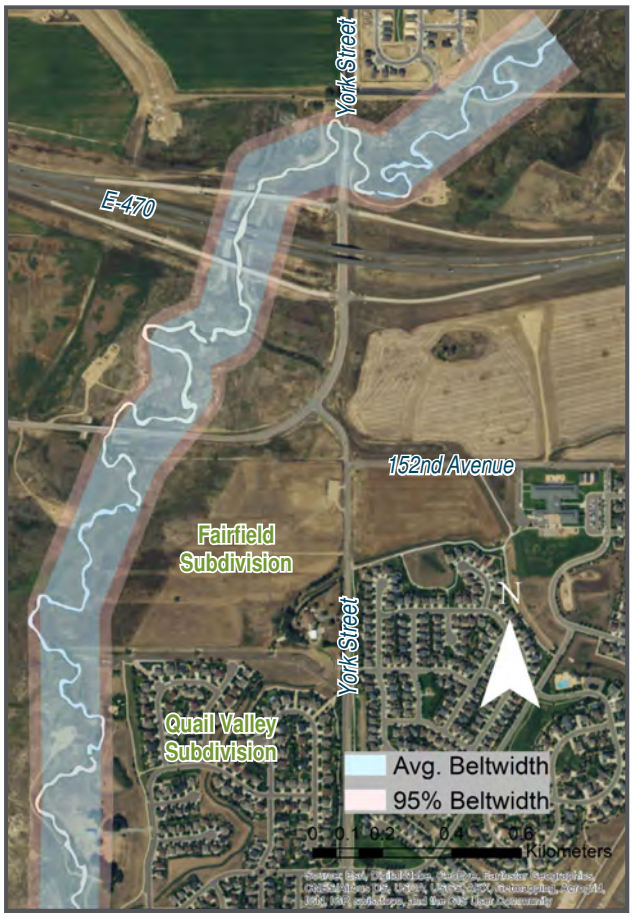
The Big Dry Creek corridor is subject to a high probability of erosion as the channel migrates laterally over time. Consequently, a meander belt width analysis was conducted. A meander belt width analysis is intended to estimate the area in which a meandering stream may occupy as it changes over time. In other words, the meander belt width analysis identifies an area adjacent to the stream which can be considered an erodible corridor where land in this area is subject to erosion by the stream channel. This analysis can be used in future planning for various stream stabilization measures, locating engineered hard points which reduce the potential for continued lateral movement,

The meander belt identifies an area adjacent to the stream, where land is subject to erosion by the stream channel; this meander belt width is overlaid on an aerial of Parcel III

and assessing proposed infrastructure locations as part of the Big Dry Creek Recreation and Floodplain Restoration Master Plan project. For this study, analysis was conducted to define the 95th percentile meander belt width. This is the width, perpendicular to the direction of flow, that contains 95% of the meanders along this portion of the stream corridor. This width is used as an indicator of potential future lateral migration due to meandering. In some cases, the 95th percentile meander width is wider than the floodplain. This is an indication that the floodplain is not a static, unchanging boundary and that due to geomorphic changes the floodplain boundaries may change over time.

The equations used to calculate the minimum meander belt width are based on natural and unconfined rivers. Exceptions include areas where Big Dry Creek has been subject to realignment for road crossings and to protect infrastructure, so the empirically derived minimum meander belt width estimate may be less applicable. However, the majority of the project area is not influenced by these factors. In addition, there are some complex meander patterns which the equations were not developed to consider.

A more detailed discussion of this analysis is provided in "Appendix C: Meander Belt Width of Big Dry Creek in Thornton, CO". A visual summary of the estimated average and 95th percentile minimum meander belt width of Big Dry Creek through the project area is provided in the meander belt maps at right. Areas within the meander belt have a high probability of erosion as the channel migrates over time. However, areas outside of the meander belt are not necessarily immune to erosion, nor should the channel be re-aligned simply to fit within this calculated meander belt. Existing creek meanders which are located near the edge of the meander belt should be considered good locations for bank armoring to prevent further lateral migration of the channel outside of the corridor. This calculated minimum meander belt width can be used as an estimate to locate areas with a high probability of erosion along the channel corridor where infrastructure may be subject to damage from lateral channel migration.



Estimated Average and 95th Percentile Meander Belt width for Big Dry Creek through the northern project area

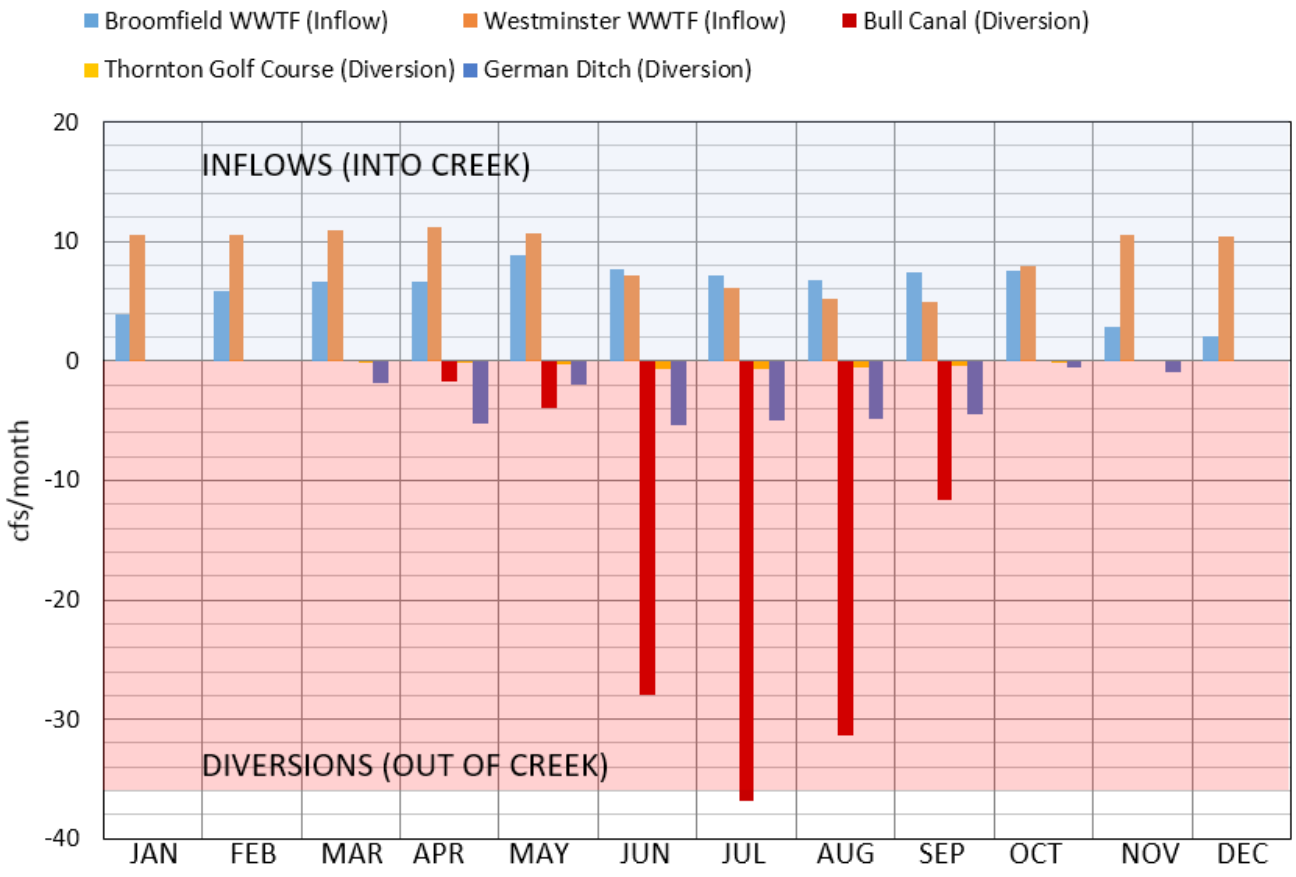
Estimated Average and 95th Percentile Meander Belt width for Big Dry Creek through the southern project area

Seasonal Flow in Big Dry Creek

The hydrology of Big Dry Creek is heavily influenced by wastewater treatment plant (WWTP) discharges, seasonal variation due to irrigation releases from Standley Lake and irrigation ditch diversions out of Big Dry Creek. United State Geological Survey (USGS) gage 06720820 Big Dry Creek at Westminster, CO, monitors streamflow in Big Dry Creek and is located approximately 4 miles upstream of the Master Plan area. Between the gage and the start of the Master Plan area there are two wastewater treatment plant discharges (Broomfield WWTP and Westminster WWTP) which add water into the creek and three water rights diversion ditches (Bull Canal, Thornton Golf Course and German Ditch) which divert water from Big Dry Creek.

In order to quantify the effects of these flow sources on the hydrologic characteristics of Big Dry Creek through the Master Plan project area, a summary of measured hydrologic influences on Big Dry Creek from 2012 to 2015 is presented in Measured Hydrologic Influences chart below. This information was provided by the Big Dry Creek Watershed Association which tracks these influences as part of their ongoing water quality monitoring program. The selected time period of 2012 to 2015 was used because Bull Canal and WWTP data are more reliable during this time, and are representative of the more recent hydrologic conditions of Big Dry Creek.

The information presented in the Measured Hydrologic Influences chart was used to develop recommendations for both baseflow and bankfull discharge estimates for channel reaches within the Master Plan project area. The following sections on existing conditions, baseflow analysis, flood recurrence interval summary and bankfull analysis provide a summary of how considerations for these hydrologic influences were incorporated in the discharge estimates and recommended restoration channel cross section design.



Measured Hydrologic Influences on Big Dry Creek affecting the Master Plan project area (2012-2015 in average cfs/month)

Baseflow Analysis

Frequently varying baseflows in Big Dry Creek contribute to bank erosion

As discussed previously, Big Dry Creek is never really dry due to wastewater return flows and irrigation releases from Standley Lake to the creek. The variability of these baseflows are contributing to bank erosion due to water surface fluctuations resulting in undercutting and sloughing of the channel banks. In order to help mitigate this issue, an assessment of seasonal baseflow rate and depth fluctuations through the Master Plan area was conducted so that stream bank or other stream restoration practices can be adequately sized and designed to reduce bank undercutting and sloughing during low-flow periods. Daily average streamflow data as well as average daily flow values for each point source WWTP inflow or diversion outflow were used to develop seasonal flow duration curves during the non-irrigation and irrigation season. These flows were then input into the Big Dry Creek Hydrologic Engineering Center-River Analysis System (HEC-RAS) model, developed as part of the Big Dry Creek FHAD (UDFCD, 2012), to provide a summary of depth fluctuations associated with the anticipated range of baseflow conditions. HEC-RAS is a 1-dimensional flow model developed by the United States Army Corps of Engineers (USACE) which is used to model channel flow characteristics under various flow conditions.

The baseflow analysis found a discontinuity in the flow during the irrigation season as a result of the diversions which occur between the USGS Westminster gage and the project area. This discontinuity occurs during lower flow periods, when diversions/outflows remove a significant portion of the flow in Big Dry Creek, potentially drying out the creek, or reducing flows to less than 1 cubic foot per second (cfs). This analysis also found that the mean baseflow condition during the non-irrigation season remains relatively constant, and is generally higher than the mean baseflow encountered during the irrigation season.

Based on the analysis, it is recommended that stream restoration projects within the Master Plan area provide a bankfull channel with a capacity of approximately 40 cfs. For bank stabilization projects without a stream restoration component, channel banks should be stabilized to a minimum depth of 3 feet above the toe of the channel bank in order to help reduce channel bank erosion associated with baseflow fluctuations. Bank stabilization projects typically only focus on stabilizing channel banks, while stream restoration will include resizing of the channel cross section and construction of a separate baseflow channel. Due to the importance of maintaining a stable bank toe to help reduce channel migration and erosion, stabilizing the banks to a minimum depth of 3 feet is recommended to help provide a reasonable amount of freeboard between the top of the baseflow water surface and the limits of the bank stabilization. See “Appendix D: Assessment of Baseflow Conditions” for a detailed summary of this analysis.

Flood Frequency Summary and Bankfull Analysis

The Peak Flow Rates by Project Parcel chart below provides a summary of the Big Dry Creek FHAD[1] peak flow rates associated with various flood recurrence intervals. These flood intervals are expressed in years, and give an indication of the probability of the peak flow rate (cfs) associated with each recurrence being equaled or exceeded in any one year. This probability is calculated as the reciprocal of the recurrence interval value. For example, a 50-yr event has a probability of 0.02 (1÷50 = 0.02), or 2%, of the peak flow being equaled or exceeded in any single year.[2]

The flows associated with each recurrence interval listed assume full buildout of the watershed, and are based on a detailed hydrologic study for the entire Big Dry Creek watershed. The values provided should be used for the purposes of establishing updated 100-year floodplain mapping as a result of channel or floodplain improvement projects.

Location of Discharge (Flow)		**Peak Discharge (cfs) for given Flood Frequency Period**				
		50%	10%	2%	1%	0.20%
		(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
PARCEL 1	McKay Lake Basin Outfall	2580	4870	8620	10230	13440
PARCEL 2	Lake Erie Basin Tributary 1 Outfall	2570	4830	8580	10210	13530
	144th Avenue	2570	4830	8580	10210	13530
	Shay Ditch Outfall	2510	4680	8470	10120	13260
PARCEL 3	Wadley South Creek Outfall	2490	4660	8440	10100	13280
PARCEL 4	Mustang Run Outfall	2500	4670	8460	10130	13330
PARCEL 5	152nd Avenue	2500	4670	8460	10130	13330
	Wadley North Creek Outfall	2480	4630	8410	10090	13330
PARCEL 6	Sack Creek Outfall	2490	4640	8430	10120	13430
	York Street	2490	4640	8430	10120	13430
	156th Avenue	2480	4620	8390	10090	13400
	Short Run Outfall	2480	4620	8390	10090	13400
PARCEL 8	Elms Run Outfall	2460	4590	8350	10060	13400

Peak Flow Rates by Project Parcel for various flood frequencies based on UDFCD, 2012

While the values provided should be used for establishing Big Dry Creek floodplain limits and location, a more refined approach is used to establish the bankfull discharge.

The definition of the bankfull discharge is the discharge (or flow) when water is just about to spill out of the channel banks and into the adjacent floodplain terraces. In urban settings, the UDFCD recommends using a bankfull discharge value equal to the developed 1.5 to 2-year flow, and that it be estimated based on stream gage records.

To estimate this bankfull discharge, a separate flood analysis was performed using stream gage data from USGS gage 06720820 Big Dry Creek at Westminster, CO, the closest gage approximately 4 miles upstream of the start of the project area. In order to account for the differences in contributing flow from the watershed area and the WWTP effluent between the USGS gage and the project area, the flood analysis results were increased by the ratio of the average contributing drainage area associated with the project area (72.8 square miles) to the drainage area associated with the USGS gage (43.9 square miles), and adding an additional 20 cfs of WWTP effluent inflow (maximum combined average discharge in cfs/month from Broomfield and Westminster WWTP's).

1 WWE, 2012. Flood Hazard Area Delineation Big Dry Creek. Prepared for Urban Drainage and Flood Control District, Denver CO. Prepared by: Wright Water Engineers, Inc. Denver, CO. Available: http://udfcd.org/

2 The frequency of occurrence of a flood of a given magnitude can be expressed as an annual exceedance probability or as a return period (also known as return interval). Most people are more familiar with return periods which are expressed in years, such as a 10-year event or a 100-year event. Return periods are inversely related to the annual exceedance probabilities. A 10-year event has an annual exceedance probability of 1/10 years which is equal to 0.10 or 10% probability of occurrence in any given year; A 100-year event has an annual exceedance probability of 1/100 years which is equal to 0.01 or 1% probability of occurrence in any given year. Most floodplain regulators prefer using annual exceedance probabilities to characterize flood frequency since return periods can more easily be misinterpreted by the public, who may incorrectly think that after a 100-year flood another flood of the same magnitude would not be expected for another 100-years.

The USGS Bulletin 17B below provides a numeric summary of the statistical analysis for specific flood frequency or flood occurrence interval periods and the corresponding 95% confidence intervals (bounding values within which the mean value fall with a 95% confidence). The values provided in the table should only be used for the purposes of sizing the bankfull channel as part of Big Dry Creek stream restoration projects within the Master Plan area. Typically, the bankfull channel should be sized for the 1.5 to 2 year event. See Chapter 4 Plan Recommendations for how this Bulletin 17B analysis was used to provide recommendations for design channel cross sections for each reach segment.

Return Period (year)	Lower 95% Confidence Interval for B17 value (cfs)	B17 Value (cfs)	Upper 95% Confidence Interval for B17 value (cfs)
2	443	522	615
1.5	348	418	490
1	119	167	213

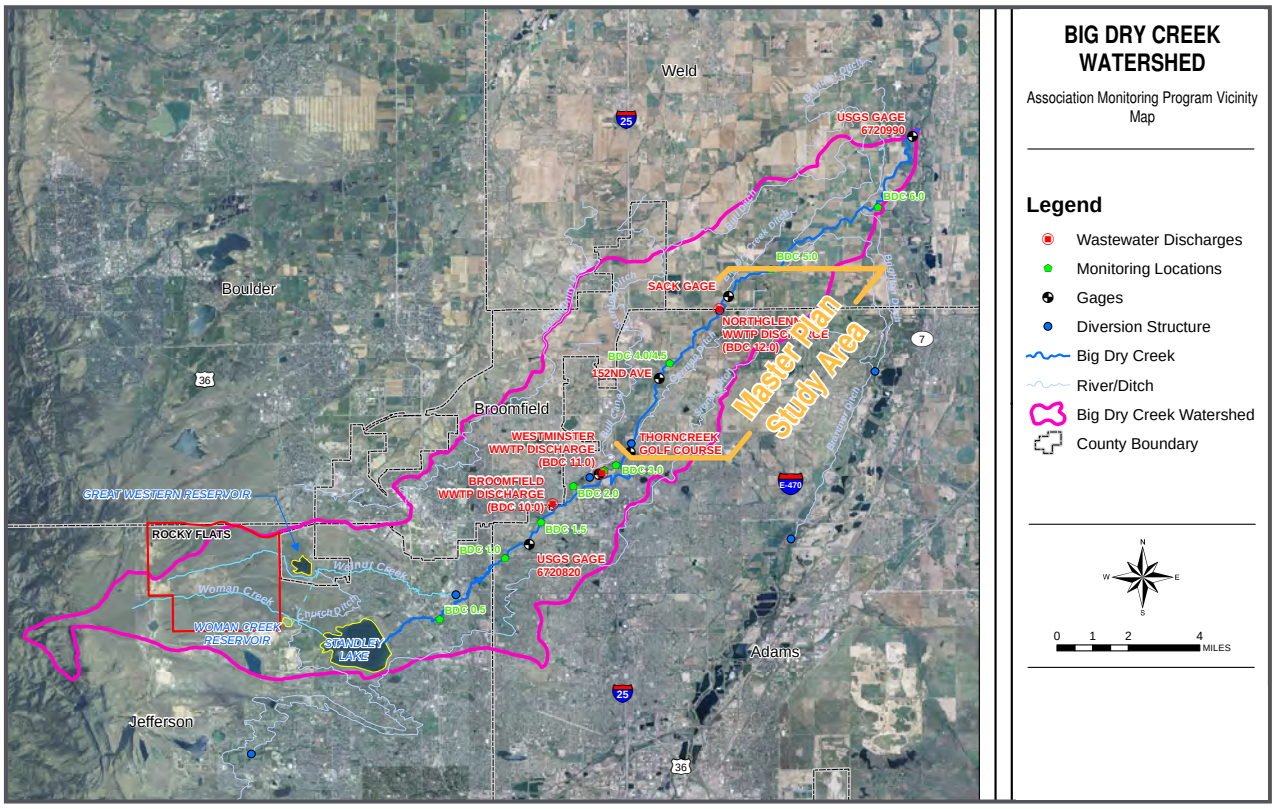
USGS Bulletin 17B Flood Analysis Data Summary for project area

Big Dry Creek channel meandering through Parcel V; areas of erosion and sedimentation can be seen along the banks

Water Quality

The water quality of Big Dry Creek is important because of the multiple beneficial uses that the creek supports. These uses range from providing habitat for warm water aquatic species to recreation to agricultural uses. Impairments that are caused by E. coli have the potential to make the water unsafe for recreation, while elevated levels of nutrients can lead to problems with algae and low dissolved oxygen that can lead to stress or death for aquatic organisms. There have been multiple efforts by the Big Dry Creek Watershed Association over the past 25 years to characterize and improve the water quality of Big Dry Creek.

The Colorado Water Quality Control Commission has established designated uses and associated stream standards for water quality in Big Dry Creek. Designated uses include agriculture, aquatic life, and recreation. As of 2016, Big Dry Creek attains all designated uses and standards with the exception of E. coli for the entire segment and iron (outside the master plan area) in the portion of the lower watershed below Weld County Road 8. Nutrient standards (e.g., total phosphorus, total nitrogen and chlorophyll-a) do not currently apply for the main stem of Big Dry Creek because the main stem is downstream of wastewater treatment plant (WWTP) discharges. However, nutrient standards may be adopted for the main stem of Big Dry Creek in the future. If the current interim values for total phosphorus and total nitrogen were adopted for the main stream, it would exceed these standards for the portion of the stream below the WWTP discharges, because of high nutrient concentrations in WWTP discharges.



Big Dry Creek Watershed Association Monitoring Program Vicinity Map

As shown in the Monitoring Program Vicinity Map above, the Big Dry Creek Recreation and Floodplain Restoration Master Plan reach includes monitoring stations BDC 3.0 at I-25 and BDC 4.0/4.5 in the vicinity of York Street. The Big Dry Creek Watershed Association (BDCWA) conducts an annual assessment of water quality conditions in Big Dry Creek, with findings documented in an annual water quality report (www.bigdrycreek.org). The monitoring program includes eight instream locations that are monitored monthly for a variety of water quality parameters, with metals monitored on a quarterly basis.

Two long-term USGS stream gages are located on the stream, with one behind Front Range Community College in the Westminster open space and another in the lower watershed above the confluence with the South Platte River near Fort Lupton. Biennially, biological monitoring is also conducted at a subset of the water quality monitoring sites. Highlights of the monitoring program are briefly summarized on the following pages.

Key findings and recommendations regarding Big Dry Creek water quality and aquatic life conditions based on analysis of the 2015 data set include (see "Appendix E: Water Quality Box and Whisker Plots" for more detailed graphs of the collected data):

1. E. coli concentrations are elevated at multiple instream locations, with the highest concentrations present at BDC 3.0 at I-25 below the Westminster WWTP discharge and at BDC 6.0 in the lower agricultural area. Depending on the location, sources of E. coli can include human sources (e.g., sanitary sewage leaks, septic systems), birds, wildlife, livestock, dogs and other sources. For example, in the lower watershed, cattle are present in the riparian area in the stream. Wildlife have also been observed throughout the riparian corridor. Source tracking of stormwater outfalls during non-irrigation periods may help to determine whether controllable human sources (e.g., sanitary leaks or discharges to the storm sewer) are present at stormwater outfalls discharging to the stream.
2. Big Dry Creek downstream of Weld County Road 8 (downstream of the Master Plan study area) is listed as impaired on the EPA's 2016 303(d) list of impaired waters for iron. Below Weld County Road 8, monitoring data collected by Metro Wastewater has shown median total recoverable iron concentrations exceeding the aquatic life stream standard of 1 mg/L. Iron and total suspended solids (TSS) are highly correlated; therefore, channel and field erosion are hypothesized to be the source of elevated iron in this agricultural reach of stream, particularly during storm flow conditions. Iron is a naturally occurring element present in soil.
3. Numeric stream standards are not assigned for total suspended solids (TSS); however, TSS concentrations generally increase in an upstream to downstream direction. TSS concentrations increase along the Big Dry Creek Master Plan area. This increase is expected to be associated with bank erosion in this area and continuing downstream through the agricultural area.
4. For the most recent five-year analysis period (2011-2015), Big Dry Creek attained its site-specific selenium standard. In 2016, the stream was removed from the EPA's list of impaired waters for selenium. Elevated selenium is due to naturally occurring geologic sources. Selenium tends to be higher during low flow conditions and is associated with groundwater inflows. Elevated selenium is not an issue in the Big Dry Creek Master Plan area.
5. Big Dry Creek does not attain the instream nitrogen and phosphorus "interim values" below WWTP discharges from the Broomfield WWTP to the South Platte River. Although these values are not expected to be adopted as stream standards on the main stem of Big Dry Creek prior to 2027, addressing nutrient sources on Big Dry Creek is an increasing area of focus for municipalities and counties along the creek. More stringent CDPHE permit limits are expected in the forthcoming permit renewal for the WWTPs.
6. Phosphorus concentrations and loads to Big Dry Creek have decreased over time as a result of treatment plant upgrades at the Broomfield and Westminster WWTPs, along with reuse programs that continue to be implemented at these WWTPs. Despite these improvements, the stream would not meet the interim total phosphorus criteria (potential future standard) from below the Broomfield WWTP to the confluence with the South Platte River near Fort Lupton.
7. The Big Dry Creek Watershed Association conducts a biennial macroinvertebrate monitoring program and calculates multi-metric index (MMI) scores to characterize aquatic life health. In accordance with Colorado's Aquatic Life Use

Attainment Policy 10-1 (CWQCC 2010), Big Dry Creek is categorized as a Plains & Xeric stream type (Biotype 3). Colorado's MMI score thresholds for Biotype 3 streams are MMI >37 for use attainment and MMI <22 for impairment—higher scores are better. The Fall MMI Scores table below summarizes MMI results for the fall of 2008, 2010, 2012, and 2014 (Aquatics Associates, Inc. 2014[1]) at six sampling sites for these years. Based on the MMI scores, the aquatic macroinvertebrate community in Big Dry Creek is generally healthy and meets MMI use-attainment criteria for aquatic life. Based on the four-year mean, all sites except BDC 5.0 are considered High Scoring Waters (MMI >44 for Biotype 3). Additionally, the long-term data set demonstrates the significant year-to-year variability that can occur at individual sites.

Site	Location	MMI Score 2008	MMI Score 2010	MMI Score 2012	MMI Score 2014	4-Year Mean
BDC 0.5	Downstream (d/s) from Old Wadsworth Ave., at Church Ranch Open Space	**60.0**	**64.1**	**64.7**	**49.9**	**59.7**
BDC 1.0	Upstream (u/s) from 112th Ave.	**65.7**	**48.8**	**50.8**	**49.2**	**53.6**
BDC 1.5C	Downstream (d/s) from 120th Ave., upstream (u/s) Broomfield WWTP	41.8	**49.0**	**46.4**	**63.1**	**50.1**
BDC 2.0	Upstream (u/s) from 128th Ave., downstream (d/s) from Broomfield WWTP	36.0	29.6	42.2	**56.4**	41.1
BDC 3.0	At I-25, downstream (d/s) from Westminster WWTP	**49.7**	28.3	**53.2**	**50.7**	**45.5**
BDC 5.0	Downstream (d/s) from Weld County Rd. 4	**45.8**	40.8	**66.7**	39.2	**48.1**

Fall Multi-Metric Index (MMI) Scores for Big Dry Creek sites for 2008, 2010, 2012 and 2014

[1]Information obtained from Aquatics Associates, Inc. 2014

Notes: Bold Blue indicates High Scoring Water (MMI>44 for Biotype 3). MMI Impairment threshold for Class 2 streams is <22. Analysis by Tami Schneck of Aquatics Associates, Inc.

Recreational Amenities

Within both the city and regional context, the Big Dry Creek corridor provides an abundance of passive recreational opportunities. Thornton and Adams County have laid the groundwork for Big Dry Creek to become a phenomenal set of recreational amenities that are connected to surrounding neighborhoods, nearby schools, local and regional trail networks. These trail and amenity networks can also be connected to RTD FasTracks stations in the area.

Big Dry Creek Trail

Currently, Thornton has a good network of existing local and regional trails in the master plan area. These trails range from sidewalks adjacent to streets, to neighborhood connections to schools and parks, to more major trails that serve as routes for walking, biking and jogging. Existing segments of the Big Dry Creek Trail run parallel to Big Dry Creek east of Parcels II and III in the Quail Valley Subdivision and near the west side of Parcel VII north of 156th Avenue.

Although they are not considered formal Thornton or Adams County trails, there are a number of oil and gas access roads that are used informally as walking trails. These access roads offer a great opportunity to connect people to additional areas of the Big Dry Creek open spaces. However, they also pose a 'gray-area' of maintenance and liability. The oil and gas operator is responsible for maintaining these roads, and without a public access easement may gate or further deter access if visitors are causing additional damage or wear to the roads.

The city of Thornton maintains a GIS database of a large variety of data, included existing and proposed trail systems, parks, schools and other recreational amenities. This database, as well as inventorying existing conditions, was used in the planning of the Master Plan trail layout. The Master Plan trail layout is discussed in greater detail in Chapter 4 Plan Recommendations.

Oil and gas access road and bridge near the Big Dry Creek Barn

One key trail feature is that both existing and future trails connect to local area schools. Silver Creek Elementary School, Stargate School, Rocky Top Middle School, Hunters Glen Elementary School and Century Middle School are all within close proximity to the Big Dry Creek corridor. South of 136th Avenue, Century Middle School and Hunters Glen Elementary School are connected by sidewalks that link them to the Big Dry Creek Trail. North of 136th Avenue, Rocky Top Middle School has connections both south of 136th Avenue and north of 144th Avenue to the Big Dry Creek Trail. The city of Thornton is working with Stargate School to build a trail across Big Dry Creek to the Big Dry Creek Trail. Silver Creek Elementary School, along 152nd Avenue east of York Street, with the development of the Fairfield Subdivision, will be linked to the Big Dry Creek Trail.

The newly constructed Stargate School directly west of Big Dry Creek Parcel II (photo credit: StargateSchool.org)

Big Dry Creek running through Thorncreek Golf Course

There are also a number of 'active' recreation amenities in the vicinity of or along the Big Dry Creek corridor. The corridor south of 136th Avenue is the Thorncreek Golf Course, owned and operated by the city of Thornton. To the north of 136th Avenue directly south of Rocky Top Middle School lies the Northern Lights Ballfields facility, also owned and operated by Thornton. This complex contains 7 baseball/softball fields, a playground, shade pavilions and a Challenger ballfield. Moving north of 144th Avenue, there are two playground areas, both maintained by the Quail Valley Subdivision HOA. Both the Fairfield Subdivision and Trailside Subdivision HOAs have similar recreational amenities under construction.

Environmental Conditions

There are three general habitat types found along Big Dry Creek. These habitat types are known as upland, riparian and wetland areas. As shown in the Typical Habitats Graphic on page 44, these habitat types are characterized primarily by moisture and frequency of flooding, which affect the types of vegetation that will establish in each area. Some reaches or areas of Big Dry Creek may include all three habitat types, whereas other reaches may have only one or two habitats represented. The Master Plan study area was inventoried for habitat type, as well as overall environmental health and recommendations. Through this process, the study area was split into subplots that are grouped into eight overall category types based on environmental conditions and health.

Upland Areas

The main upland areas located along Big Dry Creek are known as upland or short-grass prairie. Short-grass prairie is characterized by low-growing grasses, forbs, and scattered shrubs. It occurs on drought-prone, mildly alkaline, medium and fine textured soils. This upland vegetation is generally xeric and the vegetation is adapted to an average rainfall of 15 inches per year. Much of the short-grass prairie located along the Front Range of Colorado near Denver has a mix of non-native and native grass establishment due to agricultural and grazing practices. Weedy species are also mixed in with this combination of native and non-native upland grasses and herbaceous species.

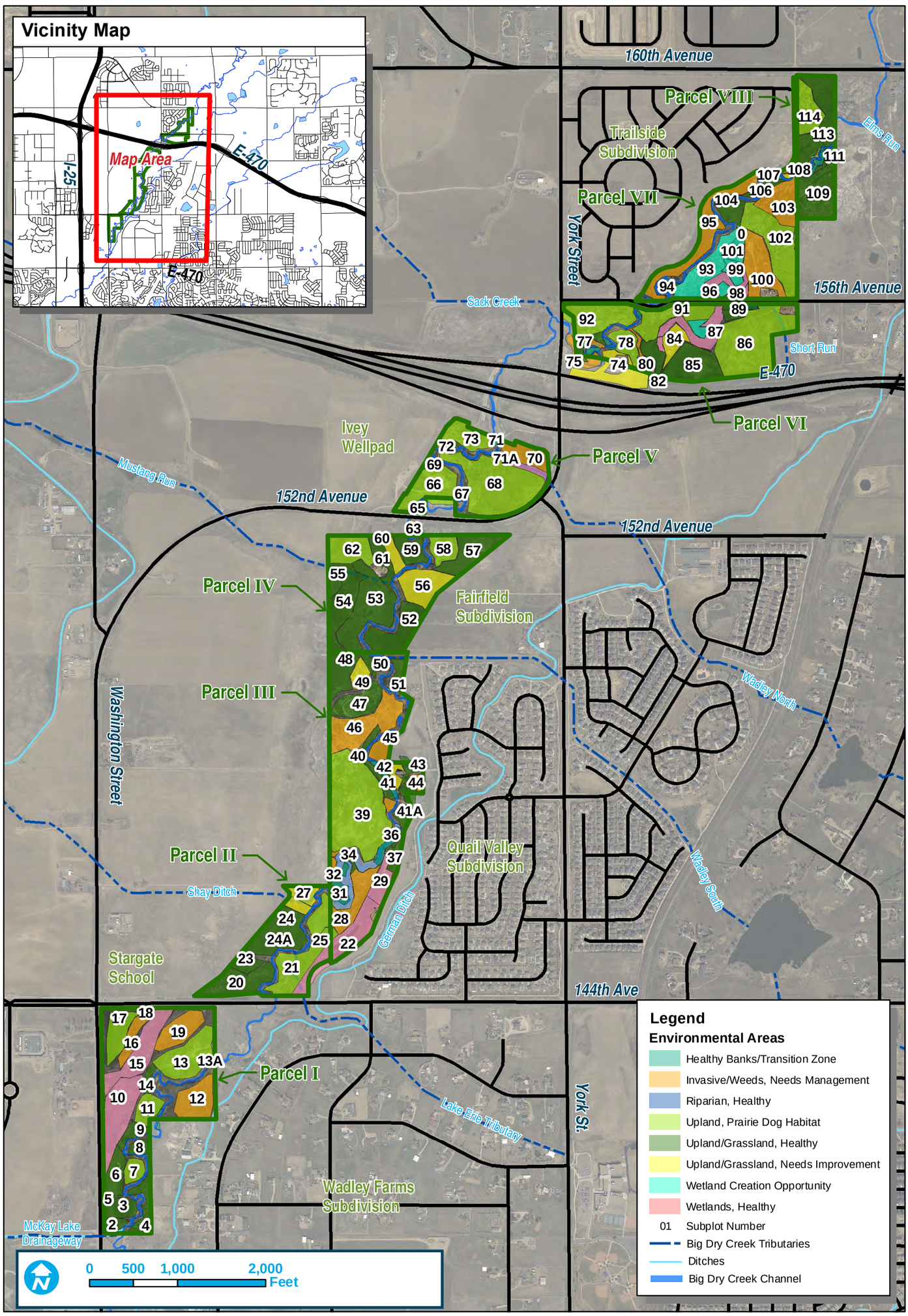
Uplands along Big Dry Creek are located between the overbank elevation and the upper edge of the floodplain (see Typical Habitats Graphic on page 44). On average, this area floods every 10+ years and is therefore exposed to erosive water forces only during large flood events. Upland areas are generally located over 2 feet from groundwater; therefore, plant species rely on surface water and available precipitation as their water source. Common Front Range upland vegetation includes upland shrubs such as rabbitbrush (Chrysothamnus nauseousus), sage (Artemisia spp), and three-leaf sumac (Rhus trilobata) with an understory of upland native and non-native grasses and herbaceous species. Trees are less common in the upland zone, although several native and non-native tree species are located in upland areas.

Riparian Areas

Riparian areas are located directly adjacent to Big Dry Creek and are shaped by the dynamic forces of regular creek inundation. Riparian areas are known as a transition between water bodies such as creeks and upland vegetated areas. They are often located adjacent to perennially or intermittently flowing streams, creeks, lakes and/or ponds. Riparian areas generally have high water tables and distinctive plant communities which are dependent on more frequent connection with available water sources. They are not wetlands however, as the association with water is less frequent and less saturated than a wetland. This narrow ecosystem commonly has a combination of native and non-native trees, shrubs and a vegetated understory mixed with native and non-native species. Riparian trees, shrubs, and undergrowth provide flood control, streambank stability, nutrient cycling, stream food web support, pollutant filtering, sediment retention, and wildlife movement and migration corridors. In addition to these functions, riparian areas provide passive recreational open space areas that are amenities in urban areas.

The riparian area is found between the bankfull elevation and the overbank elevation. On average, this area floods every 2 to 5 years and is generally flat with layered soils that have been deposited by previous flood events. The riparian zone represents a transition from areas supporting water-adapted plant species to those supporting upland plant species. Riparian vegetation has varying widths from the edge of the waterbody, depending on factors including geology, topography, elevation, soil type, hydrology, and development in the watershed. This vegetation depends on access to water but can handle occasional dry periods once established. Common Front Range vegetation found in this zone includes an overstory of plains cottonwood (Populus deltoides), peachleaf willow (Salix amygdaloides), and box-elder (Acer negundo) with an understory of sandbar willow (Salix exigua), other native and non-native shrubs, transitional area grasses, and herbaceous species.

Although riparian ecosystems represent only 3% of western habitat overall, this ecosystem is crucial for over half of the bird species and a majority of mammalian, amphibian and reptile species. The federally threatened Preble's meadow jumping mouse (***Zapus hudsonius preblei***) is known to occur along some Front Range creeks with appropriate riparian habitat. However the Master Plan study area falls within the U.S. Fish and Wildlife Service Block Clearance Map for this species. The Preble's meadow jumping mouse is therefore not a concern when working within this stretch of Big Dry Creek.

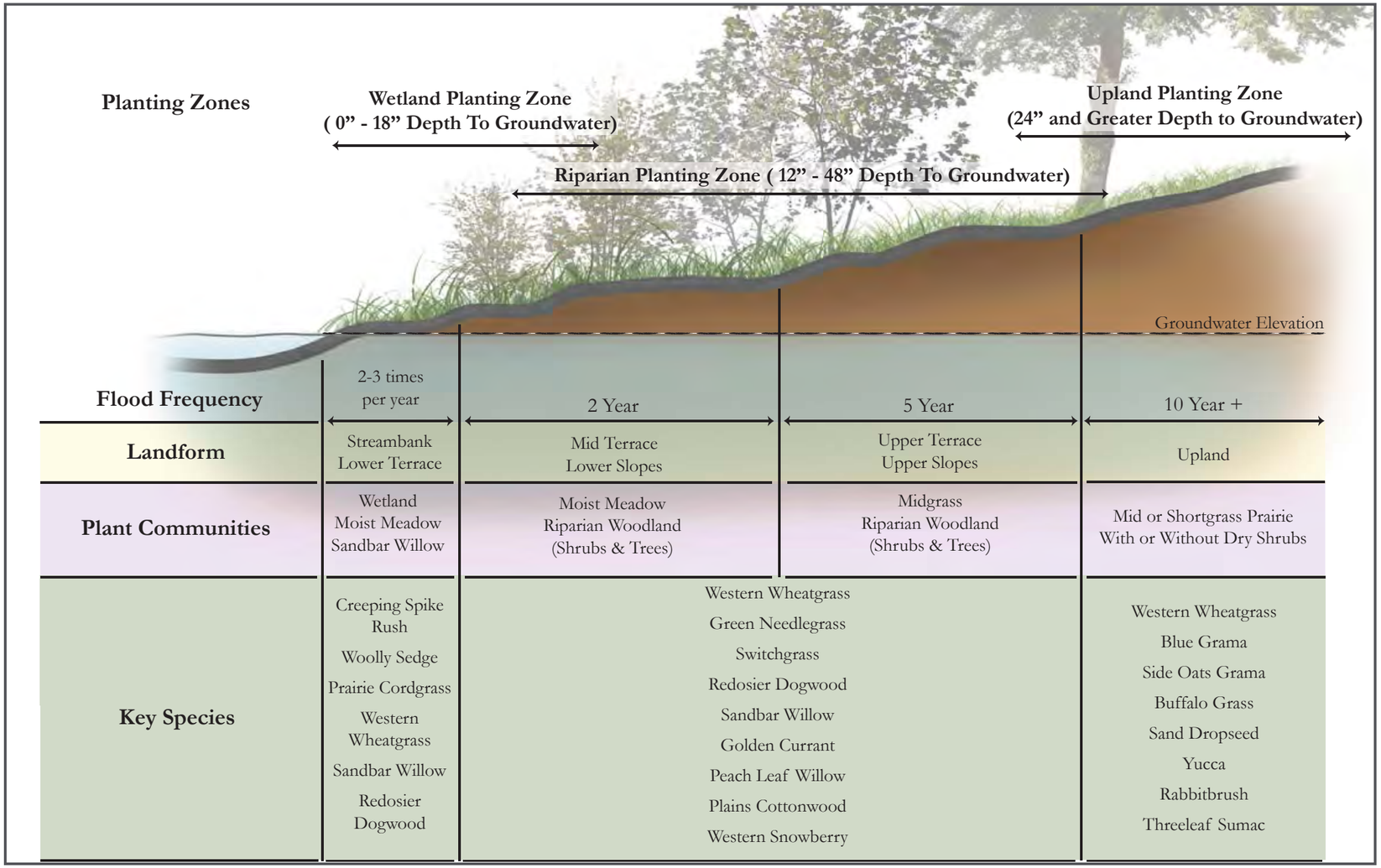


Big Dry Creek Existing Environmental Conditions Map

Wetland Areas

Wetlands areas are inundated or saturated by surface or groundwater for a certain duration of time that allows for wetland vegetation to establish. Wetlands are transitional areas between open water and drier land that are relatively shallow to permit rooted native and non-native vegetation to establish. They provide valuable functions including water quality improvement, floodwater attenuation and storage, soil stabilization, fish and wildlife habitat, and food web support.

The wetland zone along Big Dry Creek is located between the average water elevation and the bankfull discharge elevation (see graphic below). The lower section along the creek is exposed to the highest velocity flows and typically has the highest potential for erosion. The higher section (transitions into the lower riparian zone) is inundated less frequently and is exposed to less erosive forces. It is often vegetated with water-tolerant herbaceous plant species. Flexible-stemmed willows and low-growing shrubs capable of withstanding frequent inundation are found along Big Dry Creek. Common Front Range wetland species include sandbar willow (Salix exigua) and redosier dogwood (Cornus sericea) with an understory of native and non-native wetland grasses, sedge and rush.



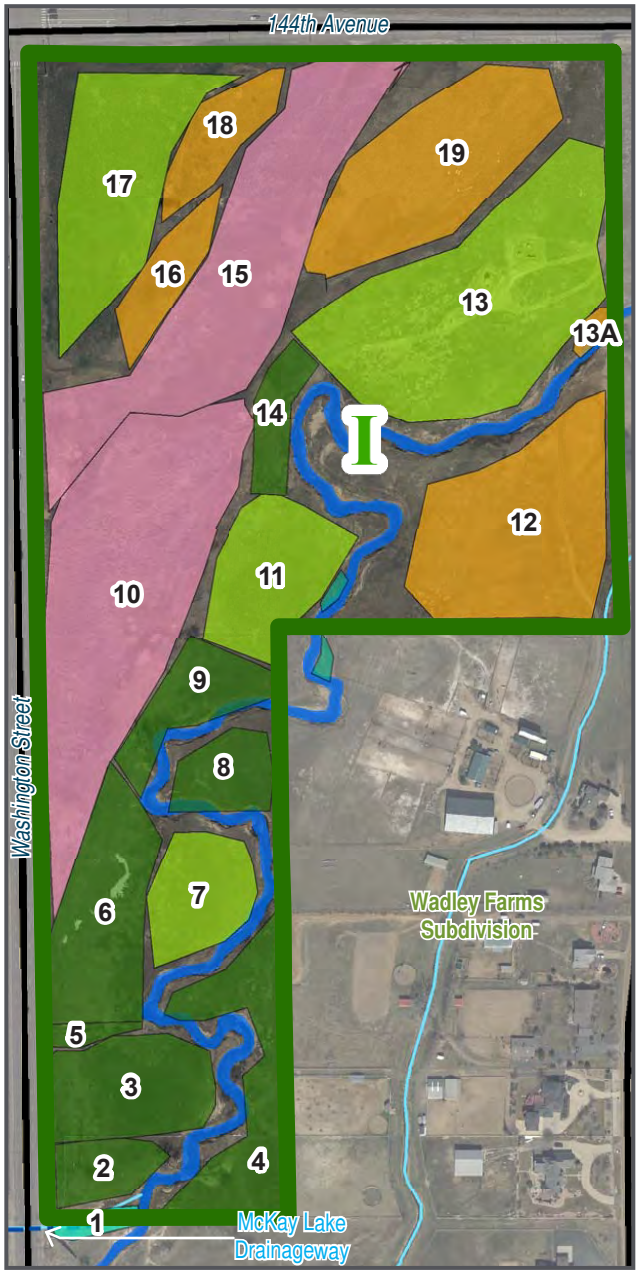
In order to gather useful data on the environmental conditions existing within the Big Dry Creek corridor, the project team spent multiple days inventorying the corridor parcel by parcel. The photographs and descriptions on the following pages catalog what was observed in each of the Big Dry Creek open space parcels.

Typical Habitats Graphic

Parcel I Environmental

Overview: Parcel I is a flat, grassy upland area likely partially mowed for weed control purposes. The upland grasses are healthiest in the southern half of the parcel especially on the east side of Big Dry Creek. Big Dry Creek winds through the parcel with few riparian trees and some riparian shrubs. There are steep eroding banks along this stretch of Big Dry Creek. A large wetland cattail complex, comprising approximately one-third of the parcel, drains to the north in the western half of the parcel. Prairie dogs and their burrows are most abundant in the northern third of the parcel, browsing heavily on upland grasses especially in the northwest corner.

Uplands: The uplands located in the southern half of Parcel I have healthy established native and non-native grass establishment, including subplots 2, 3, 4, 6, 8, and 9. Upland grass species include smooth brome (Bromus inermis), wheatgrass (Agropyron spp. and Thinopyrum spp.), sand dropseed (Sporobolus cryptandrus), crested wheatgrass (Agropyron cristatum), and Canada wildrye (Elymus canadensis). These uplands have some minor weed issues, such as kochia (Kochia scoparia), Russian thistle (Salsola tragus), curly dock (Rumex crispus), prickly lettuce (Latuca serriola), horseweed (Conyza canadensis), common burdock (Arctium minus), and Canada thistle (Cirsium arvensis), both along BDC and within upland areas. There is also Russian olive tree (Elaeagnus angustfolia) establishment, and some minor prairie dog habitat, as shown in the photos on this page. These subplots have few prairie dog burrows and are far enough from the established prairie dog towns located in the northern portion of the parcel to remain healthy and well established. Only uplands located in subplot 7 are heavily browsed by prairie dogs as a small prairie dog town is located in this subplot.



Parcel I Subplot map

Photo 1: Parcel I Uplands

Photo 2: Parcel I Uplands with prairie dog town

Uplands located in the northern half of Parcel I vary from good grass establishment with some prairie dog browse and minor weed issues (subplots 13, 14, and 19) to heavy prairie dog browse with heavy weed infestation (subplots 11, 12, 16, 17, and 18). Of these subplots, areas 11, 16, 17, and 18 are most bare due to heavy browse from the existing prairie dog towns and weedy species establishment as shown in Photo 2. Russian olive trees are also located in subplots 11 and 13 mainly along Big Dry Creek.

The overall upland condition at Parcel I is that there is fairly well established native and non-native grasses throughout with weedy patches and bare areas depending on proximity to the prairie dog town located in the northern third of the parcel. The prairie dogs are eating down the vegetation in the northern third of the Parcel and weedy patches are establishing throughout. In addition, agricultural practices are evident either through seeding activities, mowing of existing vegetation, or both. There are a few upland trees and shrubs located on Parcel I but some of the trees are dead or Russian olive trees, both of which could be removed. The dead trees are not old enough to make useful snags for wildlife.

Riparian: There are two channels entering Big Dry Creek from the west. The first one, McKay Lake Drainageway, is located in the very southwestern corner of Parcel I. This channel was excavated recently and only a small wetland fringe remains on the northern bank. It is approximately 30 – 35 feet wide and up to 1 foot deep in flowing water. This channel has perennial flow and drains directly into Big Dry Creek. The second channel, a small drainageway in subplot 5, is located slightly to the north of this first channel and is more of a wetland feature which connects flows to Big Dry Creek (see Photo 3).

Big Dry Creek itself winds through Parcel I with many steeply eroded banks. In some locations, there is benching along the creek with wetland/transitional established grasses, herbaceous plants and shrubs. This benching has a healthy mix of reed canarygrass (Phalaris arundinacae), rabbitfoot (Polypogon monspeliensis), barnyard grass (Echinochloa crus-galli), prairie cordgrass (Spartina pectinata), wild licorice (Glycyrrhiza lepidota), snowberry (Symphoricarpos occidentalis), wild rose (Rosa woodsii), teasel (Dipsacus fullonum), milkweed (Asclepias speciosa), goldenrod (Solidago canadensis), sandbar willow (Salix exigua), and primrose (Oenothera spp.)

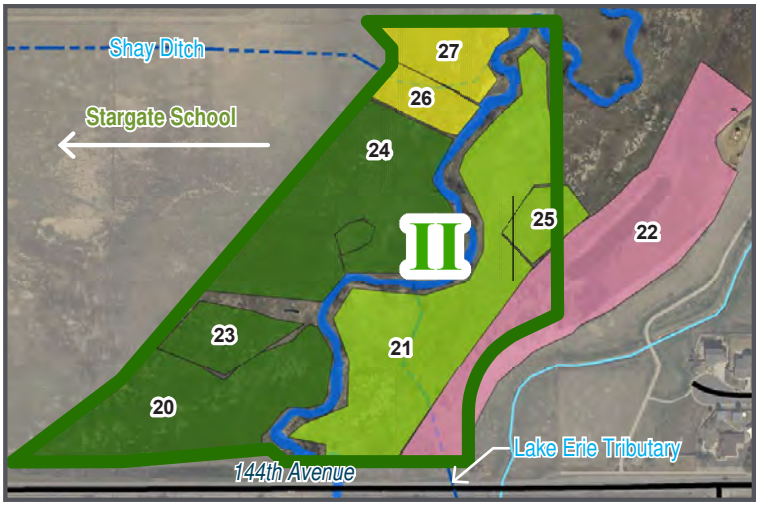
Photo 3: Parcel I Riparian

Photo 4: Parcel I Riparian

In other locations along Big Dry Creek, there are healthy stands of sandbar willow stabilizing the banks. Big Dry Creek has steep cut banks in many locations in Parcel I especially at the bends of the creek where creek velocities abut up to the bank edge, as shown in Photo 4. There are few riparian trees located along the creek and pockets of willows and riparian shrubs only. Cottonwood (Populus deltoides), peachleaf willow (Salix amygdaloides) and mainly Russian olive trees are found along Big Dry Creek throughout this parcel.

Wetlands: Wetlands located in Parcel I include a small wetland drainage located in subplot 5, and a large wetland complex that dominates sub plots 10 and 15. This larger wetland complex is dominated by cattails (Typha latifolia) in the southern portion of sub plot 10, but has greater wetland plant diversity in the northern portion of subplot 10 and throughout subplot 15. Wetland species include a variety of sedge (Carex spp.), rush (Juncus spp.), threesquare (Scirpus americanus), and spikerush (Eleocharis palustris). This appears to be a healthy wetland system with adequate hydrology to support the wetland plants. There are few wetlands located along Big Dry Creek as the banks are steep with only occasional low terracing.

Parcel II Environmental



Parcel II Subplot map

Overview: Parcel II has a flat upland grassland located on either side of Big Dry Creek, with a large linear wetland located east of the creek which stretches up into Parcel III. The upland area has generally well established upland grasses with less species diversity. There are some patchy weedy and bare areas. There are prairie dogs located east of the creek between the creek and wetland which have heavily browsed grasses leaving more bare patches. The banks along Big Dry Creek are incised and steep especially around the bends, with occasional vegetated banks providing better stability. Russian olive trees are abundant along this stretch of creek and even more abundant within the wetland area to the east. The wetland itself has established cattails and other wetland species. It is a healthy wetland and creates excellent wildlife habitat.

Legend
Environmental Areas
- Healthy Banks/Transition Zone
- Invasive/Weeds, Needs Management
- Riparian, Healthy
- Upland, Prairie Dog Habitat
- Upland/Grassland, Healthy
- Upland/Grassland, Needs Improvement
- Wetland Creation Opportunity
- Wetlands, Healthy

Uplands: Uplands located west of Big Dry Creek in Parcel II have a combination of native and non-native upland grasses including tall wheatgrasses, sand dropseed, and crested wheatgrass (see subplots 20, 23, and 24). These tall grasses have not been mowed recently. Weeds include mustards (Brassica spp.), cheatgrass (Bromus tectorum), curly dock, bladderpod (Desquerella ludaviciana) and Canada thistle (Cirsium arvense). There are some sandy bare patches throughout and remnant prairie dog burrows, as shown in Photo 5.

As you move north through this grassland, there are more sandy bare areas and more evident remnant prairie dog burrows. A new maintenance trail along Shay Ditch has been installed to access Big Dry Creek and the grasslands north of that are heavily impacted with bare dirt areas, weeds, remnant prairie dog burrows and some mowed grassy areas (see subplot 27). There are no trees and few

Photo 5: Parcel II Uplands

Photo 6: Parcel II Uplands

shrubs in this location. Uplands located on the east side of Big Dry Creek have established native and non-native upland grasses with some bare sandy areas and an active prairie dog population which increases as you move further to the north, as shown in Photo 6.

The prairie dogs and available vegetation seem to be in better balance in this location. There is also a fallen snag located in the southern part of subplot 21 which likely provides good wildlife habitat. In subplot 25, the grasses are more browsed due to active prairie dog establishment. There are more patches of bare and sandy soil than the grassland to the south, as shown in Photo 7.

Photo 7: Parcel II Uplands

Riparian: The riparian area banks located along Big Dry Creek in Parcel II are incised with steep banks mainly along bends where increased water velocities break off soil from the banks. There are locations where slopes are more graded and vegetation has established, as shown in Photo 8. In some locations, the bank is more gradual and established with sandbar willow (Salix exigua). However, Russian olive trees are abundant along Big Dry Creek in Parcel II. A few cottonwoods and peachleaf willows are also established along Big Dry Creek.

Photo 8: Parcel II Riparian

Wetlands: A healthy wetland is located east of Big Dry Creek in Parcel II, as shown in Photo 9. The wetland (see subplot 22) has moist soil and established wetland plants such as rush and threesquare in the southern portion. The wetland has stronger hydrological conditions to the north which allows for cattail, sedge, rush, threesquare, and spikerush establishment. The wetland is invaded by Russian olive trees throughout in Parcel II.

Photo 9: Parcel II Wetlands

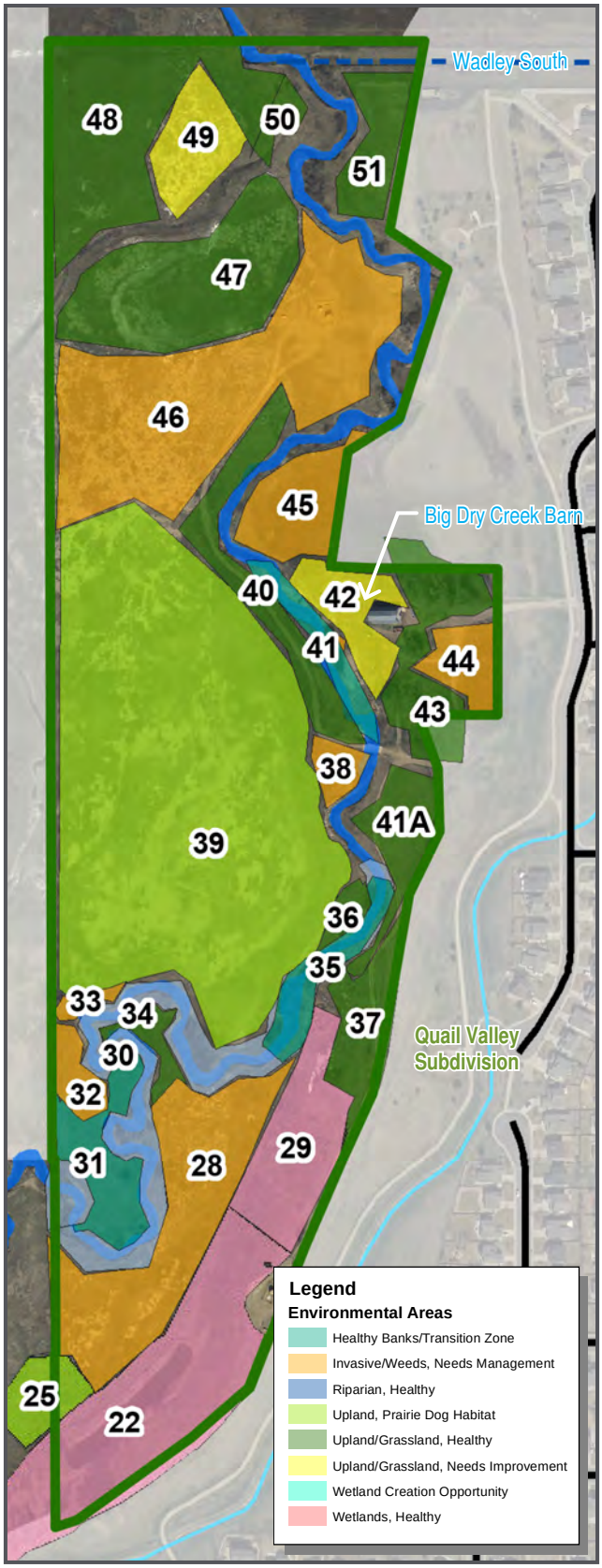
Parcel III Environmental

Overview: Parcel III contains some of the best examples of established, healthy and diverse upland, riparian, and wetland areas of all parcels. This parcel also contains some extremely degraded upland and less established and diverse riparian stretches located in the central and northern portions of the parcel. The riparian area located in the southern third of this parcel represents a reference stretch of riparian corridor that can be used for the remainder of the creek within this open space study area.

Uplands: Uplands located west of Big Dry Creek in Parcel III include excellent native and non-native grass establishment in subplot 31. This secluded area, as shown in Photo 10, is located in a bend of Big Dry Creek and provides important natural habitat for a protected natural site.

Photo 10: Parcel III Uplands

There are no active or remnant prairie dog burrows located in this secluded area. There is a multitude of bird life due to this combination of secluded upland, riparian, and adjacent wetland to the east of Big Dry Creek. The uplands located north of this subplot have teasel and other weedy species establishment. There are more prairie dog burrows and evidence of agricultural practices to the north into subplot 39 and 46. These subplots have many bare areas, prairie dog burrows, and low lying weedy species. Subplots 39 and 46 represent the largest area in Parcel III and are heavily degraded. A sliver of slightly better grass establishment is located east of subplot 39 and west of Big Dry Creek, but subplots 36 and 38 still contain many weedy species.



Parcel III Subplot map

Upland areas located west of Big Dry Creek and north of subplot 36 improve further to the north. Uplands located in subplot 47 have better native and non-native short grass establishment with a few bare areas and weedy patches, as shown in Photo 11.

Subplot 49 has many remnant prairie dog burrows, bare and weedy areas. However, subplot 48 located on both sides of subplot 49 has better upland grass establishment with some weedy patches.

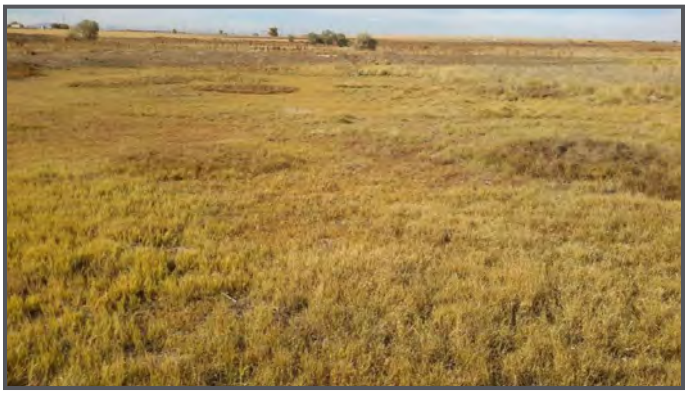


Photo 11: Parcel III Uplands

Photo 12: Parcel III Uplands

Uplands located east of Big Dry Creek in the southern portion of Parcel III include subplots 25 and 28. These subplots have some established tall grasses but patches of sandy, bare and weedy areas. There are some prairie dog burrows located in subplot 25. Uplands located in the very northern tip of subplot 28 are well established with less weeds and bare areas as this is another protected and secluded location within a bend of the creek.

Uplands located in subplot 37 have well established tall grasses and herbaceous species with less weedy patches. There are also no active prairie dogs located here. The next set of uplands located east of Big Dry Creek include uplands located around the existing historic barn. There are beautiful cottonwoods located just south of the barn, but mowed grasses with lots of bare and weedy patches are located in the under-story around the barn as shown in Photo 12.

These uplands are very dry and damaged. One dead owl was also found in this location. The upland located in subplot 51, north of the barn, is in better condition. This upland has well established upland grasses that are well maintained.

Riparian: The riparian area located in the southern third of Parcel III is a good reference for the rest of the riparian area in the open space in terms of number and species of riparian trees and shrubs present. There are many beautiful cottonwoods and peachleaf willow trees located along Big Dry Creek in this location. Several snags located along the riparian area, shown in Photo 13, create excellent wildlife habitat.

Photo 13: Parcel III Riparian

Photo 14: Parcel III Riparian

Within this parcel, there are creek stretches that are well vegetated with riparian grasses, shrubs, and herbaceous species, shown in Photo 14. There are some vertically eroded slopes along this stretch of creek also, as shown in Photo 15. Some Russian olive trees have established along this stretch of creek. The number of trees and shrubs, particularly in the southern third of Parcel III, have created a well balanced riparian ecosystem. Overall, the riparian vegetated condition along the creek throughout this parcel is good.

Photo 15: Parcel III Riparian

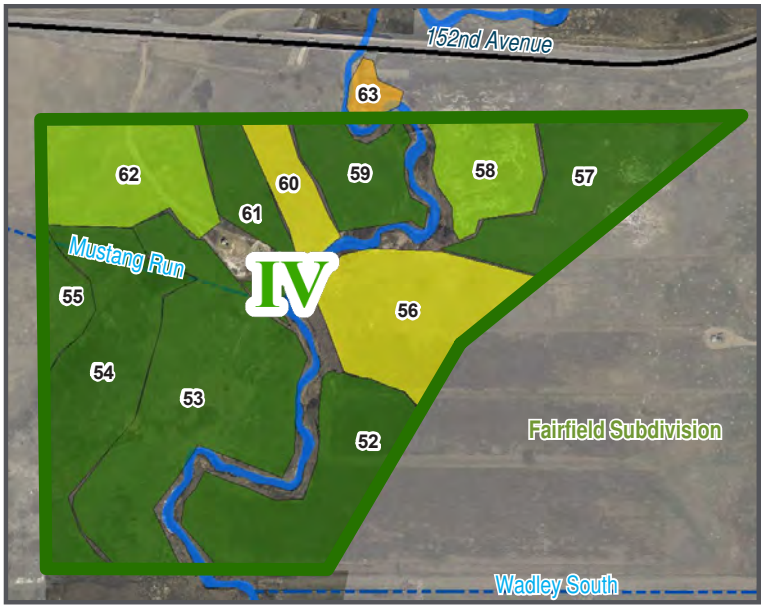
Wetlands: There is a large wetland complex located in subplot 22 that stretches north into subplot 29. This wetland has good wetland plant diversity with cattails, sedge, rush, threesquare and spikerush located throughout. This wetland complex is excellent wildlife habitat for many wildlife species including bird life. Russian olive tree establishment in the southern part of this wetland complex is a problem. Russian olive trees have also established along the eastern edge of the wetland complex.

Parcel IV Environmental

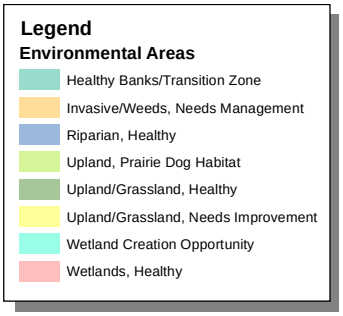
Overview: Parcel IV is a generally well vegetated upland parcel with a few prairie dogs and bare or weedy patches. Big Dry Creek winds through this upland with some vegetated riparian stretches but other steep eroding stretches. There are few trees located along Big Dry Creek in this parcel and mainly Russian olive trees.

Uplands: Uplands in Parcel IV located west of Big Dry Creek include well established wheatgrasses with patches of curly dock and teasel, as shown in Photo 16.

Subplot 54 is a more moist side drainage that has established wheatgrasses, Baltic rush (Juncus balticus), other rush species, curly dock, willowherb (Epilobium spp.) and some establishing sandbar willow. A small subplot located just west of this area (subplot 55) is an upland with prairie dog burrows, upland grasses and weedy patches. Subplot 62, located in the north-western corner of this parcel, is also a more barren upland area with prairie dog burrows, sandy soil, and bare/weedy areas throughout. The uplands improve in subplot 61 to the east but construction has completely graded subplot 60 across the creek to the east. There is residential housing being built across the creek, and this construction is related to the grading activity. Subplot 59 located to the east adjacent to Big Dry Creek has well established grasses including wheatgrasses with occasional curly dock and weeds.



Parcel IV Subplot map



Uplands located to the east of Big Dry Creek include well established areas with smooth brome, wheatgrasses and some remnant prairie dog burrows with weedy patches. As shown in Photos 17-18, subplot 56 has been graded due to development to the east.

Subplots 57 and 58 to the north have a combination of good upland grass establishment with a moderate number of prairie dog burrows and sandy soil. There are therefore bare and weedy patches throughout.

Photo 16: Parcel IV Uplands

Photo 17: Parcel IV Uplands

Photo 18: Parcel IV Uplands

Riparian: Big Dry Creek winds through Parcel IV with some nicely vegetated sections including sandbar willow, grasses and herbaceous species, as shown in Photo 19. Many stretches of the creek in this parcel are vertical and bare with eroding banks. In addition, there are few trees established along this entire stretch of creek and most are Russian olive trees.

Wetlands: The only wetland located near this parcel as shown on Photo 20 is located just north of Parcel IV on E-470 ROW in what is mapped as subplot 63. It is dominated by cattails and teasel and surrounded by mainly Russian olive trees.

Photo 19: Parcel IV Riparian

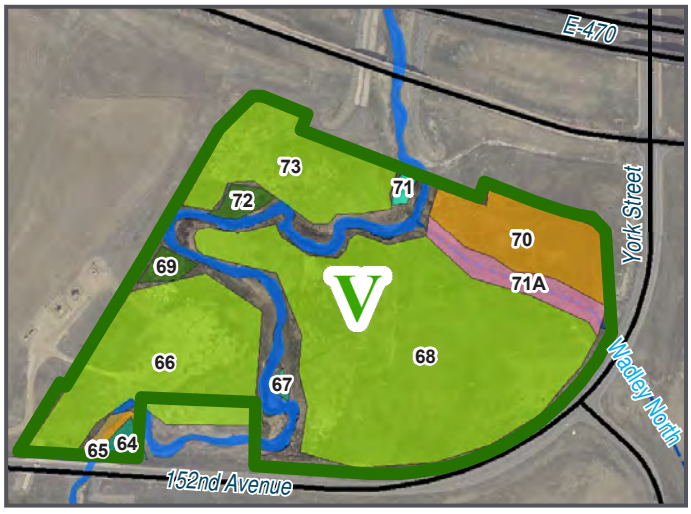
Photo 20: Parcel IV Wetlands

Parcel V Environmental

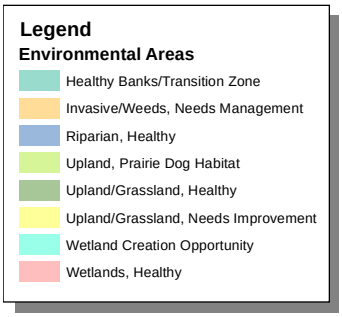
Overview: Uplands located throughout most of Parcel V have some patches of grass establishment that is either heavily browsed by prairie dogs or is also mowed. Active prairie dogs and their burrows are seen throughout and the uplands have bare sandy and weedy patches. Big Dry Creek winds through this parcel with excellent riparian shrub, grass, and herbaceous plant establishment.

Some lower terraces could be delineated as wetland benching. Cottonwood and peachleaf willow have established sporadically along Big Dry Creek with Russian olive trees established in other locations. However, the bank stability within Parcel V raises concerns.

Photo 21: Parcel V Uplands



Parcel V Subplot map



Uplands: Uplands located west of Big Dry Creek in Parcel V include mainly mowed and browsed native and non-native patches with a moderate abundance of prairie dog burrows throughout. The vegetation is sparse and there are lots of weedy low-lying patches interspersed between prairie dog burrows, as shown in Photo 21.

Subplots 69 and 72 have slightly better grass establishment. Subplots 71 and 71A include Wadley North Creek and a low-lying area adjacent to Big Dry Creek that could be lowered and/or flooded to create a wetland, as shown Photo 22. Uplands located on the east side of Big Dry Creek are similar to the western side with patches of mowed and/or browsed native and non-native grasses around active prairie dog burrows with patches of low-lying weeds.

Photo 22: Parcel V Uplands

Photo 23: Parcel V Riparian

Riparian: The riparian area located along Big Dry Creek in Parcel V is generally well vegetated with some riparian trees, good willow, grass and herbaceous species establishment. There are a few areas of steep vertical banks and erosion, but not as many as in other parcels.

Sandbar willow is well established along Big Dry Creek in the southern portion of the parcel. Subplot 64 has good cottonwood, sandbar willow, riparian grass and cattail establishment, as shown in Photo 23.

Russian olive and thistle control is needed however. Vegetation includes cottonwood and peachleaf willow trees, sandbar willow, barnyard grass, rabbitsfoot grass, ladysthumb (Polygonum persicaria), bulrush (Schoenoplectus spp.), reed canarygrass, spikerush, threesquare, teasel, and curly dock. Russian olive trees and Canada thistle need to be controlled. Two erosional features involving sloughed off side banks are also vegetated with riparian trees, shrubs, grasses and herbaceous plants stabilizing the sloughed material, as shown in Photo 24.

This variety of established riparian and wetland vegetation along Big Dry Creek in Parcel V can be used as a reference for establishing other side banks along Big Dry Creek within this open space area. Although this area provides wildlife habitat, the creek meanders are threatening adjacent infrastructure and may need to be armored and/or straightened with grade control measures.

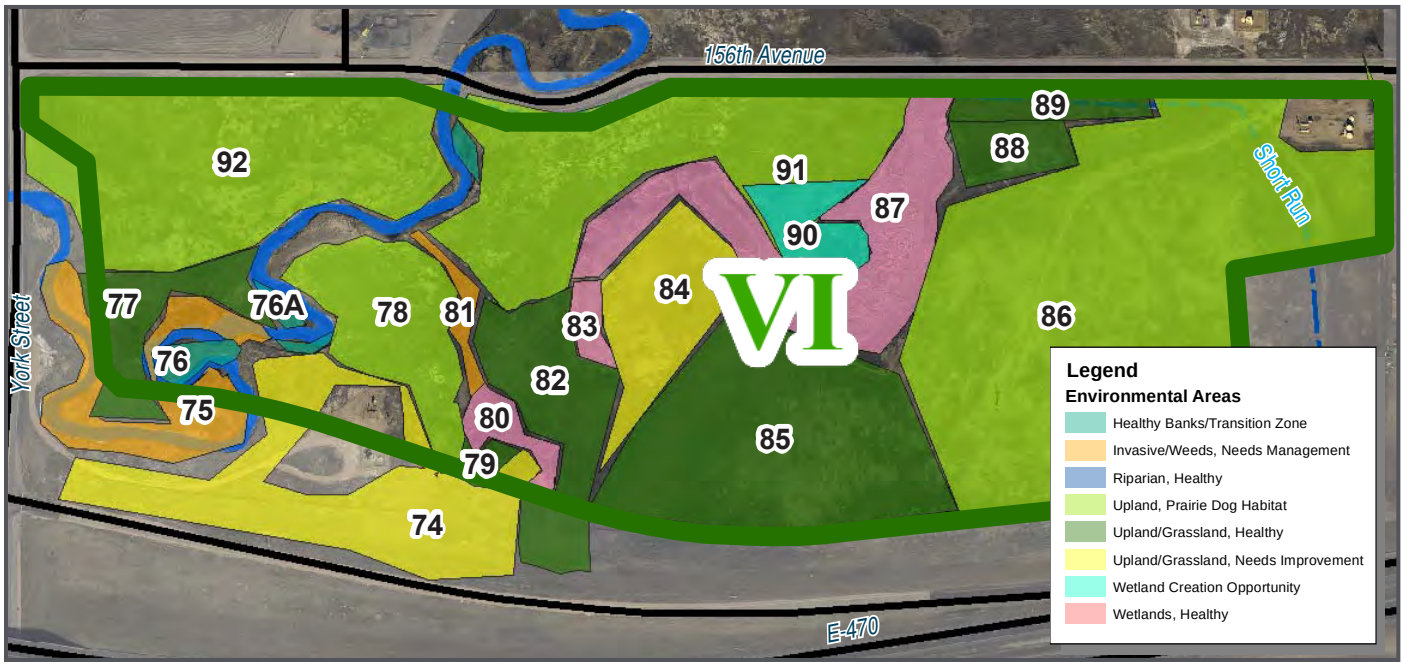
Wetlands: There are wetlands located on the fringe of riparian benching throughout this parcel. Depending on the proximity of the bench to the surface water below and established vegetation, the benching may or may not meet wetland criteria. Parcel V has a good variety of vegetated side banks with both wetland and riparian vegetation. In addition, Wadley North Creek, a wetland channel, enters Parcel V from the east drainage into Big Dry Creek, as seen in Photo 25. This approximately 50-foot wide channel is dominated by cattails with willow, sedge, rush, and three square establishment.

Photo 24: Parcel V Riparian

Photo 25: Parcel V Wetlands

Parcel VI Environmental

Overview: Parcel VI is a parcel with a short stretch of Big Dry Creek located in the western third and a large upland area to the east with remnant oxbow wetlands. These oxbow wetlands provide additional excellent wildlife habitat to what is found along the riparian corridor. The uplands are marginal but contain some patches of well established upland native and non-native grassland.



Parcel VI Subplot map

Uplands: The uplands located west of Big Dry Creek contain some upland grasses and weedy species, which are mowed and/or browsed by the moderate amount of prairie dog burrows located in subplot 92 and to a lesser extent in subplot 77. There are some bare areas also located in subplot 77.

The upland located east of Big Dry Creek shows some established upland grasses and weedy areas with prairie dogs evident in subplot 78 browsing on these grasses. In addition, there are sandy bare areas located in subplot 78. Subplot 79 is an upland patch filled with plantain as shown on Photo 26 at the end of an upland drainage located in subplot 81.

This drainage has upland grasses and weedy patches. Subplot 82 has well established upland grasses with some weedy patches but no evidence of prairie dogs as seen in Photo 27.

This contrasts to the upland area in subplot 91 which has active prairie dog burrows, weedy and bare sandy patches. A wetland meanders through the middle of this parcel and uplands on the east side of this meander include subplots 84, 85, 86 and 88. Subplot 84 is located on the inside bend of the wetland meander and could be excavated to create additional wetland areas. It is an upland grassland with weedy patches and only a few remnant

Photo 26: Parcel VI Uplands

Photo 27: Parcel VI Uplands

prairie dog burrows. Subplot 85 is a mowed agricultural field with a few remnant prairie dog burrows. The larger subplot 86 to the east has a moderate number of prairie dog burrows and many bare and weedy patches. The smaller subplot 88 to the north has better established upland grasses with some weeds and a few bare areas. Short Run drainageway runs through subplot 88 with upland grasses, weedy species, and established Russian olive trees.

Riparian: Big Dry Creek winds through this upland parcel with good riparian tree, shrub, grass and herbaceous species establishment, as shown in Photo 28. There are also steep vertical eroding banks located in stretches along the creek. There are many Russian olive trees located along the creek. There is also some lower benching with establishing rabbitsfoot, barnyard grass, reed canarygrass, wheatgrass, mustard, curly dock and horseweed.

Photo 28: Parcel VI Riparian

Wetlands: A cattail wetland is located in subplot 80 and is dominated by cattails. This area is located at the end of a small upland drainage (subplot 81) and is likely maintained by flow from this drainage and possibly groundwater also. A portion of subplot 74 and 79 could also be excavated adjacent to subplot 80 to create additional wetland area. An oxbow wetland is located in subplots 83 and 87. The wetland is dominated by reed canarygrass in subplot 83 and by cattails along with sedge, rush, threesquare and spikerush in subplot 87, as shown on Photo 29. This is a well-established wetland area which attracts much bird life and likely maintains many other wildlife species.

Photo 29: Parcel VI Riparian

Parcel VII Environmental

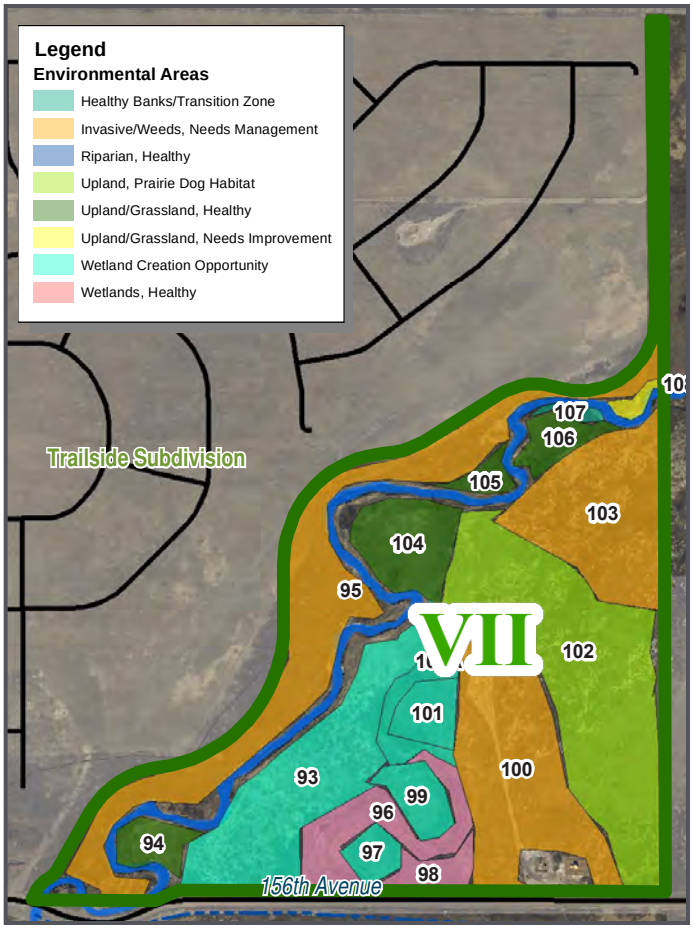
Overview: Parcel VII contains weedy uplands west of Big Dry Creek and moderately established uplands east of Big Dry Creek. The riparian area is less incised through this parcel with more vegetated side banks, however riparian tree and shrub establishment is limited. One of the best features in this parcel is the well established oxbow wetland located in the south-central portion of the parcel.

Uplands: Uplands located west of Big Dry Creek in Parcel VII are heavily infested with weeds such as dock, kochia, Russian thistle, sweetclover (Melilotus spp.), teasel and horseweed, as shown on Photo 30. There is slightly better grass establishment in subplot 105.

Uplands located east of Big Dry Creek have sandy soil, patchy areas of native and non-native grass establishment and patches of weeds. Upland vegetated subplots 93 and 100 are more patchy and damaged where there is evidence of prairie dog use and activity. The grasses are better established and less patchy in subplots 97, 99, 101, 104 and 106, where prairie dog burrows and likely prairie dog use of the area is less evident. There are also upland areas such as in subplots 102 and 103 where grasses are moderately well established with some weedy and sandy bare patches with only a moderate number of prairie dog burrows.

Riparian: The riparian area is less incised through this parcel, therefore has better grass and herbaceous plant establishment along the banks. Riparian tree and shrub establishment is limited along sections of the creek. The northern portion of this parcel has lower terraces that have well established riparian tree, shrub and understory vegetation. There are some large cottonwoods located sporadically along the creek. There are also Russian olive trees located at both ends of this parcel.

Wetlands: Wetlands located in Parcel VII include establishment along lower terraces and benching along Big Dry Creek and an oxbow wetland located in the south-central portion of the parcel. This well-established cattail wetland forms an S-curve through the parcel with upland areas 97 and 99 located within the curves. A wetland drainage is located between the creek and upland area 101. This drainage backs up water from the creek and has stronger wetland characteristics closer to the creek. Wetland plants include Baltic rush, threesquare and teasel, as shown in Photo 31.



Parcel VII Subplot map

Photo 30: Parcel VII Uplands

Photo 31: Parcel VII Wetlands

Parcel VIII Environmental

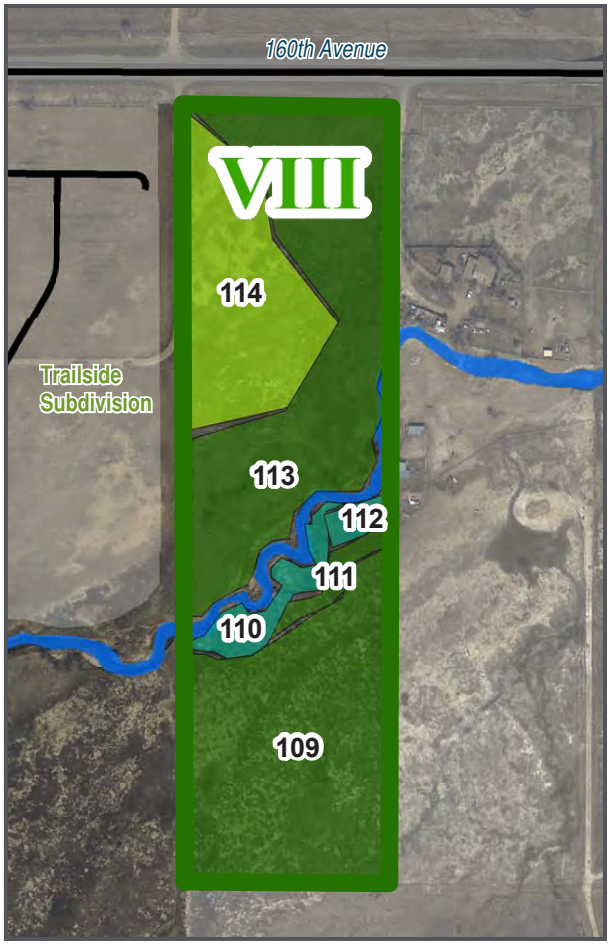
Overview: Parcel VIII is located at the northeast end of the open space areas surveyed. Uplands located within this parcel have a balance of moderately established upland grasses with some prairie dog activity. Riparian areas have excellent terracing with riparian tree, shrub, and understory vegetation. Some wetlands occur along the riparian terracing where hydrological connection allows for wetland plant establishment.

Uplands: Uplands located northwest of Big Dry Creek have good native and non-native grass establishment with some weedy and bare patches. There is a moderate amount of prairie dog activity in these upland areas with vegetation browse and bare areas increasing around the burrows. There appears to be a good balance between the prairie dog community and available vegetation for food in this parcel. Uplands located southeast of Big Dry Creek are also moderately well established with upland grasses including some bare and weedy patches. There is a smaller number of prairie dogs in this location with a greater number of bare, sandy and weedy patches adjacent to any existing burrows.

Riparian: There are several lower terraces along Big Dry Creek in this location. The lower terraces have cottonwood, peachleaf willow, sandbar willow, teasel, reed canarygrass and other riparian vegetation establishment, as shown in Photo 32.

Big Dry Creek is somewhat less incised through this parcel and riparian vegetation is found along the creek with only a few stretches of vertical eroding banks. Russian olive trees have also established along the creek throughout this parcel.

Wetlands: Wetlands are located in pockets within the lower terracing and benching along Big Dry Creek. The vegetation includes cattail, rush, sedge and threesquare, as shown in Photo 33.



Parcel VIII Subplot map

Legend
Environmental Areas
- Healthy Banks/Transition Zone
- Invasive/Weeds, Needs Management
- Riparian, Healthy
- Upland, Prairie Dog Habitat
- Upland/Grassland, Healthy
- Upland/Grassland, Needs Improvement
- Wetland Creation Opportunity
- Wetlands, Healthy

Photo 32: Parcel VIII Riparian

Photo 33: Parcel VIII Wetlands

Oil and Gas Exploration

In addition to municipal utilities, there are several oil and gas operations within or adjacent to the Big Dry Creek open spaces. As of January of 2017, companies operating within these open spaces are:

- Mendell Finisterre, LLC
- Tudex Petroleum, LLC
- KP Kauffman Company, Inc.
- Great Western Operating Company, LLC
- Synergy Resources Corporation
- Starlight Resources, LLC
- Extraction Oil and Gas, LLC
- Kerr-McGee Corporation

Oil and gas pad and access roads adjacent to Big Dry Creek Parcel V

While all of these companies have active operations in the open spaces, their mining operations vary in regards to the type of natural resources they extract as well as their levels of activeness. Most, if not all of the operations have access roads to their operation site. Although the project team reached out to these companies to investigate details of the operations and possible future partnerships, no successful partnerships were made. Great Western did however provide useful information about the operations. Typically, these wells have a lifespan of 20 to 40 years and the wellpad is reclaimed back to natural contours and vegetation once the lifespan of the well is done. The operating company is responsible for maintaining their access roads, and although they typically are not used for formal trails or paths, some companies may be open to discussions on shared use.

The operating company is responsible for reclaiming and restoring any land affected by their operations after production has stopped. This land, including their pad site, access roads, storage locations, etc., would be reclaimed in a manner that mimics the natural surroundings and supports adjacent ecosystem health. All reclamation efforts should incorporate recommendations in this Master Plan and adhere to city of Thornton and Adams County design standards and guidelines.

Near the end of 2016/beginning of 2017, Ward Petroleum submitted plans to develop one wellpad (the Ivey Wellpad) with up to 26 wells and an access road directly west of Parcel V north of 152nd Avenue. The 26 wells would not be drilled consecutively and each well has an intended production life of 20 to 40 years. The wellpad would be situated on land in unincorporated Adams County and in a letter dated February 13, 2017, Ward notes that two of the reasons the site was chosen are:

- The location will not affect any current open space.
- The wellpad is over 3,000' from any public gathering area.

The city of Thornton has notified Adams County that the adjacent Big Dry Creek Open Space (Parcel V) location that has been chosen for the Big Dry Creek pilot project (discussed in further detail in Chapter 6) and this parcel will contain trails, a trailhead (public gathering place) and interpretive signage. Thornton has provided general guidelines and recommendations to the operator for the development of this site, which are detailed in Chapter 4 Plan Recommendations.

Chapter 4 - Plan Recommendations

Recommendations Overview

This chapter of the Master Plan explains the recommendations arrived at as a result of the master planning process. These recommendations are built upon the background documents and plans presented in Chapter 2 Background, the existing conditions presented in Chapter 3 Existing Conditions, input from multiple city and county departments and the input heard at the public workshops. The entirety of the master planning process is described in detail in Chapter 7 Process.

These recommendations, as well as the entire Master Plan, are meant to act as a guiding document when individual projects within the Big Dry Creek corridor are funded, designed and installed. Rather than designing the entire corridor in detail, a 'toolbox' approach was taken to the Master Plan to provide flexibility and make the Master Plan recommendations applicable to a greater variety of projects or improvements. For example, by providing a set of stream stabilization improvements and guidance for use in applicable situations, Thornton and Adams County have the flexibility to provide specific improvement options to projects in or adjacent to the corridor. Similarly, by providing guidelines for the types of trails, site amenities, passive recreation components and general alignments of trails, Thornton and Adams County have the flexibility to install projects in phases rather than needing to acquire funding for the entire project at once.

Parcel III of the Big Dry Creek open space with the Big Dry Creek Barn

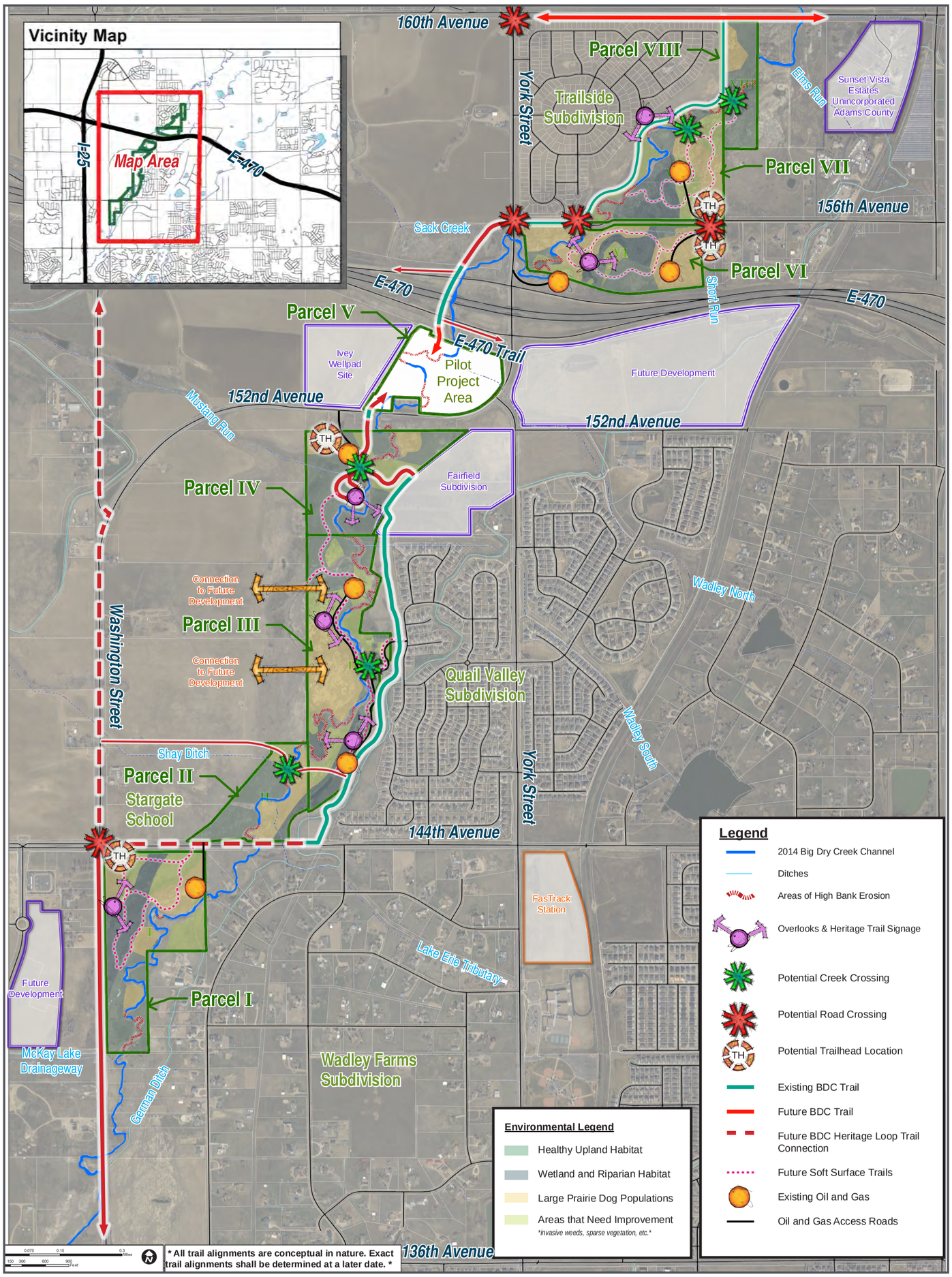
Immediately following the completion of the Master Plan, Thornton is designing and constructing a floodplain restoration pilot project on Parcel V to serve as an example of implementing the Master Plan recommendations and to garner public support for further improvements along the corridor. This pilot project is discussed in greater detail in Chapter 6.

The recommendations contained in this Master Plan are separated into three overall categories: Recreation and Infrastructure, Floodplain Restoration and Environmental Recommendations. While these categories often overlap and almost always interact, many of the actual categories can be separated out individually. However, it is the recommendation that projects encompass as many improvement categories (such as bank erosion, invasive plant species, revegetation, recreation, etc.) as possible. Cost efficiency can be increased by creating a 'multi-purpose' project, as this may reduce or eliminate the need to go through multiple permitting processes on the same site, ensures compatibility between the categories and makes the project eligible for multiple funding sources.

Recreation and Infrastructure

Recreation and infrastructure recommendations cover recreational features such as the Big Dry Creek Trail, informal trails, trailheads, site amenities including Heritage Trail theming and signage, road and stream crossings, natural play areas, as well as infrastructure such as utilities, oil and gas guidelines and requirements of adjacent developments. These recommendations are intended to be used as a guide for future projects and should only be modified with approval by Thornton or Adams County staff. On the facing page is the Big Dry Creek Master Plan Map. Criteria and elements that this map shows include:

- Existing environmental conditions
- High priority geomorphic reaches of Big Dry Creek
- Oil and gas wells and access roads
- Nearby and future developments
- Future trail connections
- Proximity to area schools
- Irrigation ditches
- Heritage Trail story node locations



Big Dry Creek Master Plan Map

Recommendations by Parcel Matrix

	Recreation Improvements	Infrastructure/External Improvements	Hydraulic/Geomorphic Improvements
Parcel I **Adams County** **48.79 Acres**	> **Trailheads:** Up to 8,000 SF with parking lot and restrooms; must be in northwestern portion of parcel. > **Trail Types:** Soft surface and boardwalks. > **Creek Crossings:** None. > **Overlooks & Heritage Trail Signage:** Healthy wetlands and riparian areas.	> Connections must be made to future the Big Dry Creek Trail that will be built on the west side of Washington Street and the north side of 144th Avenue. This could include at-grade or grade separated crossings of 144th Avenue. > Trailhead location being restricted to the northwest corner will require a vehicular access further to the east (away from the Washington Street intersection). > Oil and gas reclamation efforts to follow Master Plan guidelines.	> Bank stabilization in High Priority Reach (HPR*) 1. > Stabilize smaller eroding banks throughout. > High priority bank erosion southwest of oil/gas well could progress to an oxbow; recommend armoring or stabilization. > Maintain existing livestock fencing to separate livestock from Big Dry Creek.
Parcel II **Thornton** **24 Acres**	> **Trailheads:** None. > **Trail Types:** Shay Ditch Trail (to be built) and the Big Dry Creek Trail to be installed along the north side of 144th Avenue. > **Creek Crossings:** Shay Ditch Trail. > **Overlooks & Heritage Trail Signage:** None.	> Connections must be made to future Big Dry Creek Trail that will be built on the north side of 144th Avenue. This could include at-grade or grade separated crossings of 144th Avenue.	> Channel realignment and bank stabilization in HPR 2. > Stabilize smaller eroding banks throughout. > High priority bank erosion with high vertical bank in central portion of parcel. > HPR 3 begins in this parcel, but most of it is in Parcel III.
Parcel III **Thornton** **59.29 Acres**	> **Trailheads:** None. > **Trail Types:** Existing Big Dry Creek Trail to the east, Shay Ditch Trail (to be built) and soft surface trails, possibly on existing oil/gas access roads. Future trail connections to parcels to the west as they are developed. > **Creek Crossings:** Existing oil/gas access bridge near Big Dry Creek Barn; bridge is in need of repairs/improvements. > **Overlooks & Heritage Trail Signage:** Healthy wetlands/riparian areas, agriculture and the Big Dry Creek Barn.	> Existing Big Dry Creek Trail to the east; does not currently have 2' soft surface shoulder. > Trail connections should be made when the privately owned parcels to the west are developed. > Oil and gas reclamation efforts to follow Master Plan guidelines.	> HPR 3: Opportunity to form an oxbow and create wetlands, grade control and bank stabilization. > HPR 4: Bridge repairs/replacement to increase conveyance and abutment conditions, grade control. > HPR 5: Revegetation, grade control and bank stabilization. > Removal/reparation of blown out culverts in HPR 5 should be a high priority.
Parcel IV **Thornton** **41 Acres**	> **Trailheads:** Trailhead in northwest portion of parcel, possibly off of existing oil/gas access road with Big Dry Creek open space sign; no size restrictions. > **Trail Types:** Big Dry Creek Trail and soft surface. > **Creek Crossings:** Proposed Big Dry Creek Trail crossing; existing pedestrian bridge is not in usable condition. > **Overlooks & Heritage Trail Signage:** Big Dry Creek and healthy upland habitat.	> Existing Big Dry Creek Trail along the eastern edge to the middle of the parcel; does not currently have 2' soft surface shoulder. > Existing underpass under 152nd Avenue. > Existing oil/gas access roads offer opportunities for trailhead access and soft surface trails. Oil and gas reclamation efforts to follow Master Plan guidelines. > Existing pedestrian bridge is not in a safe/usable condition.	> HPR 6: Grade control, bank stabilization and revegetation. > Stabilize smaller eroding banks throughout. > Proposed Big Dry Creek Trail crossing of Big Dry Creek can be combined with a stream restoration project.
Parcel V **Thornton** **25.54 Acres**	> **Trailheads:** One trailhead proposed with access from York Street/152nd Avenue intersection; trailhead can be up to 36,000 SF (3% of total parcel area). > **Trail Types:** Big Dry Creek Trail and soft surface. > **Creek Crossings:** Proposed Big Dry Creek Trail crossing. > **Overlooks & Heritage Trail Signage:** Pilot project and stream restoration/habitat.	> Existing underpasses under 152nd Avenue and E-470. > Ivey Wellpad site to be developed to the west. > Oil and gas reclamation efforts to follow Master Plan guidelines.	> HPR 7 recommendations include channel realignment, bank stabilization, revegetation, grade control and oxbow wetland creation. > This parcel requires substantial stream restoration work to reduce threats to roads and adjacent oil/gas well development.
Parcel VI **Thornton** **44.08 Acres**	> **Trailheads:** None planned, but they are allowed as long as they are sized appropriately for passive recreation uses. > **Trail Types:** Existing Big Dry Creek Trail along 156th Avenue, soft surface and boardwalks. > **Creek Crossings:** Possibly with 156th Avenue bridge project. > **Overlooks & Heritage Trail Signage:** Wetlands, uplands and types of habitat.	> Existing oil/gas well and access road in the southwestern portion of the parcel; road is in need of bank stabilization. Oil and gas reclamation efforts to follow Master Plan guidelines. > Connections must be made to E-470 parcel west of York Street, Big Dry Creek Trail is built along 156th Avenue and connects to the existing Big Dry Creek Trail north of 156th Avenue. > 156th Avenue bridge project is an opportunity to combine projects.	> HPR 8 is threatening the oil/gas access road (and potentially York Street). Recommendations include bank stabilization, revegetation and wetland creation (with grade control). > Stabilize smaller eroding banks elsewhere in the parcel.
Parcel VII **Thornton** **34 Acres**	> **Trailheads:** Secondary trail/boardwalk trailhead in southeast corner of parcel. > **Trail Types:** Existing Big Dry Creek Trail to the west, soft surface and boardwalks. > **Creek Crossings:** Proposed boardwalks and secondary trails. > **Overlooks & Heritage Trail Signage:** Wetlands, uplands and types of habitat.	> Existing Big Dry Creek Trail along the western edge of the parcel; does not currently have 2' soft surface shoulder. > Oil/gas access road exists in southeastern portion of parcel where a trailhead could be located. > Oil and gas reclamation efforts to follow Master Plan guidelines.	> HPR 9: Grade control, bank stabilization and channel realignment (all of this could be addressed with the 156th Avenue bridge project). > HPR 10: Channel realignment, bank stabilization, revegetation and wetland creation. > High priority bank where Big Dry Creek is eroding towards the Fairfield Subdivision.
Parcel VIII **Thornton** **16 Acres**	> **Trailheads:** None > **Trail Types:** Existing Big Dry Creek Trail to the west, short stretch of soft surface and boardwalks. > **Creek Crossings:** Possible with boardwalks. > **Overlooks & Heritage Trail Signage:** Wetlands, agriculture.	> Existing Big Dry Creek Trail along the western edge of the parcel; does not currently have 2' soft surface shoulder. > Connection must be made to future Big Dry Creek Trail to the north.	> HPR 11: Essentially the entire reach of Big Dry Creek through Parcel VIII is a High Priority Reach. Recommendations include channel realignment, bank stabilization, revegetation and wetland creation.

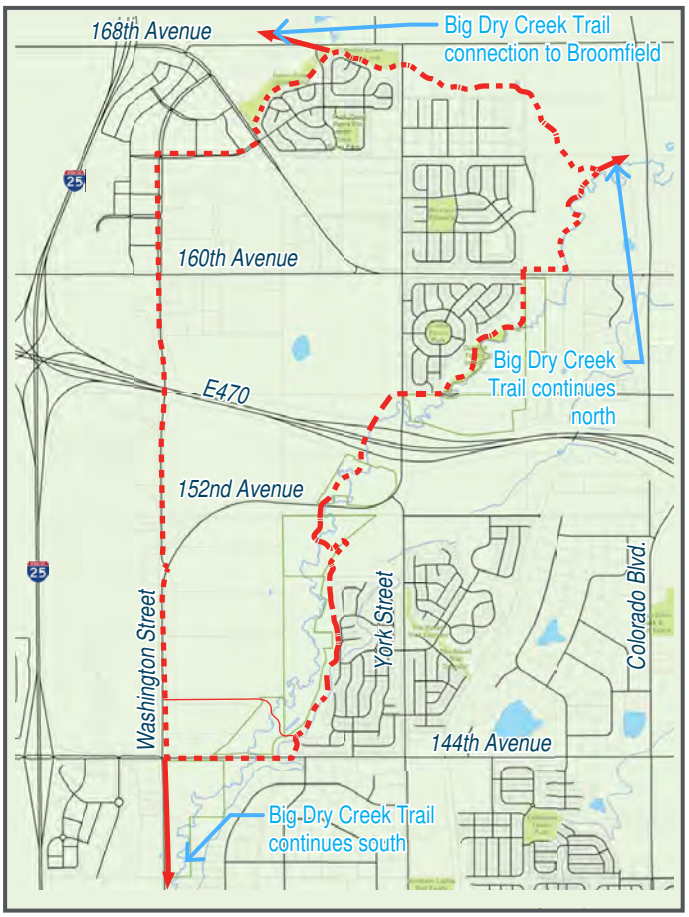
Environmental Recommendations are described in detail in the Environmental Recommendations Matrix **on page 123.**

***High Priority Reach (HPR)**

Trails and Trail Improvements

In 2007, Thornton City Council endorsed a Heritage Trail system whose purpose was to convey Thornton's spirit, character and uniqueness by integrating a diverse spectrum of themes, or stories, along trail loops within the regional and neighborhood trail system. Heritage Trail story nodes and amenity areas feature information that bring specific arts, history, education and environmental experiences to trail users and help create a sense of Thornton's cultural identity.

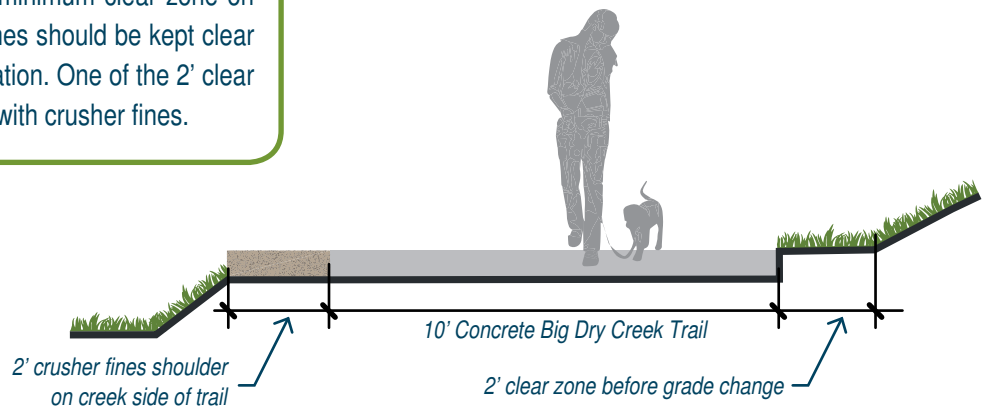
As part of the Heritage Trail system, the Big Dry Creek Trail will not only serve as a local trail system but will also serve as a connection to the larger region. The connection to Westminster's Big Dry Creek Trail occurs under I-25, south of the master plan area, and although the trail is already constructed under I-25, there will need to be a connection built (including a crossing over Big Dry Creek) from this underpass north to 136th Avenue and east to Washington Street. The Big Dry Creek Trail is proposed to connect to Broomfield open space via the Preble Creek Trail near 168th avenue.



The Big Dry Creek Trail is planned to adhere to Thornton's multi-purpose trail standards including:

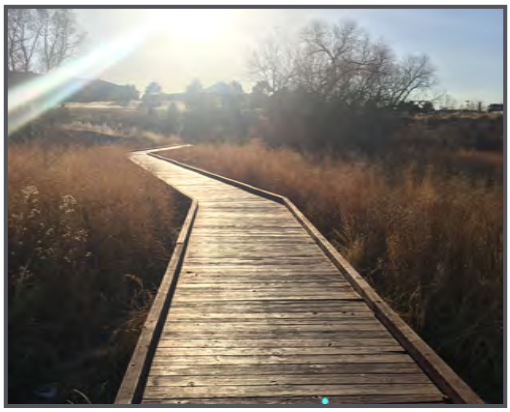
> Multi-purpose lighted concrete trails follow AASHTO guidelines, city of Thornton Parks & Open Space Master Plan and Standard & Specifications for the Design and Construction of Public and Private Improvements.

The Big Dry Creek Trail is planned to be constructed of 10' wide, 6" thick concrete, with a 2' minimum clear zone on each side of the trail. The clear zones should be kept clear of obstructions, including tall vegetation. One of the 2' clear zones should be a shoulder paved with crusher fines.



While the Big Dry Creek Trail will provide a regional route connecting the corridor to the larger area, soft surface or boardwalk trails will provide a more intimate experience into the open space areas. These trails can vary in width, but should have a minimum width of 4'. The surface should be a 5" depth of grey crusher fines cut into the existing grade, with filter fabric containing the crusher fines.

To protect sensitive wetlands ecosystems, these trails would be constructed as boardwalks. Boardwalks should be a minimum of 5' wide, with 4" curb rails on either side. These boardwalks are generally within the 100-year floodplain and should not have full railings on the boardwalks, which means that the surface of the boardwalk must not be more than 30" above the surrounding grade. Boardwalks and soft surface trails are not plowed in winter.



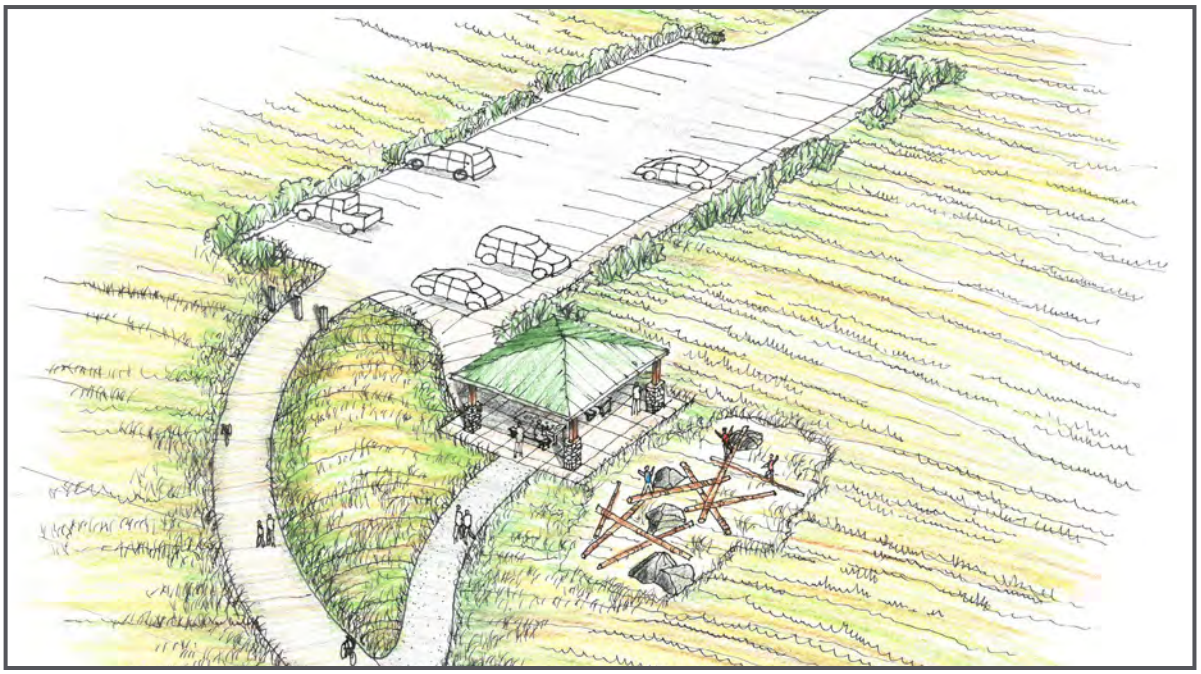
Example of a boardwalk over wetlands with a curb rail

Boardwalks can also provide access to wildlife viewing areas and will allow visitors to access sensitive environments with minimal ecosystem and wildlife habitat impact.

Along the Big Dry Creek corridor, there are a number of opportunities for new trailhead locations. These trailheads should include parking, signage, trash receptacles, portable restrooms and seating areas under shade pavilions. Because of conservation easements, the location and size of these trailheads are often defined per parcel. All of the trailheads should be designed to be above the 100 year floodplain.

Although the master plan trail alignments and trail head locations are conceptual and the final alignment will be determined as individual projects progress, the overall intent and general alignment should be followed. As much as possible, the Big Dry Creek Trail is outside of a 200' wide corridor (100' either side of the creek centerline) along Big Dry Creek. This was in an effort to preserve and conserve valuable riparian and wetland ecosystems and limit human intrusions into sensitive wildlife habitat.

Input at public workshops expressed a desire to allow equestrian use in Big Dry Creek open space. However, city of Thornton Code does not currently allow for equestrian use within city owned and maintained open spaces except on designated equestrian trails, while Adams County trails do allow for equestrian use.

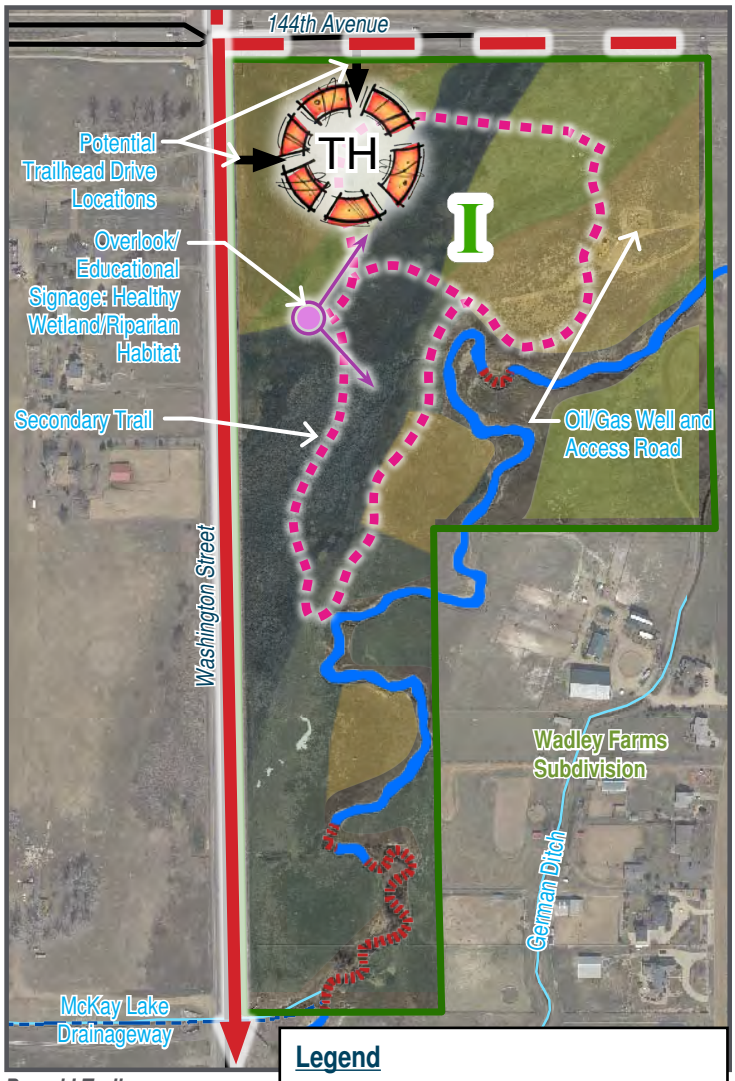


Sketch showing the character of a Big Dry Creek trailhead with parking, seating, shade, environmental play & connections to the Big Dry Creek Trail

Parcel I Trails

From the 136th Avenue and Washington Street intersection, the Big Dry Creek Trail will travel north along the west side of Washington Street. At the 144th Avenue and Washington Street intersection, the trail turns to the east and runs along the north side of 144th Avenue. In order to access the Adams County owned Big Dry Creek open space (Parcel I), there are two options:

1. Connect to the north and south of 144th Avenue via a proposed Big Dry Creek underpass. Although there is not funding available for the underpass at the time of this Master Plan, it is recommended that additional funding sources are investigated and pursued to make this underpass a possibility.
2. At the 144th Avenue and Washington Street intersection, create at-grade crossings on both the north and south sides of 144th Avenue. The south crossing would then connect to soft surface trails within Parcel I. Even if Option 1 is feasible, this second option should still be considered to create a second point of access. A privately owned parcel approximately 30' wide, running along the south side of 144th Avenue, could make access difficult anywhere except at the 144th Avenue and Washington Street intersection.



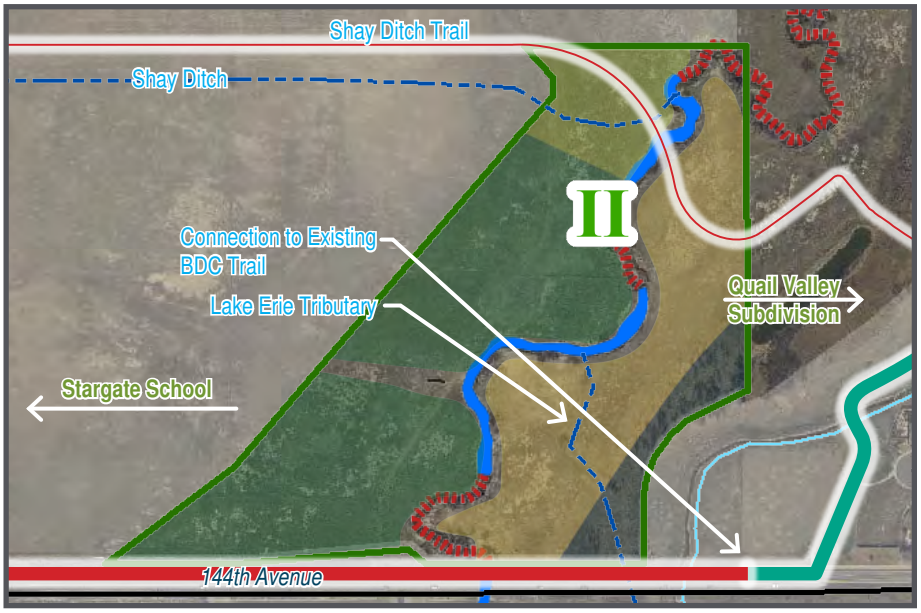
Parcel I Trails map

In Parcel I, only secondary trails will be located on the interior of the parcel. Parcel I also has a proposed trailhead location which will serve as the starting point for many visitors to this parcel. The secondary trails within Parcel I will form a set of two loops connected to the trailhead. The northern loop will be crusher fines and the southern loop, which will lay over wetlands, will be a boardwalk. Between the trailhead and the 'self-contained' secondary loop trails, Parcel I can be treated as its own area within the larger Big Dry Creek corridor. Being adjacent to private parcels with livestock, fencing should continue to be used to restrict livestock access into the open spaces and the creek corridor.

In Parcel I, the trailhead is limited to 8,000 square feet of parking with a restroom of 500 square feet. The location is in the northwest of the parcel, outside of the floodplain. Creating an access point to the east of this location will require a resolution (either acquisition or an easement) with the owner of the adjacent private parcel or an agreement with the oil and gas operator to use their access road at the eastern edge of the parcel.

Parcel II Trails

The Big Dry Creek Trail will run adjacent to the southern border of Parcel II, within the 144th Avenue right of way. It will connect to the existing trail on the western edge of the Quail Valley Subdivision, east of Parcel II. While not a part of the BDC Trail, the Shay Ditch Trail will be a paved concrete trail connection that connects the Shay Ditch drainage area east of Washington Street and Stargate School to the existing Big Dry Creek trail in the Quail Valley Subdivision.



Parcel II Trails map

Parcel II does offer opportunities for boardwalks and soft surface trails, but the Master Plan is not recommending any secondary trails beyond the Shay Ditch Trail at this time. As the Shay Ditch Trail becomes more widely used and development occurs along Parcel II's northern border, secondary trail options should be investigated, particularly west of Big Dry Creek.

No trailheads are recommended in Parcel II as part of this Master Plan.

Aerial view showing Big Dry Creek, existing oil/gas access road and Big Dry Creek Trail. Quail Valley Subdivision is shown in background.

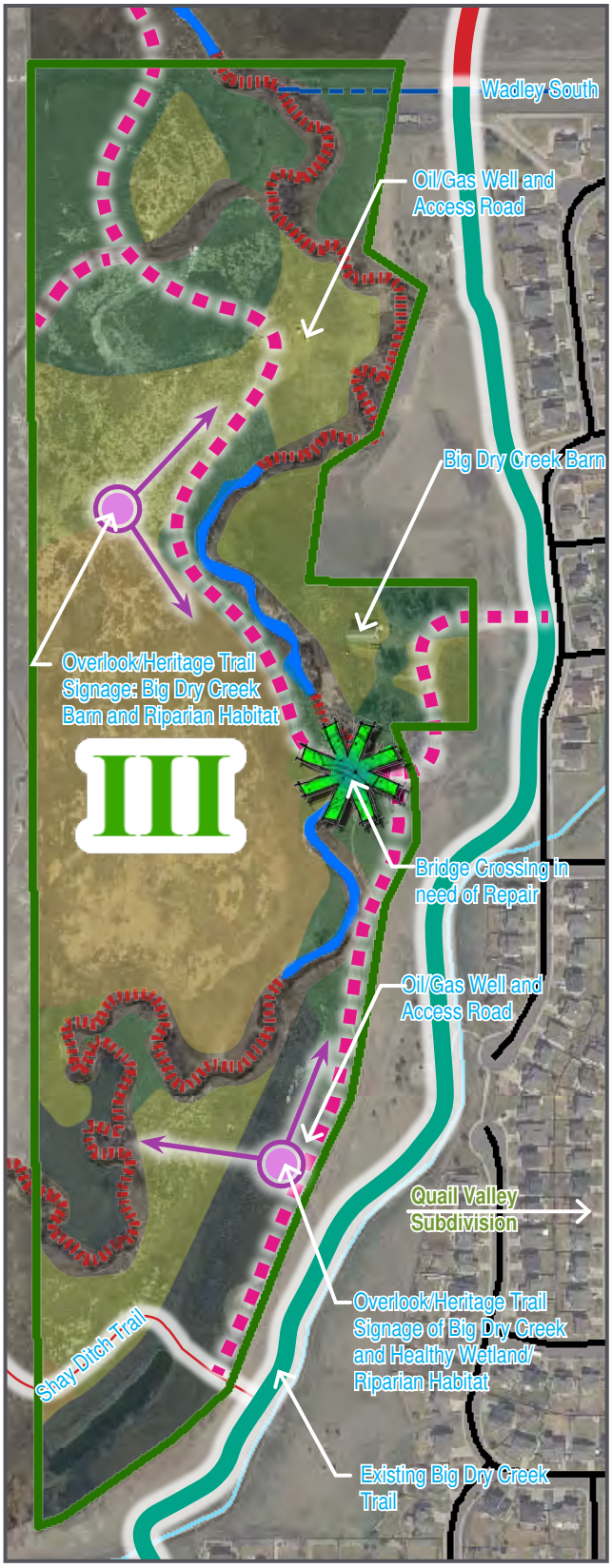
Parcel III Trails

The Big Dry Creek Trail is built along the eastern edge of Parcel III. This trail is situated on high ground adjacent to the creek and offers great visual access to the open space while limiting access to environmentally sensitive areas. Access from the trail into Parcel III will be via two main points:

1. Shay Ditch Trail: This trail will begin at the existing Big Dry Creek Trail in Quail Valley Subdivision, proceed west through Parcel III to Big Dry Creek, cross the creek and continue along Shay Ditch to the Stargate School and the pedestrian underpass at Washington Street.
2. Big Dry Creek Barn Soft Surface Trail: The historic Big Dry Creek Barn is located within Parcel III. Two gated oil and gas access roads are located here, stemming north and south from the barn. These access roads are commonly used as a walking path. The road to the north includes a concrete bridge that crosses Big Dry Creek and could connect to future development west of Parcel III. It is recommended that the city engage the oil and gas operator about a partnership to repair/improve the condition of this bridge and designate it as a shared use for both oil and gas access and trail use.

Legend

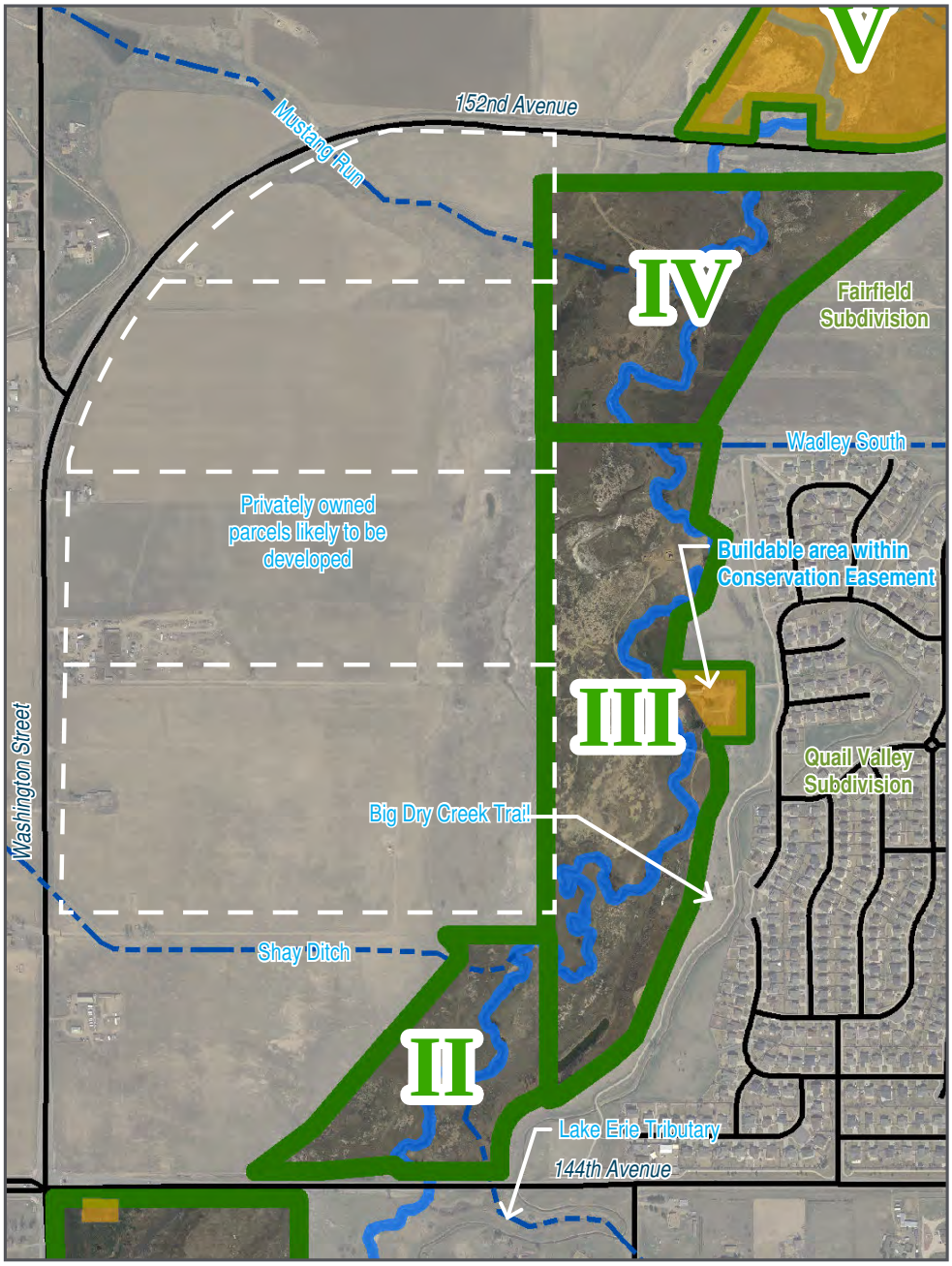
- 2014 Big Dry Creek Channel
- Ditches
- Areas of High Bank Erosion
- Potential Trailhead Location
- Potential Creek Crossing
- Existing Big Dry Creek Trail
- Future Big Dry Creek Trail
- Shay Ditch Trail (Paved)
- Future Secondary Trail



Parcel III Trails map

While the conservation easement defines a 2.3 acre building area surrounding the barn, input at the public workshops showed concern over creating a trailhead interior to the neighborhood, bringing additional traffic. It is recommended that a trailhead not be constructed on Parcel III.

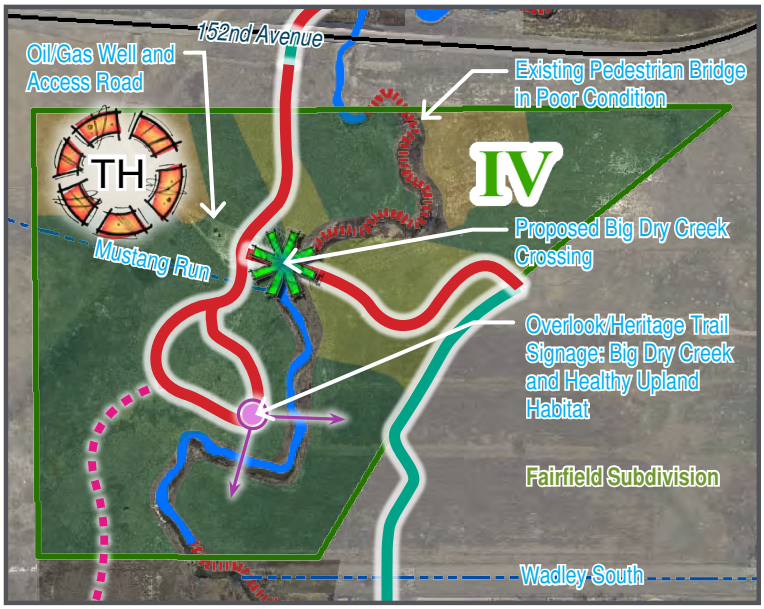
Directly west of Parcel III exist three large, privately owned parcels (50+ acres each) that are likely to be developed as Thornton grows (see parcel map below). It is recommended that future development build trail connections into the Big Dry Creek open spaces and link to the Big Dry Creek Trail. These connections are most likely through Parcel III, although there are also opportunities through Parcel IV. The connections should meet city design standards and secondary trails that spur off of the main connections should follow the soft surface trail guidelines set forth in this Master Plan.



Privately owned parcels west of Parcel III and Quail Valley Subdivision

Parcel IV Trails

As the Big Dry Creek Trail continues north of Parcel III, a portion will be constructed as part of the Fairfield Subdivision until it turns northwest into Parcel IV. As shown on the Parcel IV Trails Map at right, it is recommended that the Big Dry Creek Trail avoid the healthy upland areas in Parcel IV. The section of the proposed Big Dry Creek crossing has been identified as a High Priority Reach geomorphically, and it is likely that a single project could create the trail connection as well as geomorphic, hydraulic and environmental benefits. Although there is an existing bridge on Parcel IV, it is an old, metal pedestrian bridge that is neither safe nor suitable for a regional trail and would require removal or complete replacement.



Parcel IV Trails map

Once the trail crosses Big Dry Creek, it will continue west where there is an opportunity for a trailhead. Soft surface trails will route people south from the trailhead, connecting to future development west of Parcels III and IV. As this area is currently healthy uplands, care should be taken to minimally impact the vegetation and wildlife habitat. From the trailhead, the Big Dry Creek Trail will continue north and connect to the existing trail underpass under 152nd Avenue linking to Parcel V.

There is no conservation easement associated with this parcel, and therefore, trailhead parking lot size and allowable structures are not restricted.

Legend

- 2014 Big Dry Creek Channel
- Ditches
- Areas of High Bank Erosion
- Potential Trailhead Location (TH)
- Potential Creek Crossing
- Existing Big Dry Creek Trail
- Future Big Dry Creek Trail
- Future Secondary Trail

Existing metal pedestrian bridge that currently crosses Big Dry Creek in Parcel IV will need to be removed and replaced as part of the Big Dry Creek recreation improvements.

Parcel V Trails

The final alignment of the Big Dry Creek Trail and soft surface trails through Parcel V will be determined as part of the pilot project immediately following the completion of the Master Plan, but the Big Dry Creek Trail will connect to the existing underpasses at E-470 and 152nd Avenue. Additional information about the proposed improvements to Parcel V can be found in Chapter 6 - Pilot Project.

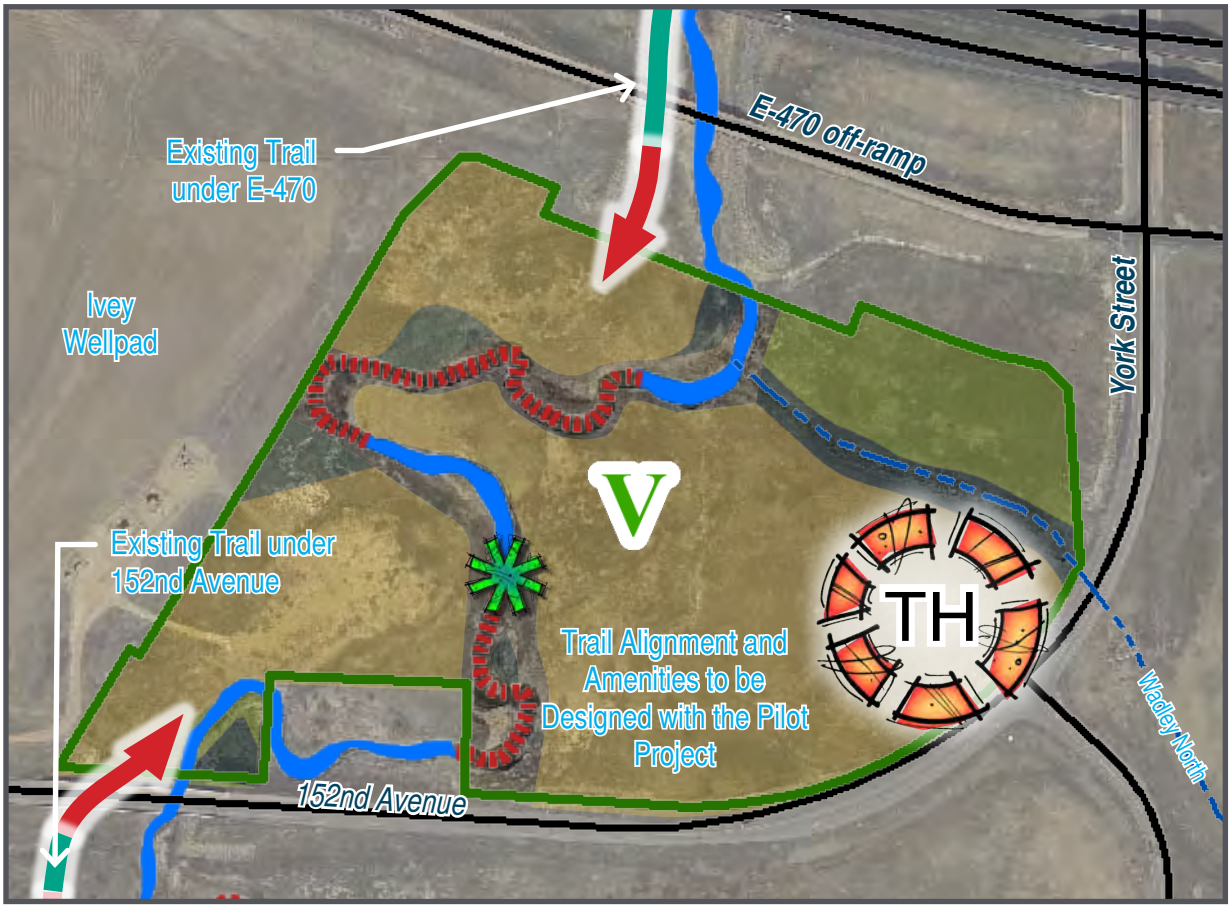
Parcel V's conservation easement allows for a parking lot and trailhead. The general location will be across from the York Street/152nd Avenue intersection. This location would result in the need for a crossing of Big Dry Creek that matches city standards.

Legend

- 2014 Big Dry Creek Channel
- Ditches
- Areas of High Bank Erosion
- Potential Trailhead Location
- Potential Creek Crossing
- Existing Big Dry Creek Trail
- Future Big Dry Creek Trail
- Future Secondary Trail

The trailhead located in Parcel V will be the first trailhead installed in the project area. Traffic and usage of this trailhead will act as a precedent for other trailheads throughout the project area and will help prioritize the construction of other adjacent trailheads. The success of this trailhead may determine if construction of the trailhead south of 152nd in Parcel IV is needed, or may influence its design.

The final design and location of the trailhead will be determined as part of the design phase of the pilot project.



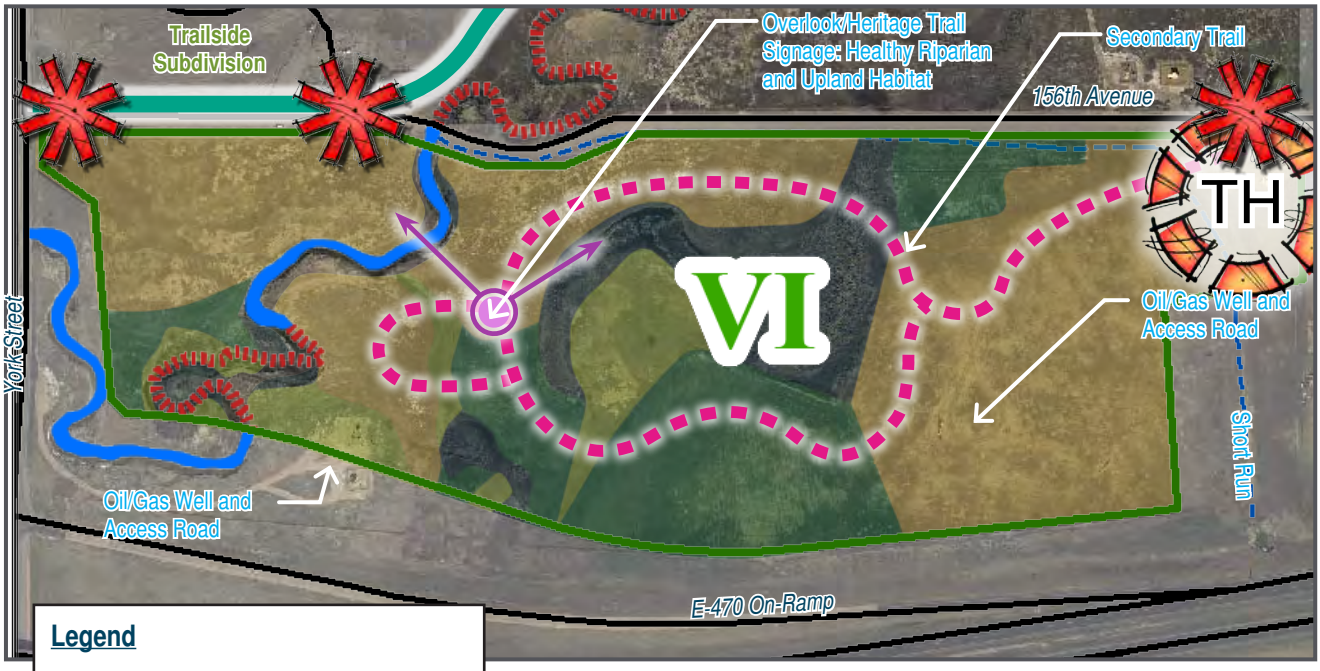
Parcel V Trails map

Parcel VI Trails

North of E-470, the trail will need a public access easement through E-470 owned property to the intersection of York Street and 156th Avenue. After crossing York Street, the Big Dry Creek Trail will continue east on the north side of 156th Avenue to meet up with the existing Big Dry Creek trail in the Trailside Subdivision. However, if the 156th Avenue bridge re-construction allows for a trail underpass under the new bridge (156th Avenue over Big Dry Creek), it would be more desirable for the trail to follow Big Dry Creek within Thornton's open space (Parcel VI), crossing underneath York Street and 156th Avenue and then connecting to the Big Dry Creek Trail in Parcel VII.

Parcel VI offers unique opportunities for the secondary trails to be designed as boardwalks that cross sensitive wetland and oxbow areas. These secondary trails are designed as loops that connect to the proposed trailhead in the northeast corner of Parcel VI. Some of the secondary trails align with High Priority Reaches of Big Dry Creek, and offer the opportunity to create multi-faceted projects that address trails, geomorphology, hydraulics and vegetation/wildlife habitat.

Parcel VI's conservation easement does not restrict the construction of a trailhead or limit its location, but does limit the size and design to be consistent with the uses reserved in the easement (passive recreation). Similar to other trailhead locations, there are existing oil and gas access roads that could provide a shared access to the trailhead locations.



Parcel VI Trails map

Big Dry Creek moving laterally into the oil/gas access road SW of Parcel VI

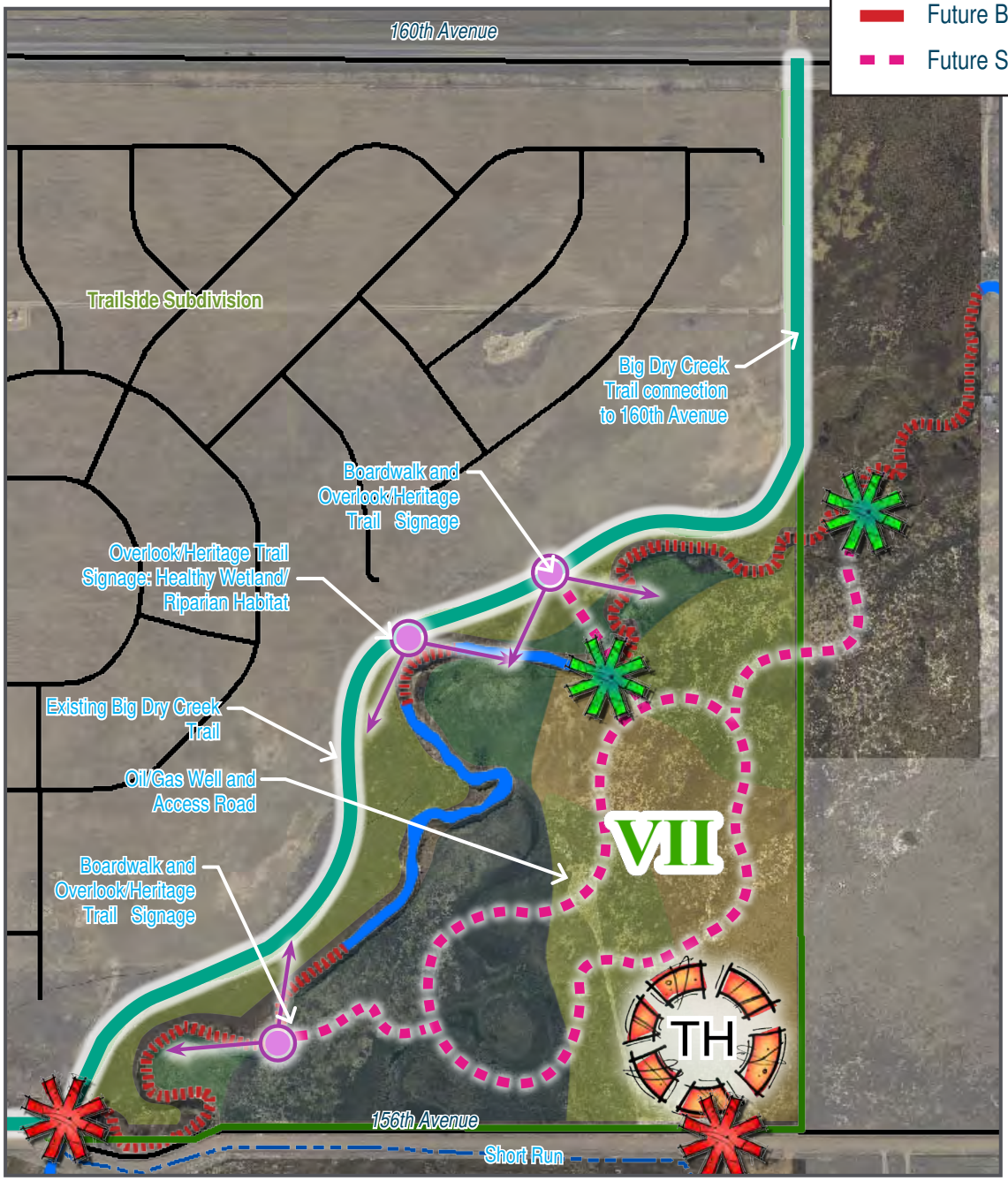
Parcel VII Trails

Through Parcel VII, the Big Dry Creek Trail continues north along the western edge of the city's property, adjacent to the Trailside Subdivision, up to 160th Avenue.

The trailhead in Parcel VII would connect to the Big Dry Creek Trail via the soft surface trail. The secondary trails would be comprised of a main loop trail, connected to the trailhead and three spur trails that provide access to the creek, wetlands and cross Big Dry Creek to connect to the Big Dry Creek Trail on the west side of Parcel VII. In sensitive wetland and wildlife habitat areas, boardwalks will be designed to give access to these ecosystems, keeping the trails' impact minimal.

Legend

- 2014 Big Dry Creek Channel
- Ditches
- Areas of High Bank Erosion
- Potential Trailhead Location
- Potential Road Crossing
- Potential Creek Crossing
- Existing Big Dry Creek Trail
- Future Big Dry Creek Trail
- Future Secondary Trail

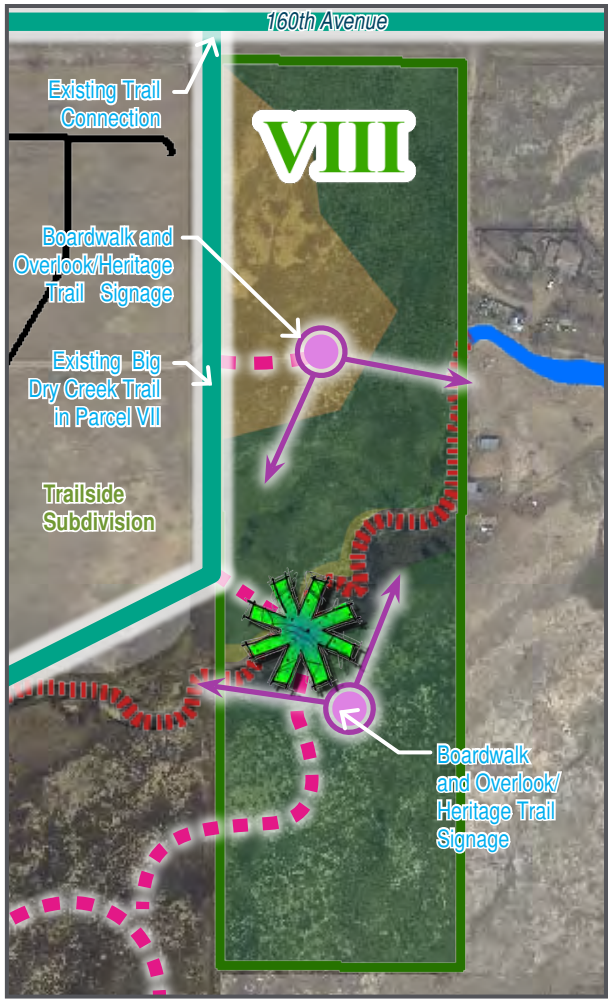


Parcel VII Trails map

Parcel VIII Trails

No trailhead is proposed in Parcel VIII. One secondary trail, originating in Parcel VII, will extend into Parcel VIII. This trail could potentially be a boardwalk, with overlooks and Heritage Trail signage.

In Parcel VII, the Big Dry Creek Trail continues on an existing concrete trail that runs along the eastern edge of the Trailside Subdivision. The Big Dry Creek Trail culminates at 160th Avenue on the north side of Parcel VIII.



Parcel VIII Trails map

Properties in the Big Dry Creek corridor north of 160th Avenue are privately owned, but the long-term vision of the Big Dry Creek Trail is to continue it north and east to Colorado Boulevard and 168th Avenue (the County boundary) to ultimately continue through Weld County to Fort Lupton and the South Platte River.

Pedestrian bridge in Thornton

Environmental Play

While traditional playgrounds are considered active recreation and are not desired or allowed by conservation easements within Big Dry Creek open spaces, there is a large desire to integrate environmental play areas into these parcels. Environmental play areas contain natural materials such as logs and boulders instead of swings and slides. Incorporating environmental play can help to spur curiosity, promote a spirit for exploration and provide recreational and educational opportunities for community health and wellness.

Environmental play areas contain natural materials such as logs & boulders

Environmental play areas are designed to connect children to nature by allowing them to learn by discovery. Children may find bugs living in the fallen logs, see firsthand what happens to sand when water runs over it, or feel the different textures of varying types of stones. Children must have some control over the direction of their learning.

Environmental play areas can be designed to fully meet play structure safety requirements, or they can be designed as much more informal areas where children are encouraged to explore and discover their surroundings. Ultimately, this decision lies with the municipality/agency that is responsible for the area.

Environmental play focuses on learning through discovery

Environmental play areas are both effective and desirable. They promote interaction with the natural environment through hands on contact, exploration and reflection.

It is recommended that environmental play areas be integrated throughout the BDC corridor and there are a number of different types of play features that can be utilized. Some of the opportunities for environmental play include:

- **Rocks, stones and logs:** An important piece of environmental play is having direct interaction with natural materials. Allowing children to touch, move and climb on boulders and logs is important.
- **Rope climbers:** Many playground companies now make rock and log climbers with ropes incorporated. These can be a great environmental play option for slightly older children who would like a more challenging play environment.
- **Wildlife paw prints:** Incorporating paw prints of wildlife into concrete trails and concrete hydraulic structures (described in more detail in the Hydraulic Toolbox) can create a sort of 'scavenger hunt'. If these paw prints are also incorporated into a open space guide, visitors can learn more about the wildlife native to the area.
- **Movable sand/soil/small rocks:** While access into Big Dry Creek is not recommended, environmental play areas can be designed to teach the hydraulics and creek mechanics taking place along Big Dry Creek. Whether it is a pre-manufactured 'water play table' or a custom designed water play system in the ground, children can have the opportunity to 'move the ground' and see the effects it has on a simulated stream system.
- **Wetland boardwalks:** There are numerous opportunities for both wetland creation and boardwalk trails throughout the Big Dry Creek open space that create prime opportunities to have a close look at what makes wetlands special. The boardwalks can be designed to highlight different plant communities, as well as provide views of wildlife habitat (particularly birds). Combined with interpretive signage, the boardwalks can be used by parents, teachers, schools and nature groups to provide visitors of all ages with a unique way to learn about these sensitive ecosystems.

Environmental play can be as simple as positioning fallen tree logs

Water play area where children can learn how rivers and creeks work

Site Amenities and Furnishings

An important part of an open space network is the amenities and site furnishings that are chosen to be installed throughout it. While site amenities should be in accordance with appropriate design standard and guidelines, the Big Dry Creek corridor offers an unique opportunity to create a clear identity and character befitting of this special ecosystem.

The following pages contain site amenities and furnishings selected for the Big Dry Creek Heritage Trail. These themed options should be used within the corridor as described.

Benches

Annova Site Furnishing's 6' Airi Stix Contour bench (or approved equal) should be used as possible along the Big Dry Creek Trail. These benches are constructed of powder coated steel and aluminum components. The frame color shall be 'Sage' and the seat color shall be 'Pine.'

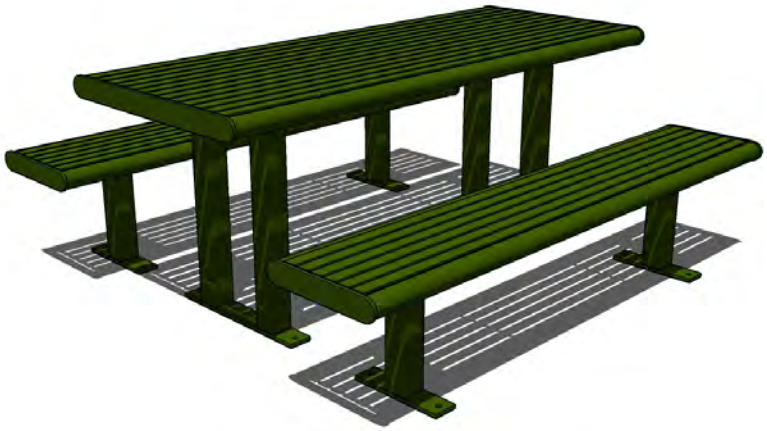
Along soft surface trails, benches crafted from reclaimed tree trunks will provide a Heritage Trail themed element that is in keeping with the character of Big Dry Creek. These benches should be constructed from on-site fallen trees whenever possible. While each bench will be unique and one-of-a-kind, they should all be designed and built in a similar fashion.

Annova Site Furnishings Airi Stix Contour bench

Frame Color: 'Sage'

Seat Color: 'Pine'

Example of a simple log bench made from fallen trees

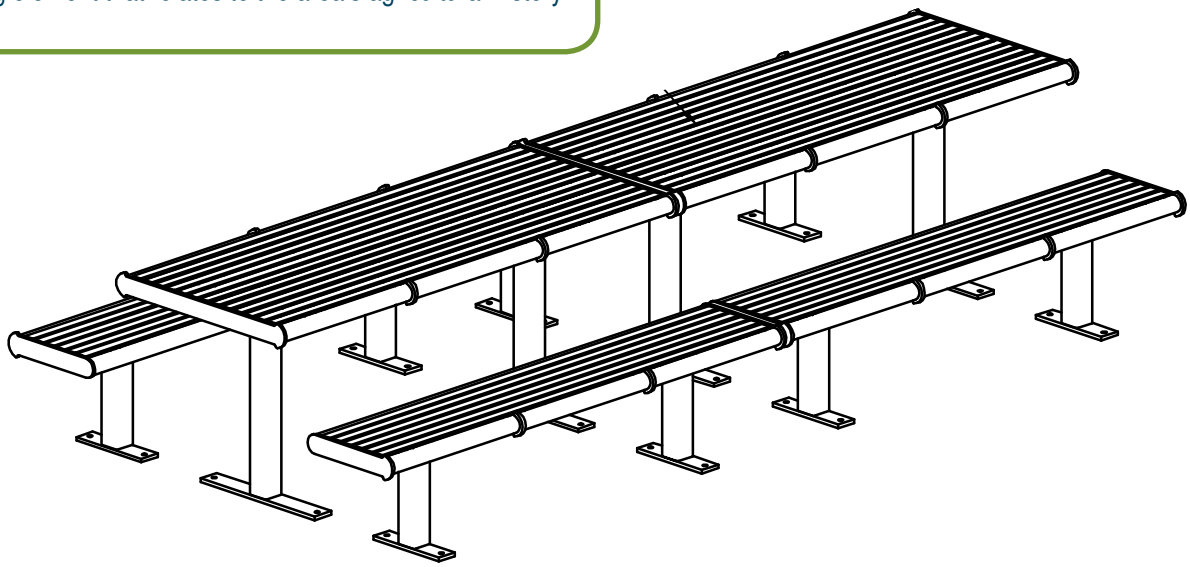


City of Thornton standard picnic table

Tables

Tables are in important site amenity for trail networks and should be located in sitting areas along the Big Dry Creek Trail, trailheads and gathering locations. Along the Big Dry Creek Trail corridor, a powder coated steel table similar to those shown on this page should be used. As possible, longer harvest tables should be incorporated to reflect the agricultural history of the area and encourage community gatherings. Harvest tables can be single large tables, or a series of smaller tables installed adjacent to each other (shown below).

At larger trailheads or in combination with interpretive signage, long harvest tables will provide a unique table and sitting element that relates to the area's agricultural history.



Individual tables installed adjacent to each other can form harvest tables

Trash Receptacles, Bike Racks, Portable Restroom Facilities, Dog Stations and Trail Lighting

The city of Thornton has established standards for trash receptacles, bike racks, portable restroom facilities, dog waste stations and trail lighting. As these do not contribute significantly to the aesthetic and character, the Master Plan recommends installing city and county standard products on their respective open space parcels.

Picnic and Shade Shelters

Picnic shelters for Big Dry Creek have been split into two categories; large shelters for trailhead and gathering areas and smaller 'trail-side' shelters. Small sitting or viewing areas with one or two benches and a small shade structure will provide rest areas along the trail.

Large shelter with curved design & combination slatted and solid roof

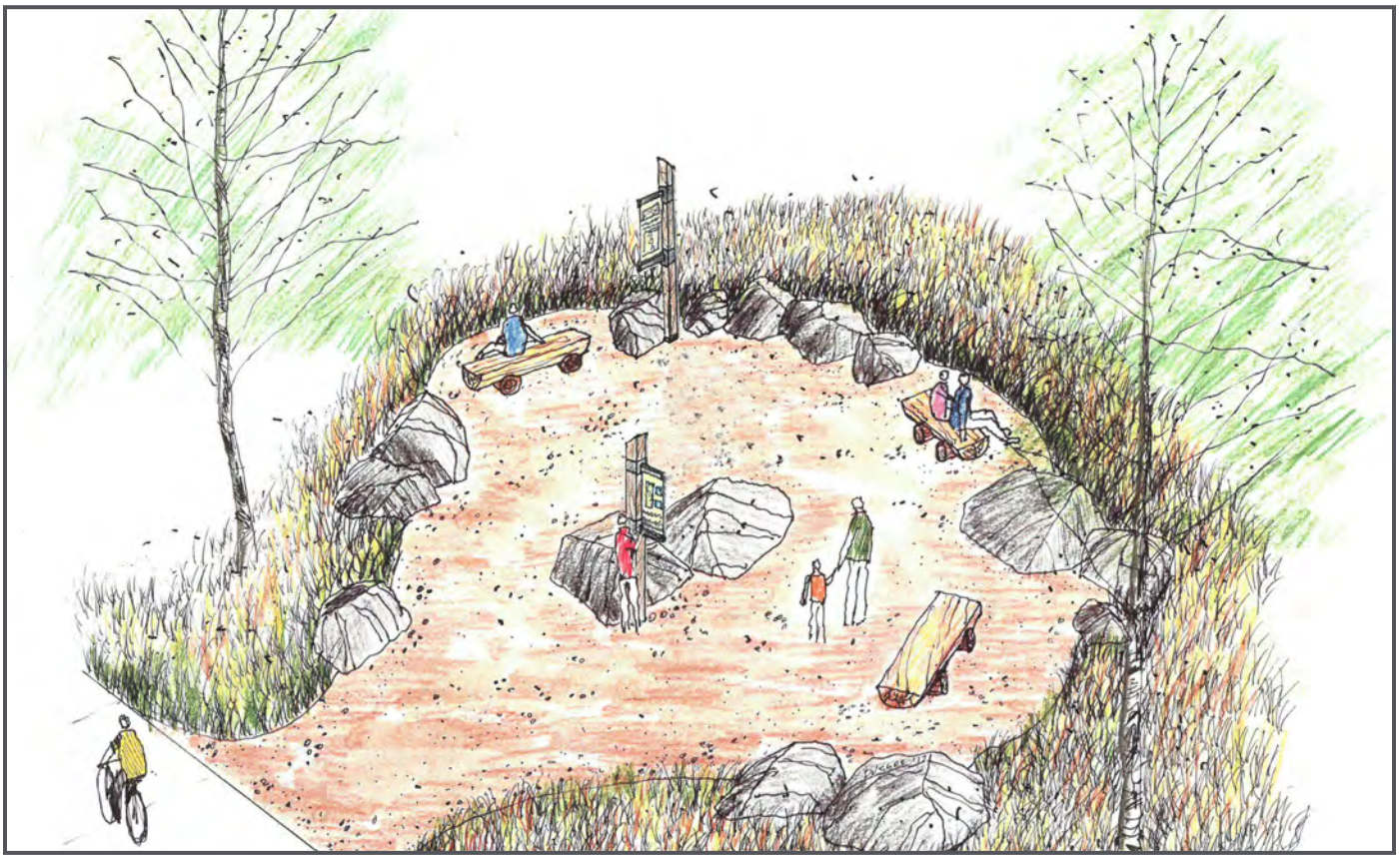
Small shelter with slatted roof design

At trailheads, shelters similar to those shown above (or approved equals) should be used. These shelters fit the Big Dry Creek aesthetic character through the use of thick columns, angled roof lines and slatted roofs. Corrugated metal panels can be used on top of the slats for additional protection. Metal columns can be accented with natural stone. Colors and materials should be picked to match other Big Dry Creek amenities. Along the trails, the smaller shelters should match the aesthetic and design of the larger shelters.

Small shade shelter with slatted/trellis roof; smaller shelters should match the design, color and aesthetic of the larger structures

Overlooks and Heritage Trail Signage

There are ample opportunities to provide areas for sitting, relaxing and enjoying nature both along the Big Dry Creek Trail and along secondary trails throughout the corridor. Generally, these areas should be soft surface. Size will vary from small areas with only one or two benches, to larger areas with multiple benches, tables, and picnic shelters.



Character sketch showing a sitting area off the Big Dry Creek Trail including seating, wildlife viewing opportunities and Big Dry Creek Heritage Trail interpretive signage

Opportunities to utilize existing or proposed grade to create elevated overlooks with Heritage Trail signage should be investigated. These could vary from a portion of boardwalk that is elevated to a seating area that is built off of an existing high point. Elevated overlooks can provide a better understanding of the larger context of the area, as well as the impacts small actions can have.

Elevated overlook using the grading of floodplain terraces to extend the overlook out over the floodplain

Heritage Trail interpretive and educational signage is an important component of the future Big Dry Creek corridor. The Heritage Trail signs will take advantage of opportunities to provide visitors with information regarding the area's wildlife and ecological features, as well as the cultural heritage and history of the site.

Possible topics for the Big Dry Creek Heritage Trail signs:

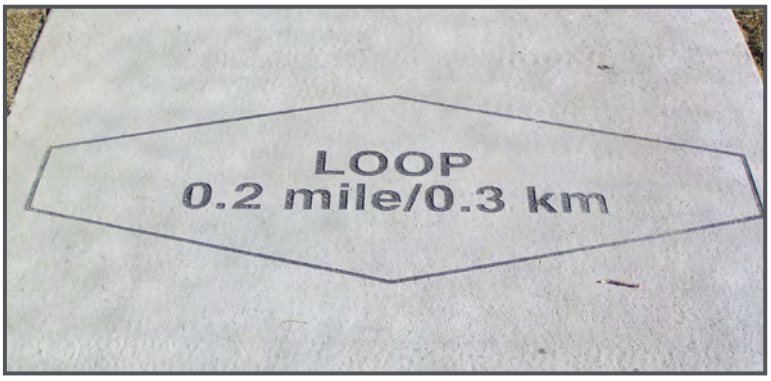
- Wetland and riparian ecosystems
- Wildlife birds, raptors, mammals, & aquatic life
- Oil and gas exploration
- History of the Big Dry Creek Barn, agriculture, early families and settlement
- Big Dry Creek watershed & hydrology
- Open Space values

Heritage Trail signage along the Eastlake Heritage Trail

The Big Dry Creek Heritage Trail logo (at left) captures the crucial elements of the area such as Big Dry Creek, the Big Dry Creek Barn, upland/grassland ecosystems, riparian ecosystems, passive recreation and wildlife. The colors chosen for the logo relate directly to the colors that are found throughout the seasons within the Big Dry Creek corridor. Complimenting the logo, the Big Dry Creek Heritage Trail poster (on facing page) can be used for community awareness, events or marketing materials to help inform the public about the Big Dry Creek Open Space and Heritage Trail and improvements to the creek corridor.

Big Dry Creek Heritage Trail Logo

In addition to themed signage and amenities, the Heritage Trail should have sandblasted concrete mileage markers every 1/4 mile.



Sandblasted concrete trail mileage marker

The Big Dry Creek Heritage Trail poster

Future Development

There are multiple adjacent developments either currently underway or that will occur in the future. Below is a list of these developments, as well as a summary of how they can relate and connect to the Big Dry Creek corridor.

1. **Future RTD Light Rail stop**: RTD FasTracks has future light rail lines planned throughout the Denver Metro area, including the N Line (aka North Metro rail line) which will provide service from Union Station north through Denver, Commerce City, Thornton, Northglenn and Adams County. The first 13 miles of the N Line is scheduled to open in 2018 and will bring service north to Eastlake and 124th Avenue in Thornton. The next stop north is at York and 144th Avenue, which is near the Big Dry Creek corridor. The city of Thornton should plan appropriately to ensure trail connections occur between the Big Dry Creek Trail and the York Street and 144th Avenue station.
2. **Private parcels between 136th and 144th Avenues:** Big Dry Creek runs through a number of private parcels in this area on both the west and east sides of Washington Street. On the east side of Washington Street are relatively small privately owned residential parcels and the Master Plan is not making any recommendations within them. However, if the owners are interested in selling the floodplain portions of their property in the future, these would be good additions to the Big Dry Creek corridor that could provide opportunities for trail, floodplain and environmental improvements.
3. **Stargate School:** As has been previously discussed, partnership opportunities between the city of Thornton and the Stargate School should continue to be identified. The proximity to Parcel II provides excellent opportunities for the Stargate School to benefit from access to the open spaces and the city of Thornton to benefit from financial and/or community support from the Stargate School.
4. **Private Parcels west of Parcels III and IV:** As discussed in the trail section of this chapter, these farming parcels are likely to be developed into residential, retail, office and/or commercial uses as Thornton continues to grow. As these parcels are developed, Thornton should engage the developers to assist in creating connections into the Big Dry Creek open space and links to the Big Dry Creek Trail. When possible, these projects should be combined with environmental and floodplain improvements.
5. **Ivey Wellpad:** Directly west of Parcel V (the pilot project site), Ward Petroleum is planning on developing a wellpad with 26 horizontal wells. Horizontal wells are typically drilled from a central location and spread out horizontally underground. This wellpad will have an impact on the pilot project site, and Ward Petroleum should be engaged during the pilot project design phase to try to identify partnering opportunities.
6. **East of Parcel V and York Street:** This is a future development site that will likely consist of single family homes and neighborhood parks. As this development comes closer to final planning and construction, trail linkages to the Big Dry Creek Trail should be investigated.

Utilities

The utility projects that are currently known have been discussed in Chapter 2. These include the sanitary sewer line parallel to Big Dry Creek and the planned lift station expansion. Utility projects and parks/open space projects frequently share the same project site, yet too often do not align or coordinate with each other. This is due to many varying factors such as funding sources, timeline and whether the project is being done as a part of private development or Thornton owned improvements. Regardless, there are opportunities for these projects to overlap and create a much larger/greater return on investment.

For example, a large development utility project was undertaken during the master planning process to connect the new Fairfield Subdivision to Thornton's utilities. This included installing a large underground utility through Parcel IV, including a crossing underneath Big Dry Creek. On the surface, the result is a wide swath of land that has been cleared, graded and re-seeded. This project needed to be completed quickly before the Master Plan was completed, which hampered the opportunity to combine it with Big Dry Creek open space improvements. However, if the timing of the project had been more favorable, Thornton might have partnered with this development project to also install corrective hydraulic toolbox strategies (discussed later in this chapter) at the utility crossing which occurs in a High Priority reach of the creek, to control invasive plant species and plant desirable vegetative communities and to install portions of trail, including a future trail crossing of Big Dry Creek. All of these objectives overlap and interact, and with proper planning and favorable timing, they can all be integrated into a single project. Hopefully, the pilot project will be an opportunity to showcase how projects can address multiple issues at once.

Another important utility to consider within the Big Dry Creek corridor is oil and natural gas wells. The following general guidelines, as well as any additional city and/or county requirements, should be met by oil and gas well operators:

- Provide adequate landscaping and site mitigation to buffer adjacent open space, trails and passive recreation amenities.
- Preserve wildlife habitat, water quality and passive recreational opportunities as described and recommended in the Master Plan.
- Work with city and/or county staff to locate abandoned lines within open space parcels.
- Following completion of well's life span, remove abandoned utilities and remediate the area to match or improve surrounding wildlife habitat, vegetation and water quality.

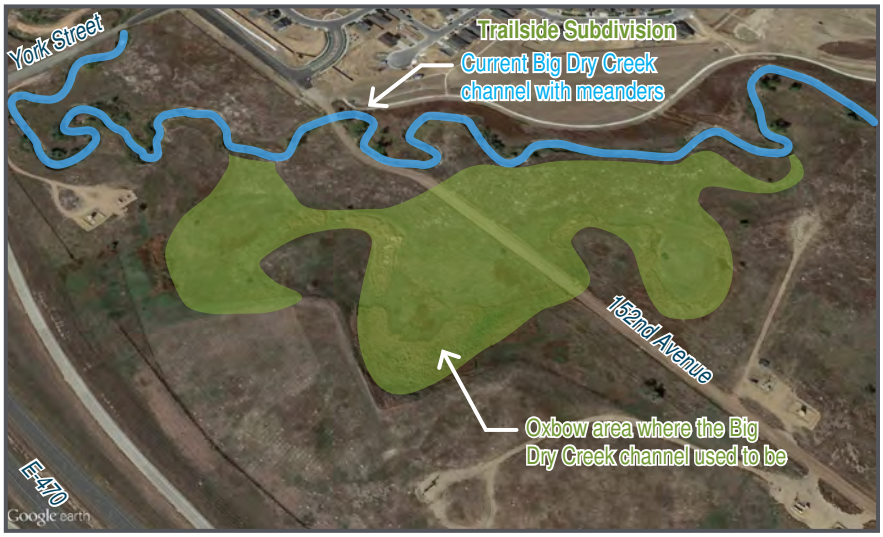
Floodplain Restoration

Channel restoration projects within the boundaries of the Big Dry Creek corridor through Thornton should use natural channel restoration design approaches whenever possible. Guidance and criteria for natural channel design can be found in Volume 1 of the Urban Stormwater Drainage Criteria Manual (USDCM) (UDFCD, 2016). Natural channel design uses the principles of fluvial geomorphology as a basis for bringing a degraded channel into quasi-equilibrium with a changed flow regime and sediment load resulting from urbanization or water management activities.

The parcels associated with this Master Plan have been zoned as open space and the channel restoration approaches presented herein should be used to meet the aesthetic and recreational vision of this channel corridor. Natural channels are not lined with concrete, and should be vegetated with native grasses and riparian species. Channel restoration projects within this Master Plan corridor should make reconnecting Big Dry Creek with its historic floodplain a priority consideration as part of the design approach.

It is important to note that filling the existing channel in order to raise the channel bed and reconnect it with its historic floodplain may have effects on base flood elevations (100-year water surface elevations) and may not be feasible in some locations. Fortunately, Adams County and Thornton own the open space parcels adjacent to the channel. This provides some latitude relative to changes in base flood elevations and flexibility to offset rises due to channel filling activities elsewhere in the floodplain. For any channel modifications, this type of hydraulic analysis and floodplain permitting (local and or federal) will be required.

Another important item to discuss is the difference between meanders and oxbows, and when they should be considered a detriment to the system. A creek meander is a curve in an active creek channel. In contrast, an oxbow is an abandoned creek meander that is leftover after a meander is cut off. Both meanders and oxbows occur naturally along creeks. However, meanders can degrade the quality of the creek and can threaten important infrastructure in certain cases. For example, in the aerial image at right, Big Dry Creek is meandering towards a public road, an oil/gas access road and a neighborhood. In this scenario, action should be taken to prevent further migration towards these important pieces of infrastructure.



Aerial of Big Dry Creek meander and oxbow through Parcels VI and VII

When an oxbow occurs from a meander being cut off, the resulting creek is a shorter length than it was prior to the cutoff. This means the slope of the creek is steeper which can cause erosion and headcutting up or downstream of the cutoff point. In this case, or when a meander is being intentionally cut off to create an oxbow, grade control measures should be installed to minimize these headcutting effects.

The recommended restoration design channel parameters should be used as a starting point for projects within the project area's boundaries. It is beyond the scope of this document to identify site specific circumstances and issues that may require modifications to the recommended approaches and design parameters provided. However, individual site problems seen throughout the project area are representative of the entire project. Ultimately, it is the responsibility of the design engineer to design a channel which provides an approach to meet the needs of a specific project.

Meander curve of Big Dry Creek in Parcel V

Vertical cut bank on Big Dry Creek

Cut bank erosion caused by flow changes and freeze/thaw damage

Incised channel along Big Dry Creek

Recommended Channel Restoration Design Parameters

The channel restoration design parameters for this Big Dry Creek Recreation and Floodplain Restoration Master Plan, have been developed based on the following elements:

1. Design of a stabilized baseflow channel sized for anticipated baseflow fluctuations in the range of 25 to 40 cfs
2. Design of a stabilized bankfull channel sized to convey approximately 420 cfs
3. Reconnecting Big Dry Creek with its historic floodplain

The following sections provide a summary and discussion of each recommended design parameter. The Recommended Restoration Channel Design Parameter Tables on page 89 provide an overall summary of each restoration channel design parameter, and the Typical Recommended Cross-Sections graphic on page 89 provides a conceptual level illustration of the recommended restoration channel cross-section.

The overall strategy of the recommended channel cross-sections is to re-connect Big Dry Creek with its floodplain. Over the past decades, Big Dry Creek has become incised for a variety of reasons: increased flows, frequent variation in flows, freeze/thaw cycles, adjacent development deposits of fine sediment bank and bed material, and so on. In order to re-connect the creek with the floodplain, the channel must be remediated. This can be done in two ways: either raise the channel so that flood waters will reach the floodplain, or grade back the banks so the floodplain is closer to the existing channel. In floodplain restoration work, typically the first priority is to raise the channel to re-connect it to the floodplain. This is to return the channel to its historical condition. As such, the first priority for Big Dry Creek is to raise the channel where possible. In doing so, the designers must be careful to not cause a rise in the floodplain. Given that Thornton and Adams County have acquired such wide parcels of property that encompass the floodplain, there should not be an issue achieving this condition in most locations. In locations where raising the channel is not feasible, the next priority would be to lower the surrounding banks to re-connect the floodplain with the creek. Recommended cross-sections for both situations have been developed for each Big Dry Creek parcel and can be found in "Appendix G: Recommended Channel Cross Sections by Parcel".

Channel Slope

As discussed in the following section, incision of the Big Dry Creek has slowed or halted in many areas due to a number of artificial or natural grade controls which are relatively resistant to further erosion. As a result, further extensive down cutting and incision of the channel is not expected to continue, and the channel is adjusting primarily through bank erosion and lateral migration. Therefore, the existing average channel slope of 0.002 ft/ft is generally recommend as part of this Master Plan.

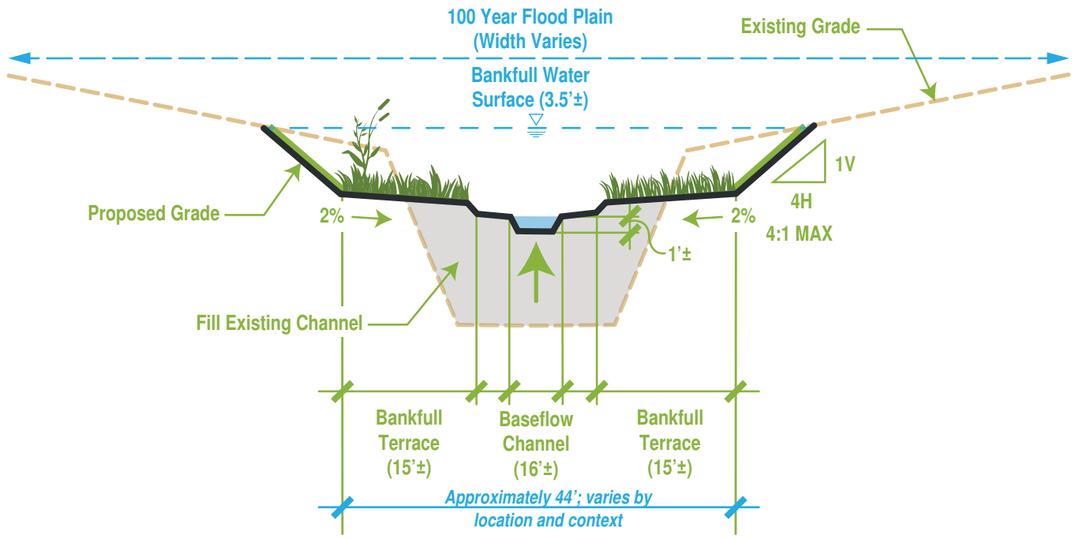
Baseflow Channel

As discussed in Chapter 3, due to the highly varying flows in Big Dry Creek throughout the year, channel banks are eroding due to undercutting and sloughing of the channel banks. This Master Plan recommends that channel restoration approaches incorporate a stabilized baseflow or low-flow channel sized for approximately 40 cfs to help deepen and maintain baseflows in the center of the channel. Based on a design channel slope of 0.002 ft/ft, a stabilized channel with a 16 foot wide bottom width and 4H:1V side slopes provides an approximately 1 foot water depth under a 40 cfs baseflow condition. It is recommended that both the toe and the banks of this baseflow channel be stabilized in accordance with the strategies outlined in the Master Plan Toolbox. Lining the banks with a hard material, such as logs and or boulders is generally recommended to minimize the effects of the fluctuating water level.

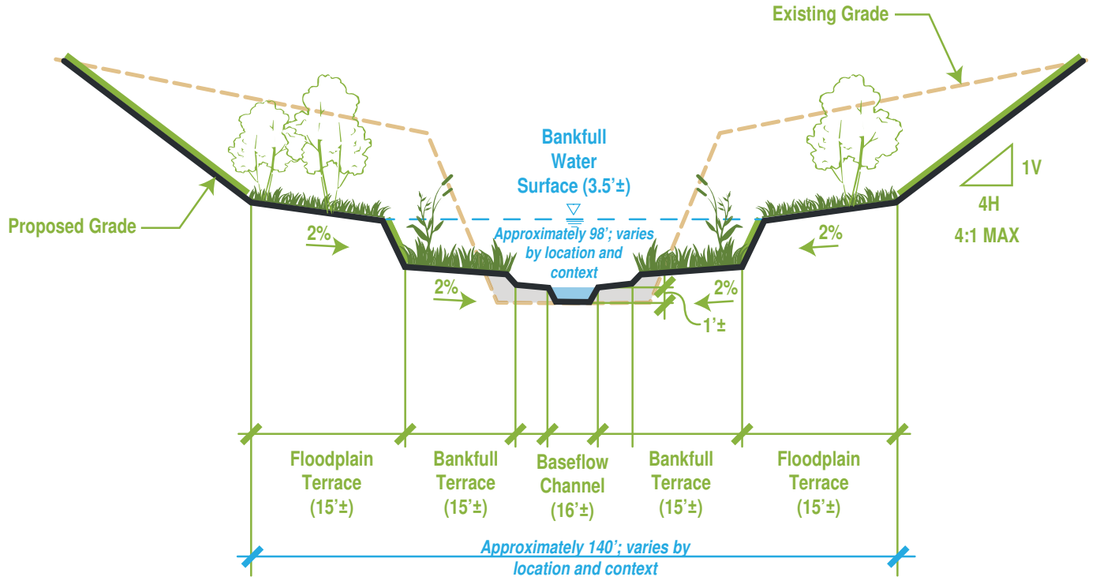
Bankfull Channel

In an effort to help reduce the potential for lateral migration of the channel, implementation of a bankfull channel is recommended. Adequately sizing and configuring the bankfull channel cross section is considered to be the most critical aspect to maintaining floodplain function. Volume 1 of the Urban Stormwater Drainage Criteria Manual (USDCM) (UDFCD, 2016) recommends using a bankfull discharge value equal to the 1.5 to 2 year flow when sizing the bankfull channel.

Typical Recommended Cross-Sections



Recommended cross-section showing the existing channel being filled in order to reconnect Big Dry Creek with the floodplain



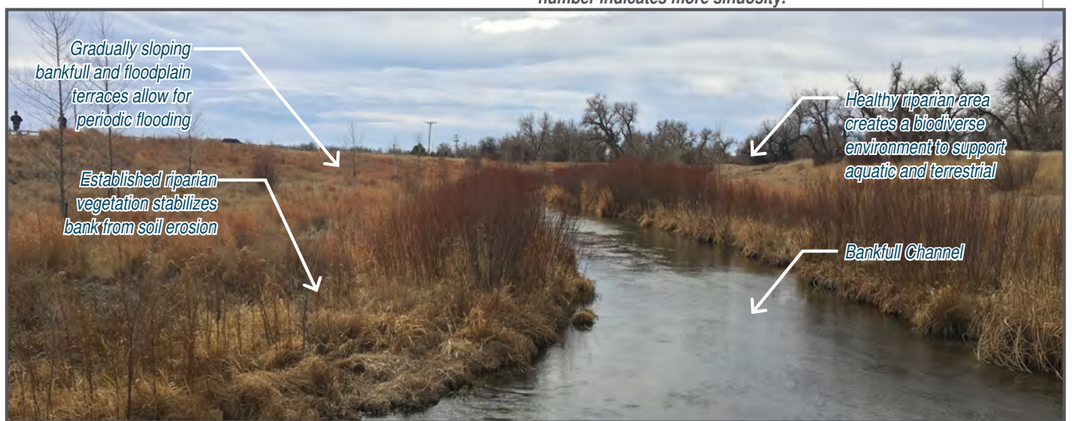
Recommended cross-section showing the existing banks being cut back to form bankfull and terracing the floodplain in order to reconnect Big Dry Creek with the floodplain

Recommended Restoration Channel Design Parameters Tables

Parameters Specific to Big Dry Creek Corridor through Thornton	
Design Parameter	**Recommended Value**
Channel Slope	0.002 ft/ft
Baseflow Channel Discharge	40 cfs
Baseflow Channel Bottom Width	16'± feet
Baseflow Channel Side Slopes	4H:1V
Baseflow Channel Normal Flow Depth	1 foot
Baseflow Channel Roughness (Manning's "n" Value)	0.03
Bankfull Discharge	418 cfs
Bankfull Terrace Slope	2%
Bankfull Terrace Distance	10 feet
Bankfull Channel Side Slopes	4H:1V
Bankfull Channel Normal Flow Depth	3.5 feet
Bankfull Channel Roughness (manning's "n" value)	0.04

General Design Parameters for Naturalized Channels (UDFCD, 2016)	
Design Parameter	**Recommended Value**
Maximum 100-Year Depth Outside Of Bankfull Channel	5 feet
Maximum 5-Year Velocity, Main Channel (Within Bankfull Channel Width)	5 ft/s
Maximum 100-Year Velocity, Main Channel (Within Bankfull Channel Width)	7 ft/s
Froude No.[1], 5-year, main channel (within bankfull channel width)	≤0.7
Froude No. [1], 100-Year, Main Channel (Within Bankfull Channel Width)	≤0.8
Maximum Shear Stress, 100-Year, Main Channel (Within Bankfull Channel Width)	1.2 Lbs/Ft^2
Bankfull Channel Sinuosity [2]	1.1 to 1.3
Maximum Overbank Side Slope	4H:1V
Minimum Radius Of Curvature	2.5 Times The Top Width (Ft)

1. Indicator of hydraulic flow regime.
2. A ratio of stream length following curvature of stream between two points to straight-line distance between the same two points. A higher number indicates more sinuosity.



Example of a healthy floodplain and channel on Cherry Creek; the water is able to safely rise on a regular level and inundate the bankfull benches

For this Master Plan, an estimated bankfull discharge value of approximately 420 cfs has been selected based on the flood frequency analysis summarized in Chapter 3. This bankfull discharge value is based on a USGS Bulletin 17B analysis of stream flow data from USGS gage 06720820 Big Dry Creek at Westminster, CO located approximately 4 miles upstream of the project area. Please note that the results of the gage analysis were increased by a contributing watershed area ratio adjustment and by an additional 20 cfs of WWTP effluent (maximum combined average discharge in cfs/month from Broomfield and Westminster WWTPs). These additions to the results from the gage analysis are a conservative assumption but help to provide a reasonable level of buffer between existing conditions recorded by the gage and future conditions as urbanization continues throughout the watershed area.

Based on a design channel slope of 0.002 ft/ft, and a design bankfull discharge of 420 cfs, a 2.5 feet deep (total depth of 3.5 feet deep including the baseflow channel) stabilized channel with a 44 foot wide bottom width (centered over the baseflow channel) and 4H:1V side slopes provides an adequately sized channel to convey the bankfull event (see cross sections on page 91).

It is recommended that the bankfull channel terrace and banks be stabilized in accordance with the strategies outlined in the Master Plan Toolbox. Potential bank stabilization practices include but may not be limited to bank shaping and planting, geotextile stabilization, and brush layering. Natural or bioengineered approaches to stabilization are preferred, however, hard lining of channel sections may be necessary in the event high bank shear stresses are anticipated or providing an additional level of protection for adjacent infrastructure is required.

Water Quality Benefits of Channel Restoration

The channel restoration projects implemented as part of this Master Plan are expected to provide multiple water quality, aquatic life, and habitat benefits. The stabilized channel is expected to reduce sediment loading to the stream, as well as reduce sediment-related pollutants such as phosphorus and iron. Recent research by Rod Lammers in the December 2016 newsletter of the Big Dry Creek Watershed Association indicated that phosphorus loading from channel erosion on Big Dry Creek is on the order of 10-20 percent of the annual phosphorus load. Additional phosphorus sources are wastewater treatment plant discharges and non-point sources (e.g. fertilizer use on lawns and farm fields, pet waste).

A restored riparian corridor along the stream should provide improved instream and terrestrial habitat. Although restoration of the channel itself may not provide a major change in E. coli loading, healthy native grasses along the channel can provide filtering of upland runoff. BMPs for E. coli in the open space include signage related to leash laws and pet waste pickup, as well as providing trash cans for pet waste disposal.

UDFCD Maintenance Eligibility

All projects within the Master Plan area should be designed for UDFCD maintenance eligibility. In order for a specific project to be considered maintenance eligible, the project must meet the criteria described in the most recent version of the UDFCD's Maintenance Eligibility Program Guidelines document which can be found at *http://udfcd.org/* (UDFCD, 2012). In general the project must meet the following overarching criteria in order to be considered maintenance eligible:

1. The design of the facility must be in accordance with the "Urban Storm Drainage Criteria Manual" (USDCM).
2. The design of the facility must be approved by the District.
3. A certification acceptable to the District must be provided which certifies that construction of the completed facility has been accomplished in accordance with the approved design.
4. Satisfactory maintenance access and public access easements or rights-of-way must be provided in order to adequately maintain the facility.

There are more detailed requirements outlined in the UDFCD Maintenance Eligibility Guidelines for specific project aspects, including drop structures, road crossings and channel restoration design approaches. It is recommended that these guidelines be reviewed at the project planning stage so that maintenance eligibility requirements can be incorporated into the early phases of project development.

Floodplain Restoration Toolbox Strategies

Purpose of the Toolbox

The Floodplain Restoration Toolbox outlines identified strategies and techniques for the restoration and management of the Big Dry Creek corridor. It is the intent of the Toolbox to enable the users of the Master Plan to develop a conceptual restoration approach for a variety of potential deficiencies along Big Dry Creek. Toolbox measures are developed to include general information about the practice along with applicable information to Big Dry Creek. The conceptual approach will not only identify appropriate improvement techniques and their subsequent costs, but will expedite the restoration process.

In evaluating the deficiencies of Big Dry Creek, the overall creek seems to be troubled with the same problems throughout the corridor: over widened low flow channel, minimal bank vegetation, entrenchment, unstable toe of banks, erosion at tributaries, capacity at crossings, oxbows that threaten infrastructure, etc. Therefore, many of the Toolbox restoration techniques can be applied at multiple locations throughout the corridor. Furthermore, many of the Toolbox techniques can be and some should be used in combination to provide addition ecosystem benefits or added level of confidence in the stream restoration technique.

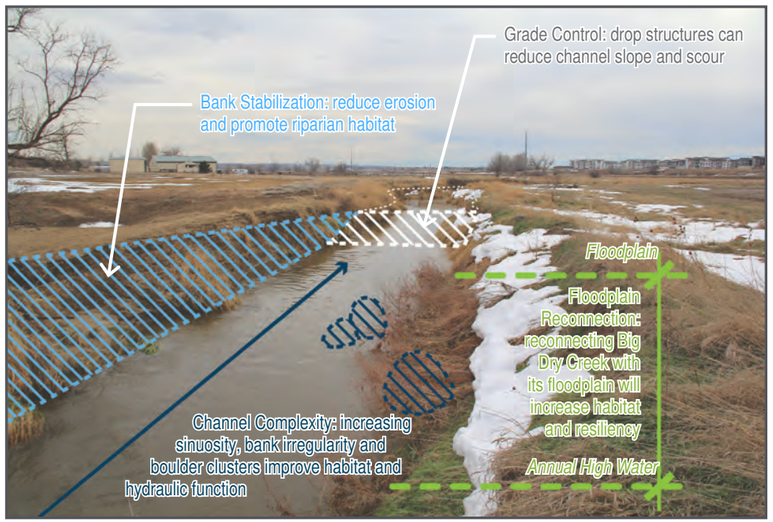
The majority of the Toolbox features outlined here are considered natural channel design techniques. Though natural channel techniques are preferred, it may be necessary to couple these techniques with more typical, engineered approaches. By using natural channel design techniques, the overall system will become more aesthetic and also able to adapt over time.

How to use the Toolbox

The Hydraulic Toolbox Matrix on the facing page was developed to guide the users of this Master Plan to the most appropriate strategies and techniques given a variety of project objectives. This matrix identifies which techniques are best suited for addressing project objectives relevant to Big Dry Creek. A suite of potential project relevant objectives was developed and listed along the top of the matrix. An 'x' indicates that the particular toolbox technique will work to address the identified objective. This system allows for the users of the Master Plan to quickly identify potential strategies and techniques relevant to the project goals. Applicable costs to install each measure are also included. The range of cost for natural channel design techniques can vary greatly from site to site and within a single project area.

Design considerations and 2017 installed costs for each of the Toolbox techniques are discussed in the section following the Hydraulic Toolbox Matrix. In both this section and the matrix, similar techniques are organized together by their overarching strategy. Four overall categories of strategy were identified for Big Dry Creek:

1. Floodplain Reconnection and Restoration
2. Bank Stabilization
3. Channel Complexity
4. Grade Control



This picture demonstrates where each of the overall strategy categories could be used along a stretch of Big Dry Creek

The Hydraulic Toolbox Matrix and the brief descriptions of each technique will provide the user with a general approach to a restoration solution. Still, further design evaluations should be accounted for on a case by case basis. It is recommended that, where applicable, a natural channel design approach should be taken when restoring Big Dry Creek consistent with the parameters presented in the previous sections.

Hydraulic Toolbox Matrix

Toolbox Strategies		Objectives/Problems: Channel Stability	Scour	Sediment Control	Flood Risk Reduction	Stream Crossing	Outfall Protection	Bank Terracing	Wetland Creation	Conveyance	Water Quality	Aquatic Habitat / Fish Passage	Riparian / Upland Habitat	Vegetative Communities	Prairie Dog Management	Weed Management	Unit Cost	Unit
Floodplain Reconnection and Restoration	Natural Channel Design	x	x	x	x			x	x	x	x	x	x	x			$ 300	LF
	Maximize the Floodplain	x		x	x			x	x	x	x	x	x				$ 300	LF
	Off-line Floodplain Culvert	x			x	x				x							$ 150	LF
	Wetland Sod Mat											x	x		x	x	$ 7	SF
Bank Stabilization	Bank Shaping and Planting	x	x	x				x	x	x	x		x	x			$ 200	LF
	J-Hooks, Root Wad, Log Vane	x	x	x									x	x			$5000-7500	EA
	Bendway Weirs	x	x	x								x					$ 7,500	EA
	Log Toe	x	x	x	x			x				x					$ 14	LF
	Boulder Toe	x	x	x	x			x				x					$ 75	LF
	Coir Logs	x		x				x			x		x	x			$ 6	LF
	Willow Stakes	x		x					x		x	x	x	x			$ 5	EA
	Cottonwood Poles	x		x					x		x	x	x	x			$ 25	EA
	Geotextiles	x		x				x						x			$ 8	SY
	Soil Riprap	x	x	x		x		x						x			$ 70	CY
	Brush Layering	x	x	x				x			x		x	x			$ 140	LF
	Offset Buried Riprap Revetment	x	x	x	x									x			$ 100	CY
	Riprap Revetment	x	x	x		x		x									$ 85	CY
	Inlet / Outlet Protection Blanket		x	x	x		x										$ 90	CY
	Flared End Section with Boulders		x	x		x	x			x							$ 2,000	EA
	Headwall and Wingwall		x	x	x	x	x			x							$ 750	CY
	Pier and Bank Protection		x	x	x	x											$ 90	CY
Channel Complexity	Boulder Clusters											x					$ 1,000	EA
	Log Roller	x	x	x								x					$ 2,000	EA
Grade Control	Cross Vanes	x	x	x	x	x						x					$ 15,400	EA
	Constructed Riffles	x	x	x				x				x					$ 110,000	EA
	Sills	x	x	x								x					$ 2,750	EA
	Drop Structures	x	x	x													$ 55,000	EA

Conservation Management Techniques

As a general practice, rather than a design approach, conservation involves property acquisition with the primary intent being to preserve and protect the floodplain, the riparian corridor and adjacent lands. This is accomplished through direct property purchases and placing the purchased lands in public ownership to be managed as open space or through the purchase of a conservation easement on private property that mandates management as open space or agricultural use. As a rule, it can be generally stated that the more property that can be managed as an open space conservation area, the healthier the creek corridor. Conservation areas allow the natural functions of the creek to continue uninterrupted. Generally, one of the strategies of this Master Plan would be to manage the entire 100-year floodplain area within the project limits as a conservation area. In addition to the 100-year floodplain, this Master Plan has identified a 200' wide riparian buffer zone with limited human interaction and development.

Thornton and Adams County have already done an exceptional job of conserving open space areas along Big Dry Creek and they should continue this practice. Adopted city and county maintenance standards for open spaces should be updated to reflect the unique characteristics of the Big Dry Creek corridor. These updates could include specific invasive weed management, checking for and removing log jams and debris along the creek and regular evaluations. A maintenance and evaluation schedule could be developed that evaluates the creek at regular intervals such as once a year. Additionally, the corridor should be evaluated after large storm events to check for new or worsening damages and/or concerns.

In order to manage and maintain Big Dry Creek, it is essential to understand the features that define a healthy system, indicators of an unhealthy system, how to manage and cleanup waste safely and how to identify and manage invasive or noxious weeds. Urban Drainage Flood Control District (UDFCD) and the city and county have developed comprehensive standards on how to address these issues.

Revegetation

Revegetation is an important part of any stream restoration project and it should be included whenever possible. This revegetation will vary from upland seeding, to upland tree and shrub plantings, to riparian corridor tree plantings, to wetland plugs, to riparian plantings and seeding. The Master Plan makes specific plant species and seed mix recommendations parcel-by-parcel further along in this chapter. The benefits of healthy vegetative communities are far-reaching and impact the corridor ecosystem's water quality, bank stability, wildlife habitat, recreational and aesthetic qualities.

Structural Underpinning of Bioengineering Methods

The Hydraulic Toolbox strategies incorporate a variety of traditional engineering and bioengineering elements to help stabilize banks, improve habitat and encourage ecosystem health along Big Dry Creek. The engineering elements utilized in the following toolbox strategies can be designed and installed individually or in conjunction with each other. Traditional engineering elements such as a buried riprap revetment could be installed behind bioengineering elements such as a soil lift to provide additional structural support. By incorporating natural bioengineering techniques and traditional engineering techniques, this approach will promote increased habitat and ecosystem health while ensuring longterm stabilization of priority reaches. The level of structural underpinning needed beneath/behind the bioengineering measures will need to be determined on a project-by-project basis. Overall, the intent should be to create a bioengineered solution that appears as a natural element on the surface while providing the necessary structural support for long-term success and stability of the project.

1. Floodplain Reconnection and Restoration

When restoring identified projects or sections of channel, there are various design applications and techniques that can be applied based upon the unique characteristics of the reach. A specific restoration plan should be applied to a length of channel to repair the identified deficiencies while also increasing the stability throughout the length of channel. The natural channel design approach uses natural form and materials to restore stream function and establish a bankfull channel which provides access to the adjacent floodplain, allowing for overflow across the floodplain in larger events, and a low flow channel to provide necessary flow depths during times of reduced runoff. This can be achieved through the implementation of a desirable stream type (as described in the recommended cross-sections on page 89), coupled with various bank protection and grade control measures to aid in returning the channel to a naturally stable cross section, slope, and pattern suitable for the stream and corridor characteristics.

Throughout the project area, Big Dry Creek is not well connected to its floodplain. There are many areas where the banks are so tall that it would be difficult for the floodwaters to actually reach the floodplain. Where the floodplain is not connected, the majority of the flow will be conveyed through the incised channel at high velocities, causing additional erosion. The bankfull elevation of the 1.5-year storm is used to demark the limit of when the channel should be reconnected to the floodplain because even frequently occurring storms (statistically occurring every 1.5 to 2 years) cause significant erosion through the creek channel. The floodplain could be connected throughout the corridor to provide for a more resilient creek.

Following are tools to reconnect the floodplain to the creek as part of the Big Dry Creek restoration.

Entrenched channel results in the creek being disconnected from the floodplain

Lack of bank vegetation on Big Dry Creek with eroding banks

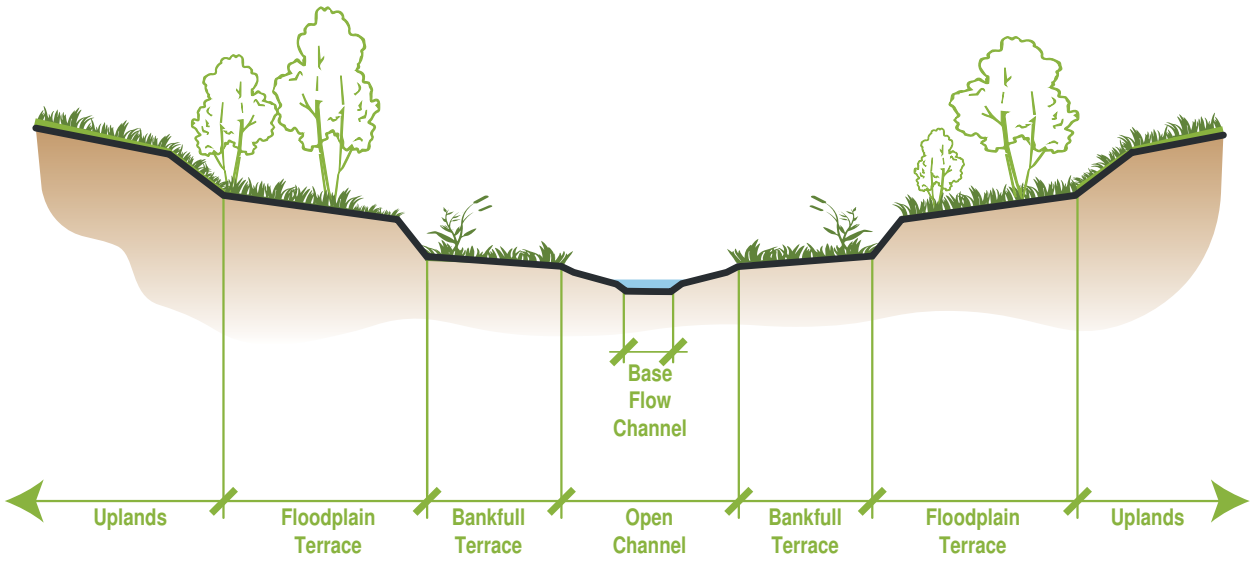
Natural Channel Design *(Floodplain Reconnection and Restoration)*

The majority of the toolbox features outlined here are considered natural channel design techniques. Though natural channel techniques are preferred, it may be necessary to couple natural channel design techniques with more traditional, hard-engineered approaches. By using natural channel design techniques, the overall system will become more aesthetic and able to adapt over time. By coupling the natural channel design aspect with a more traditional engineering approach such as offset buried revetment or structural underpinning, natural channel designs can be implemented with the added level of protection from the more traditional hard engineering approach. See bank stabilization section for Riprap Revetment, Soil Riprap or Offset Buried Riprap for additional information on traditional hard engineering approaches.

Cost per Unit: $300/LF

Problems Addressed:

- *Channel Stability*
- *Scour*
- *Sediment Control*
- *Flood Risk Reduction*
- *Bank Terracing*
- *Wetland Creation*
- *Conveyance*
- *Water Quality*
- *Aquatic Habitat/Fish Passage*
- *Riparian/Upland Habitat*
- *Vegetative Communities*



Typical Healthy Floodplain *Section View*

Maximize the Floodplain *(Floodplain Reconnection and Restoration)*

Cost per Unit: N/A

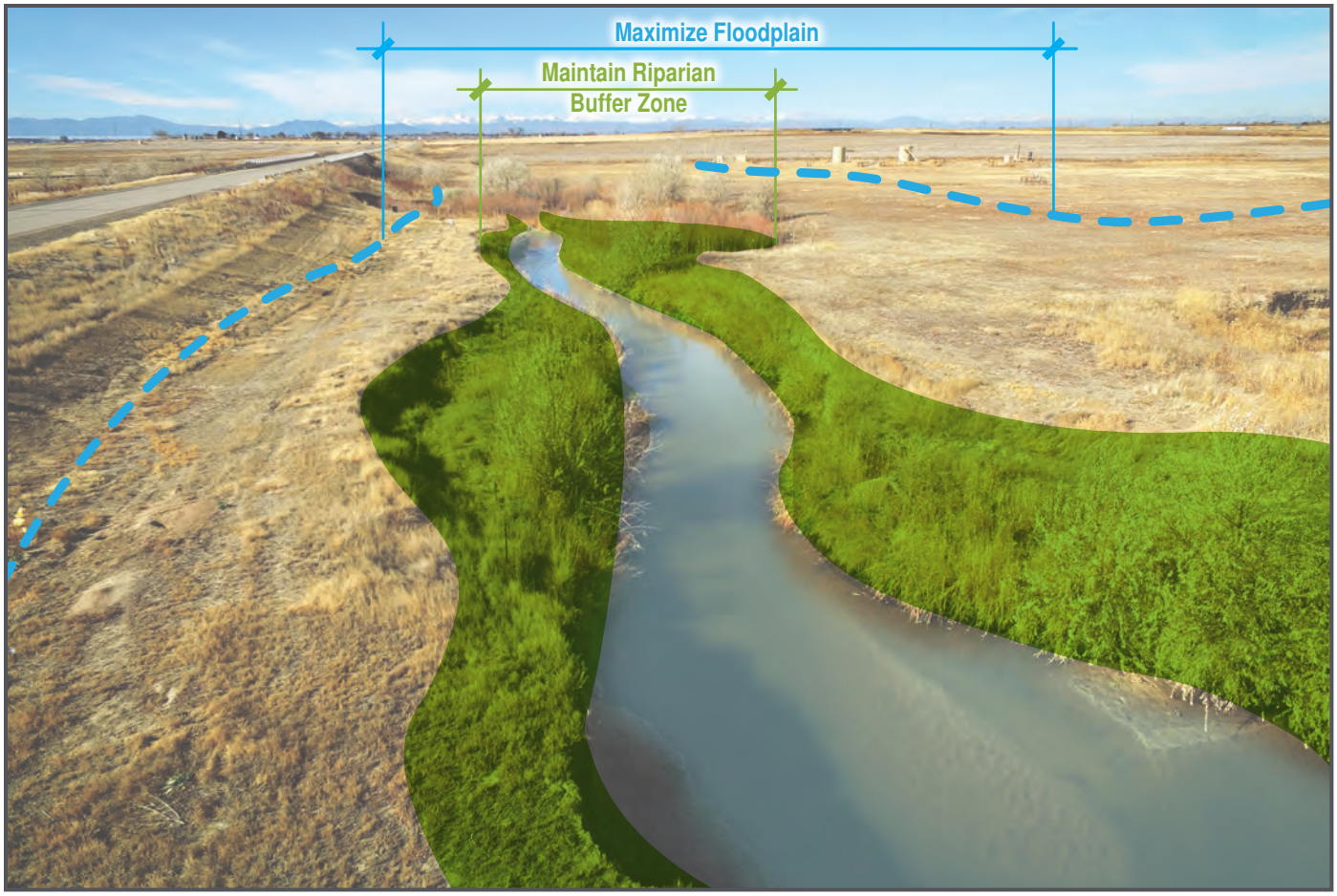
Problems Addressed:

- ***Channel Stability***
- ***Sediment Control***
- ***Flood Risk Reduction***
- ***Bank Terracing***
- ***Wetland Creation***
- ***Water Quality***
- ***Riparian/Upland Habitat***
- ***Vegetative Communities***
- ***Prairie Dog Management***
- ***Weed Management***

Riparian buffer zones prevent built developments from establishing too close to the creek and help expand wildlife habitat areas. Providing riparian buffers are often an option when easement or acquisition of lands for conservation is not possible. For the Big Dry Creek corridor, the Master Plan established a riparian buffer of 200' (100' to either side of the creek's centerline), and only recommends placing the Big Dry Creek Trail within this buffer area where it is absolutely necessary to cross the creek.

Within the riparian buffer zone, restoration work should maximize the floodplain wherever possible, including removing barriers in the floodplain so that flood flows effectively move through the floodplain without encountering structures or impediments that could either be damaged or cause damage. Maximizing floodplain within the riparian buffer zone increases flood storage, reduces flood depth and the sheer stress that damages the creek corridor. It also helps to protect developments established outside of the riparian buffer zone from the threat of floods.

Big Dry Creek floodplain restoration work will need to be done within the 200' buffer zone, and does not exclude restorative work within it. Rather, the 200' buffer should be respected when considering human access/interaction and recreation projects following the restorative work.



Maximizing a riparian buffer zone and a floodplain for high flows to dissipate energy within will benefit both hydraulics and wildlife habitat

Off-line Floodplain Culvert *(Floodplain Reconnection and Restoration)*

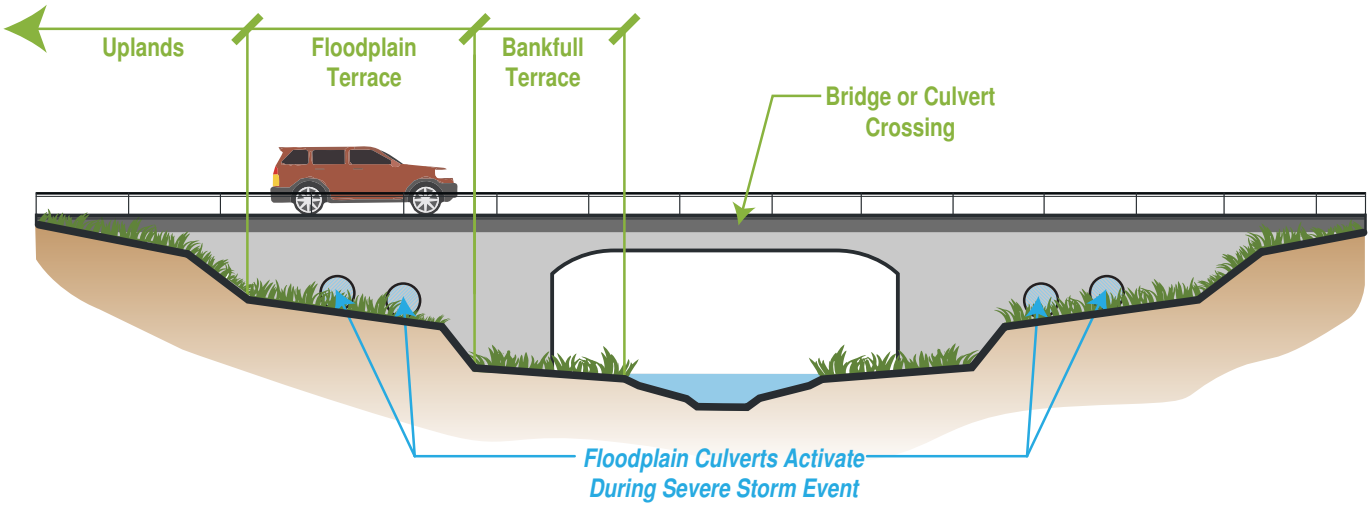
Cost per Unit: $150/LF

Problems Addressed:

- ***Channel Stability***
- ***Flood Risk Reduction***
- ***Stream Crossing***
- ***Wetland Creation***
- ***Conveyance***

Off-line flood culverts are pipes that are placed in the floodplain at a creek crossing to reduce the amount of constriction of the main channel necessary to convey the flood flow through a crossing. The off-line floodplain culverts convey flow from one side of a crossing to the other without causing increased velocity and associated scour. With Big Dry Creek's expansive floodplain, it is recommended to add off-line flood culverts at crossings.

Off-line floodplain culverts are utilized during large storm events where flood flows exceed the capacity of the bankfull channel and therefore spread across the floodplain. Installments such as off-line flood culverts help meet floodplain connectivity, protection of aquatic habitat and maintenance of the channel's natural capacity for sediment transport, while reducing flood risk.



Off-Line Floodplain Culvert *Elevation View*

Wetland Sod Mats *(Floodplain Reconnection and Restoration)*

To promote revegetation in aquatic and upland areas, sod mats can be installed with appropriate plant species that are native to their respective saturation zone within the stream corridor. It is critical that the species are checked and placed in areas where design velocities and shear stresses are low enough for the plant material to withstand larger storm or flood events. Wetland sod mats are typically used on the lower terraces of streambanks, where their roots will have access to moisture from typical low flows. They are especially useful in situations where it is desirable for plant communities to be established quickly and fully. More expensive than typical seeded or hand planted wetland plantings, wetland sod mats establish faster and more consistently. Wetland sod mats can be used for key design areas on a project, while the larger areas receive the less costly wetland plugs and seeding treatments.

Cost per Unit: $7/SF

Problems Addressed:

- ***Bank Terracing***
- ***Wetland Creation***
- ***Water Quality***
- ***Aquatic Habitat/Fish Passage***
- ***Riparian/Upland Habitat***
- ***Vegetative Communities***
- ***Weed Management***

Wetland sod installed at the toe of the bank can provide immediate vegetative establishment for high priority areas

2. Bank Stabilization

There are numerous approaches to bank stabilization. Banks can either be stabilized in place with the addition of stabilization measures or the bank can be regraded and laid back as a terraced floodplain which reduces the steep, unstable nature of the bank in its entirety. The recommended approach for the Big Dry Creek corridor is to modify the channel slope and develop a low flow channel and terraced floodplain (as described in the Recommended Cross-Sections on page 89) to address the problem of bank stabilization directly at the source.

Floodplain reconnection will reduce the near bank stress and develop a hydraulic regime that the substrate materials of the creek banks can sustain. The low flow channel and terraced floodplain bench allows for a stabilized toe in the form of boulders or logs that can resist greater velocities than the bank material, while at the same time provide the required width-to-depth ratio of the channel. As described in Revegetation on page 92, revegetation of deficient areas throughout the creek corridor can further increase stream stability and resiliency.

The majority of the banks along Big Dry Creek are nearly vertical and composed of fine granular material that is not resistant to erosional forces. Compounded with the fact that the base flow level fluctuates greatly due to the wastewater inflows, the bank material is constantly going through a wetting and drying cycle that can cause sloughing and bank failure via undercutting. In areas where channel grading and terraced floodplain creations cannot take place, it is recommended to use bank stabilization measures in the form of vegetation and rock to stabilize the channel. In areas of high velocities and shear stresses, it is also recommended to stabilize the lower base flow and bankfull channel area with a hard lined material such as logs and boulders to reduce the effects of the fluctuating water level.

Bank stabilization along Big Dry Creek could take place in the majority of the corridor due to the entrenched nature of the creek. It also could take place around the outside bends where erosive velocities are being encountered, at crossing locations where flow is rapidly constricted and then expanded, and where other material has been used to stabilize the banks improperly.

Following are bank stabilization tools that could be used as part of stabilizing the Big Dry Creek floodplain.

Eroding banks on outer bend

Eroding banks protected incorrectly with concrete scraps

Bank Shaping and Planting *(Bank Stabilization)*

Where possible, degraded or unstable banks should be re-shaped to a stable design geometry with the use of channel grading and laying back of banks prior to using any of the other measures listed here. A bankfull channel with an inlaid low flow channel and terraced floodplain should be used to accomplish this goal. These dimension of the various channel parameters are set by the hydraulics associated with the specific site.

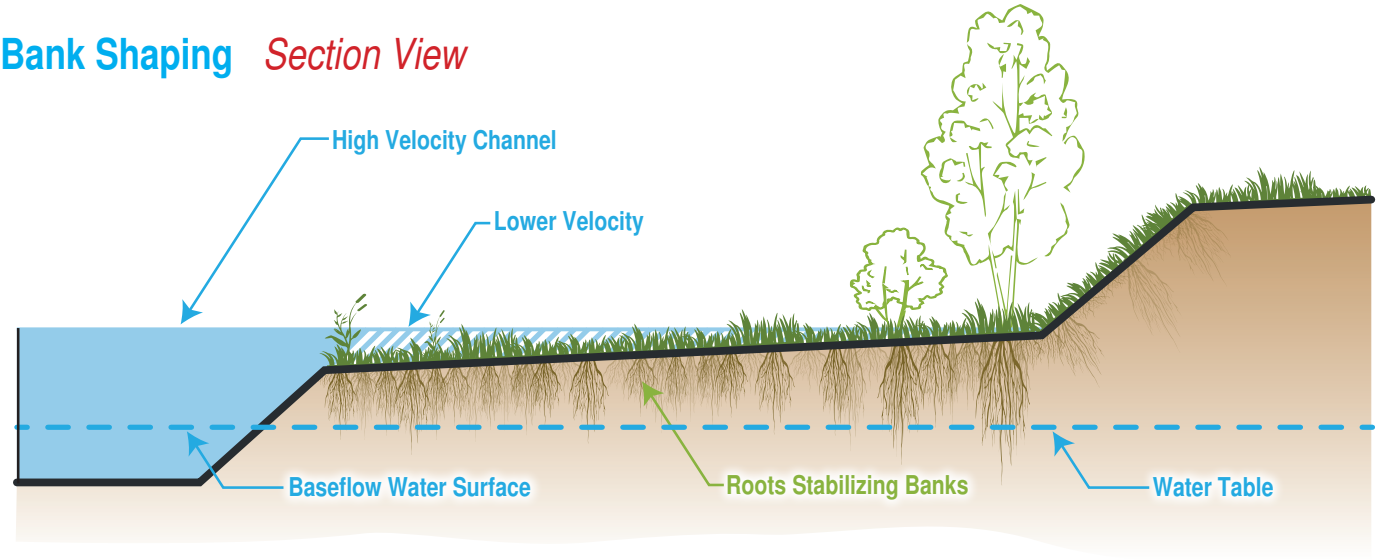
By reducing the vertical stress, the erosive forces on the banks can be reduced, therefore stabilizing the banks naturally. Planting the re-shaped bank will provide further stability. The shape of the bank should provide consistency with the cross-sectional geometry of the rest of the channel reach. In some areas bank shaping might not be necessary and in those locations additional stabilization features in the form of vegetation and rock could be used.

Cost per Unit: $200/LF

Problems Addressed:

- *Channel Stability*
- *Scour*
- *Sediment Control*
- *Bank Terracing*
- *Wetland Creation*
- *Conveyance*
- *Water Quality*
- *Riparian/Upland Habitat*
- *Vegetative Communities*

Bank Shaping *Section View*



Eroding banks along Big Dry Creek in need of stabilization through re-shaping and vegetation

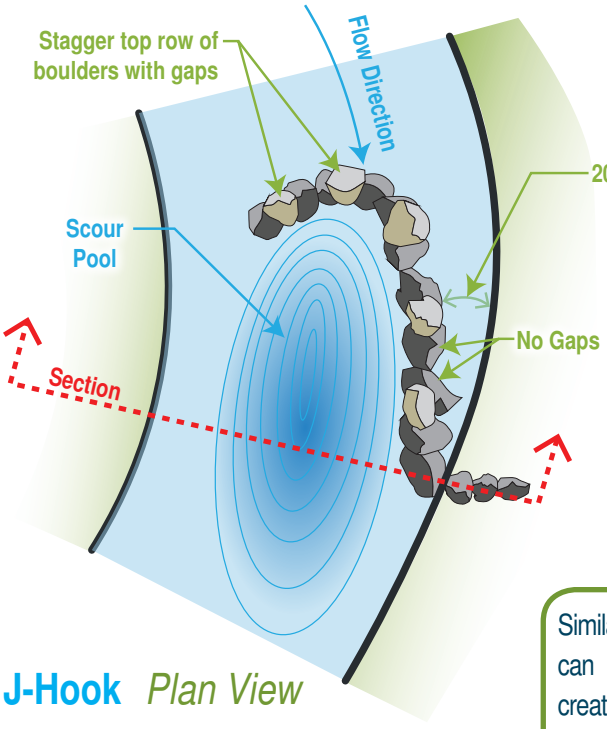
J-Hooks, Root Wads and Log Vanes *(Bank Stabilization)*

Cost per Unit: $5,000/ea

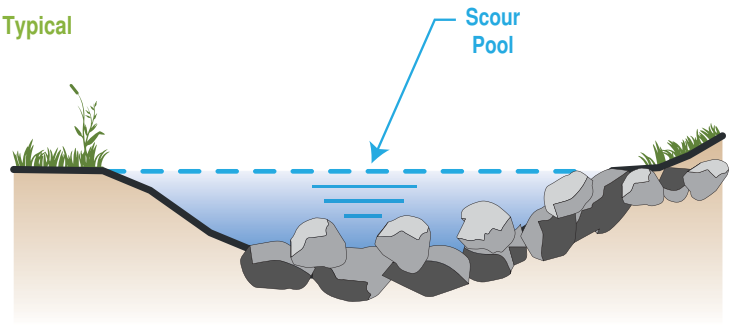
Problems Addressed:

- *Channel Stability*
- *Scour*
- *Sediment Control*
- *Riparian/Upland Habitat*
- *Aquatic Habitat*

The J-Hook is a boulder structure that is located on the outside bend of a channel to redirect the flows back toward the center of the creek, thereby reducing erosive near-bank velocities and preventing avulsions. These are upstream facing structures that span about 2/3 of the channel. The arc of the hook is typically centered at the channel thalweg forcing the flow towards the center and inside of the channel bend. Although similar to the design of the cross vane, discussed on page 118, the J-Hook does not span the width of the channel and is often constructed along a bendway. To diversify channel materials, the J-Hook arm can be constructed with trees and other woody structures. J-Hooks can also create additional habitat in the creek and cover for aquatic species because they create deeper pools within the channel and reduce velocities.

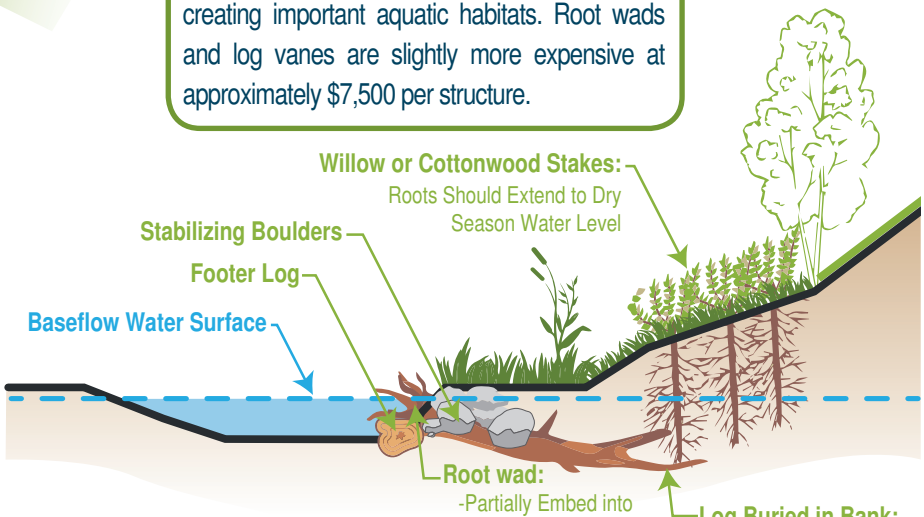


J-Hook *Plan View*



J- Hook *Section View*

Similar to J-Hooks, root wads and log vanes can be used to control/direct flows while creating important aquatic habitats. Root wads and log vanes are slightly more expensive at approximately $7,500 per structure.



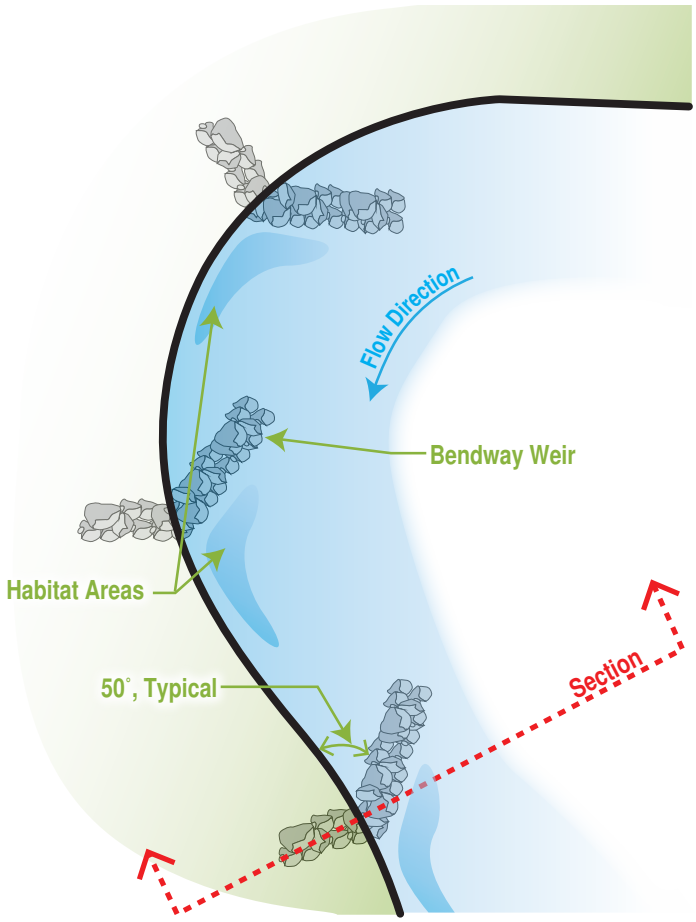
Root Wad *Section View*

Bendway Weirs *(Bank Stabilization)*

Cost per Unit: $7,500/ea

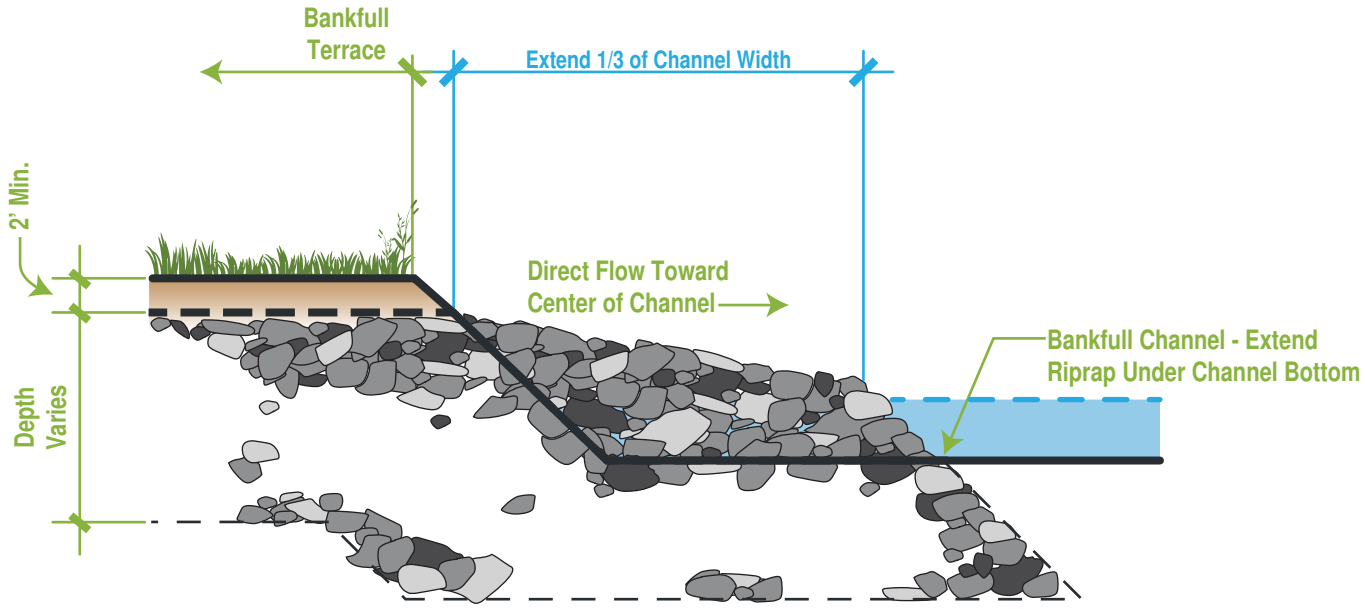
Problems Addressed:

- ***Channel Stability***
- ***Scour***
- ***Sediment Control***
- ***Aquatic Habitat***



Bendway Weir *Plan View*

Similar to the J-Hook, a bendway weir is a structure that is located on the outside of a bend to redirect flow back toward the center of the channel, reducing high velocities around the outer bank that can cause a bank to become unstable. Bendway wiers span about 2/3 of the channel, however, unlike the J-Hook, they do not curve back around in the center of the channel and are typically designed to be fully submerged in a bankfull event. Bendway weirs can also provide critical habitat and deep pools to form on its downstream side for aquatic habitat and are composed of either larger riprap or boulders that can resist movement.



Bendway Weir *Section View*

Log Toe *(Bank Stabilization)*

Cost per Unit: $14/LF

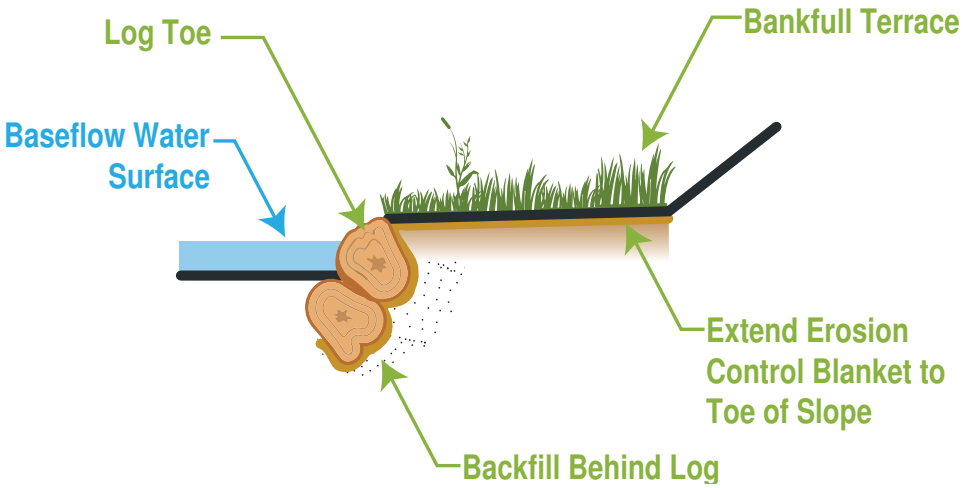
Problems Addressed:

- *Channel Stability*
- *Scour*
- *Sediment Control*
- *Flood Risk Reduction*
- *Bank Terracing*
- *Aquatic Habitat/Fish Passage*

A log toe uses the trunks of trees to stabilize riparian habitat along waterways and reduce bank erosion. Existing trees that are removed during the construction process can be reused to create a log toe on-site, making them a responsible and cost effective bank stabilization method. Log toes are less permanent than boulder toes and typically last between 10-20 years.

Log Toe

Log toes are constructed by partially burying a log into the creek bank to resist moderate velocities. The species and diameter of the logs will vary based on availability on site and height of the banks. A log toe can consist of multiple logs stacked on top of each other to achieve the desired height. At least 2/3 of the log toe structure should be buried into the existing grade to reduce the chances of undercutting. Log toes will help prevent bank erosion thus giving vegetation enough time to establish along the channel and riparian benches and can be used in combination with boulders to lock the structures in place.



Log Toe *Section View*

Boulder Toe *(Bank Stabilization)*

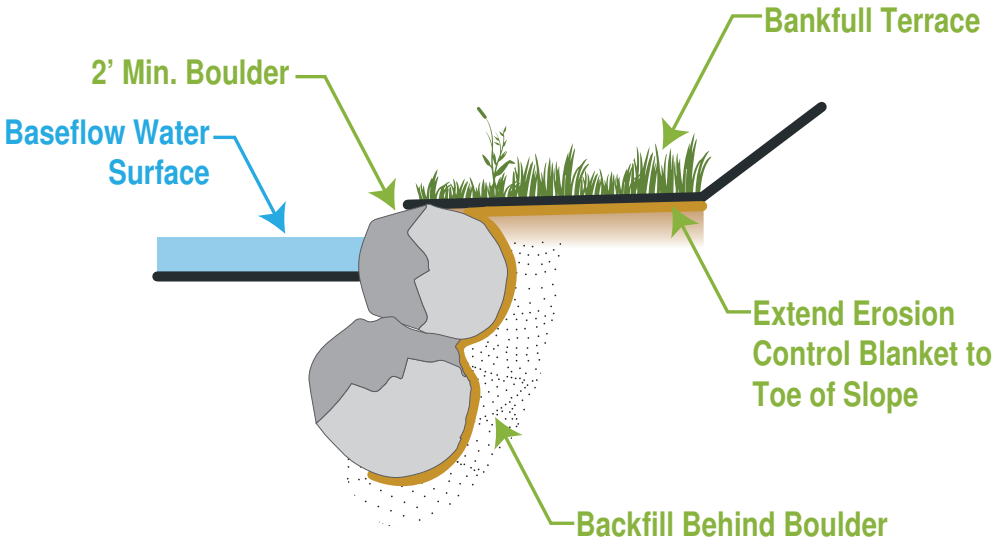
Cost per Unit: $75/LF

Problems Addressed:

- *Channel Stability*
- *Scour*
- *Sediment Control*
- *Flood Risk Reduction*
- *Bank Terracing*
- *Aquatic Habitat/Fish Passage*

Boulder toes are bank stabilizing tools that can resist high velocities and are usually positioned on the outside bends of the channel. Boulder toes consist of 1, 2 or 3 boulders of varying sizes stacked on top of each other and buried 2/3 into the exiting grade. In cobble soils, the bottom of boulder toes can be installed on existing bed material. In sandy soils, structural fill or geotextile fabric should be installed underneath the boulder toe to prevent the structure from sinking or moving. Boulder toes will reduce erosion along banks and allow vegetation to re-establish and take hold. Willow stakes can be installed in-between the boulders during construction to mitigate the visual impact, provide additional habitat and increase the strength of the boulder toe over time.

Boulder Toe



Boulder Toe *Section View*

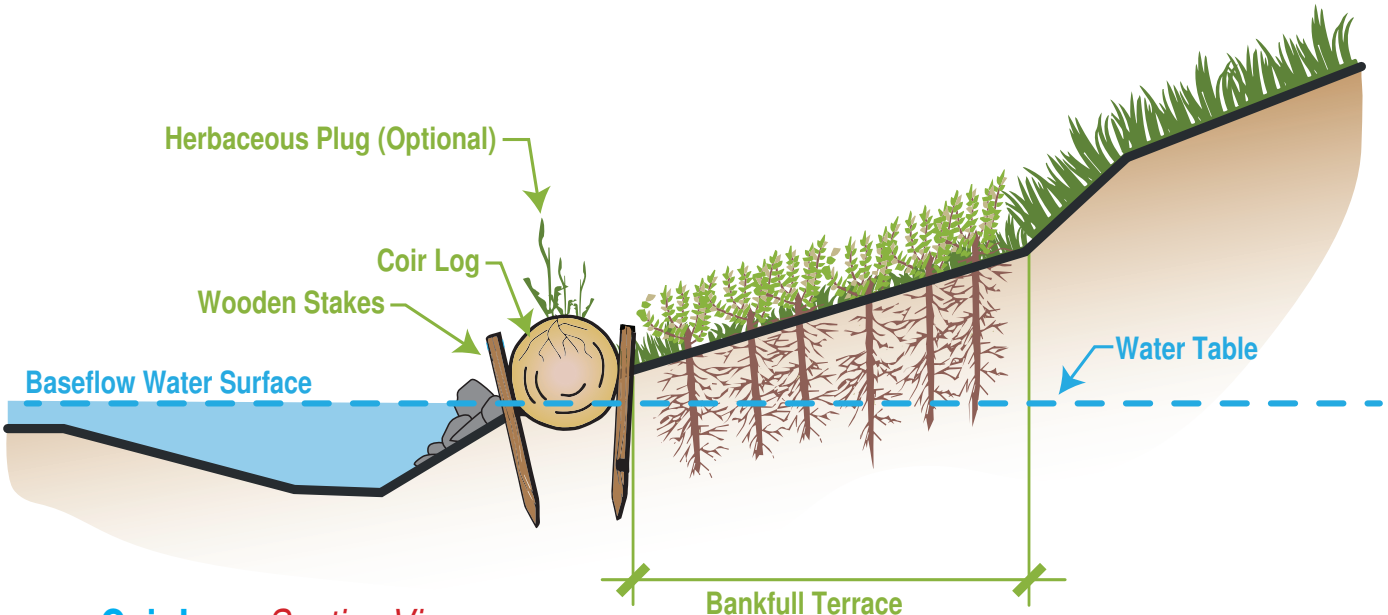
Coir Logs *(Bank Stabilization)*

Coir logs are tightly bound cylinders of coconut fibers or soil held together by a coconut fiber netting made from coconut twine, or other biodegradable products. Coir logs act as a structural support of the soil behind it, but also trap water and sediment to support the vegetation planted behind the coir log. Layering coir wrapped soil in a stair stepping application can provide erosion control and structural support to a bank in areas of reduced velocity. Additionally, vegetation can be used in the logs and between the layers to provide further stabilization and plant growth for the floodplain.

Cost per Unit: $6/LF (without plantings)

Problems Addressed:

- *Channel Stability*
- *Sediment Control*
- *Bank Terracing*
- *Water Quality*
- *Riparian/Upland Habitat*
- *Vegetative Communities*



Coir Log *Section View*

Coir logs with vegetation (photo credit: salixrw.com)

Willow Stakes and Cottonwood Poles *(Bank Stabilization)*

Cost per Unit: $3-$5/ea (Willows) $25/ea (Cottonwood)

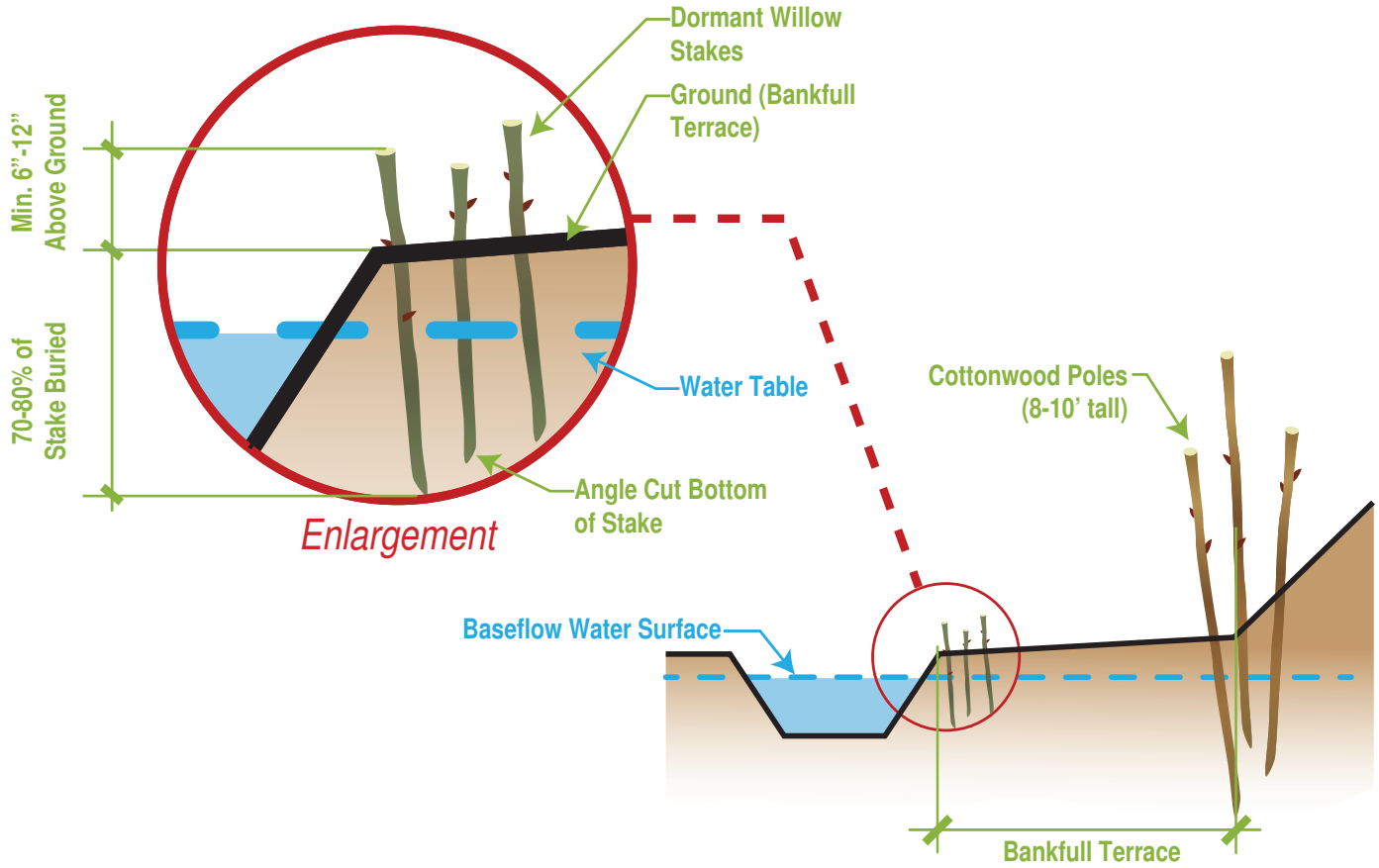
Problems Addressed:

- *Channel Stability*
- *Sediment Control*
- *Wetland Creation*
- *Water Quality*
- *Aquatic Habitat/Fish Passage*
- *Riparian/Upland Habitat*
- *Vegetative Communities*

Willow stakes can often be installed by volunteers

Planting live willow stakes and cottonwood poles along degraded stream banks not only increases stream stability but improves riparian habitat. This approach is applicable where banks experience relatively low shear stresses and velocities. Typically, cottonwood and willow stakes/poles can be harvested on-site or on nearby sites. This provides a higher probability of survival and a lower probability of creating an imbalance in the ecosystem.

Planting willow and/or cottonwood stands along banks also provides excellent bird and small mammal habitat, as well as shades the water which cools temperatures and creates healthier habitat for aquatic organisms. This is one of the lowest cost and easiest to install bank stabilization methods. It is so easy that willow/cottonwood pole plantings are often done by volunteer groups.



Willow Stakes and Cottonwood Poles *Section View*

Geotextile Stabilization *(Bank Stabilization)*

Cost per Unit: $8/SY

Problems Addressed:

- *Channel Stability*
- *Sediment Control*
- *Bank Terracing*
- *Vegetative Communities*

Geotextile stabilization consists of using a blanket of interwoven generally biodegradable fibers laid down on sloping exposed soils to reduce the potential for erosion and increase the potential for vegetation to establish. Geotextile fabrics or blankets can be an effective means of stabilizing banks to allow enough time for vegetation to take root and stabilize the bank on its own.

Biodegradable fabrics allow vegetation to establish itself, growing through the woven fabric as the fabric breaks down and decomposes into mulch and compost, increasing the stability throughout the bank. Non-biodegradable materials can be used in areas where vegetation is not designed to grow or where high flows are expected. Geotextile stabilization does have to be installed with care. If the material is not installed and staked properly, it can be susceptible to tearing and failing.

Geotextile bank stabilization used for revegetation

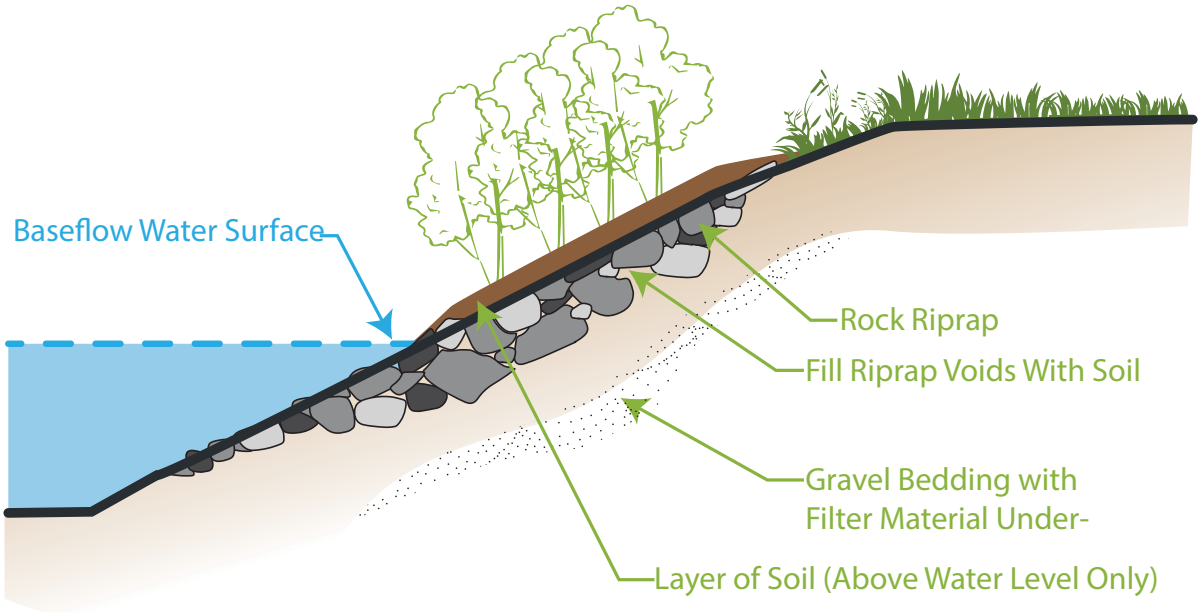
Soil Riprap *(Bank Stabilization)*

Soil riprap consists of a mixture of rocks and soil used to stabilize banks. This material is less costly than rock riprap alone, and can be just as effective if installed properly when designed for the right conditions. The rock and soil mixture allows for placement of more erosive, finer material, and generates greater slope and channel stability than backfill alone. Soil riprap is sometimes viewed as more aesthetically pleasing than rock or boulder riprap and has a greater chance of establishing vegetation to acquire the look associated with natural channel design. The vegetation is used to support aesthetic aspects along with resistance to erosive flows during more frequent events and the riprap acts as a last line of defensive to more erosive velocities seen during large storm events.

Cost per Unit: $70/CY

Problems Addressed:

- ***Channel Stability***
- ***Scour***
- ***Sediment Control***
- ***Stream Crossing***
- ***Bank Terracing***
- ***Vegetative Communities***



Soil Riprap *Section View*

Void-filled riprap is an alternative to soil riprap that is designed to emulate natural rock riffle material found in steep gradient streams. It contains a well-graded mix of cobbles, gravels, sands, and soil that fills all voids and acts as an internal filter, therefore a separate bedding layer between subgrade and rock is not required. In applications where it is difficult to establish vegetation, void-filled riprap is better able to resist the direct, prolonged impingement of water on the riprap installation compared to soil riprap. However, void-filled riprap is more difficult to properly mix and install compared to soil riprap. UDFCD recommends review of the technical paper titled Demonstration Project Illustrating Void-Filled Riprap Applications in Stream Restoration (Wulliman and Johns 2011). This paper provides background on the derivation of void-filled riprap and its applications in stream restoration and is available on the UDFCD website.

Brush Layering (and Soil Lifts) *(Bank Stabilization)*

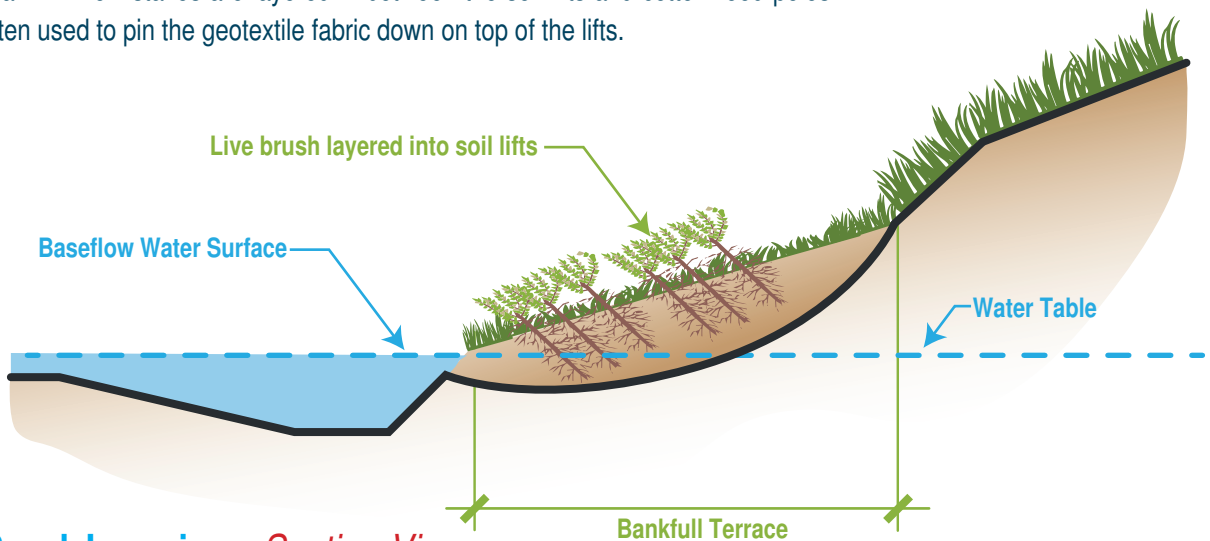
Cost per Unit: $140/LF

Problems Addressed:

- *Channel Stability*
- *Scour*
- *Sediment Control*
- *Bank Terracing*
- *Water Quality*
- *Aquatic/Riparian/Upland Habitat*
- *Vegetative Communities*

Brush layering is an additional option for stabilization when velocities and flows are less erosive. Installed on the outside bend of a curve, this tool is inexpensive and is easier to vegetate than soil riprap but the installation can be quite labor intensive. Brush layering is desirable because of its natural look, however if large flows or debris flow is experienced, the brush layering can tear and result in erosion and additional loss of bank or channel material. This technique can be complimented with the installation of large woody materials, such as trees, at the toe of the bank and is especially desirable if the design goals pertain to aquatic habitat restoration.

Brush layering can be installed to also provide strong bank stabilization/re-construction through the use of vegetated soil lifts. Vegetated soil lifts consist of layers of soil wrapped in geotextile fabric and stacked along the creek to form the new bank. Willow stakes are layered in between the soil lifts and cottonwood poles are often used to pin the geotextile fabric down on top of the lifts.



Brush Layering *Section View*

Willow stakes installed as part of a vegetated soil lift bank stabilization (at time of installation)

Willow stakes installed as part of a vegetated soil lift bank stabilization (after establishment)

Offset Buried Riprap Revetment *(Bank Stabilization)*

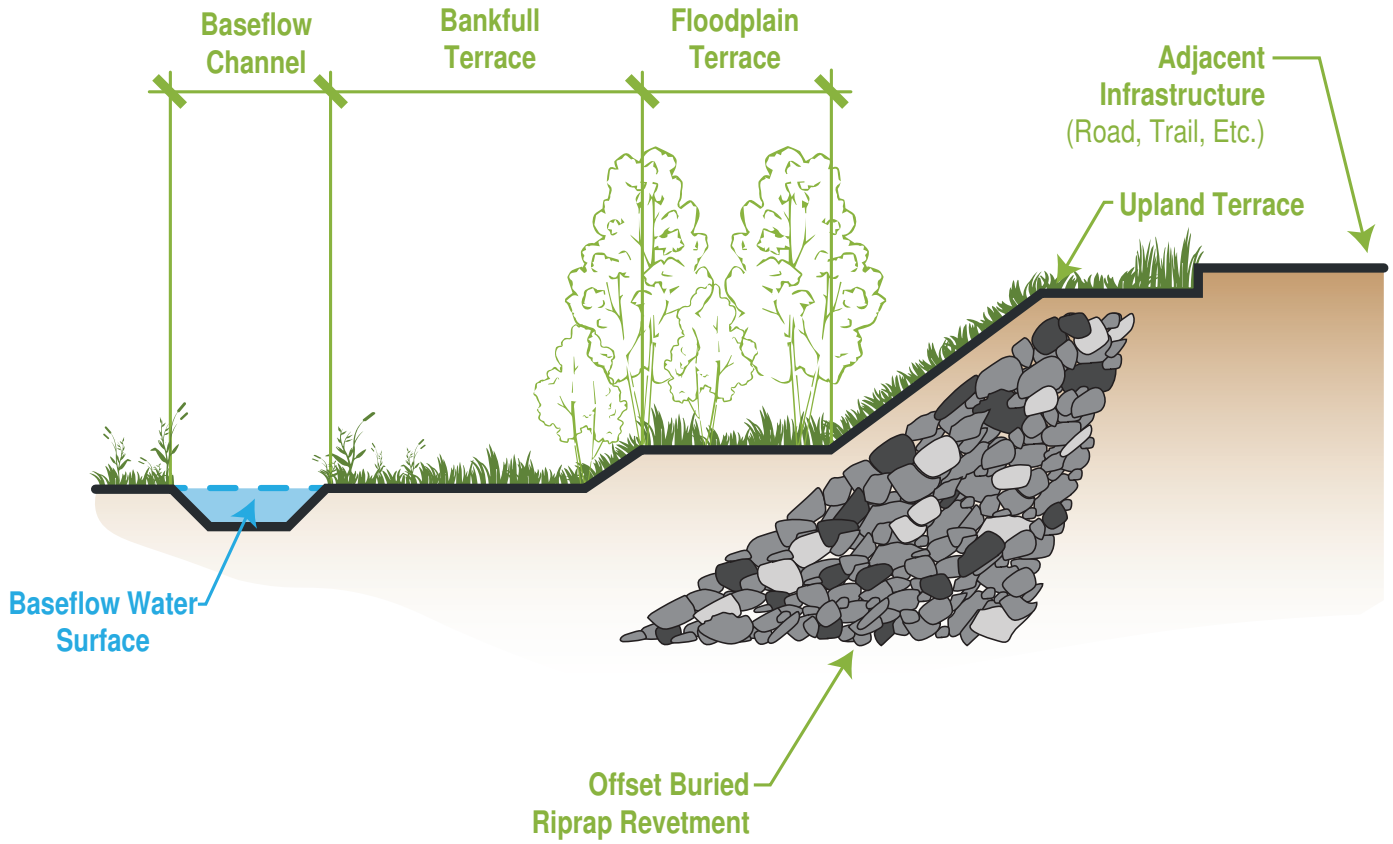
Cost per Unit: $100/CY

Problems Addressed:

- ***Channel Stability***
- ***Scour***
- ***Sediment Control***
- ***Flood Risk Reduction***
- ***Vegetative Communities***

A riprap revetment can also be buried offset of the channel location to provide protection when the stream corridor migrates laterally. This type of technique can also be used as structural underpinning of more soft engineering strategies to provide an additional level of protection while also using natural channel design. Offset buried riprap size, depth, and area of coverage would be calculated in the same way a normal riprap revetment would be designed.

Offset buried revetment can be used as a last line of defense to protect infrastructure in the channel migration zone. As the channel laterally migrates over time, the offset, buried revetments can act as a protection for the infrastructure to allow time, to perform routine maintenance and relocate channel or infrastructure projects as necessary.



Offset Buried Riprap Revetment *Section View*

Riprap Revetment *(Bank Stabilization)*

Cost per Unit: $85/CY

Problems Addressed:

- ***Channel Stability***
- ***Scour***
- ***Sediment Control***
- ***Stream Crossing***
- ***Bank Terracing***

Riprap, while typically the most expensive option for bank stabilization, allows for a detailed design utilizing rock of a specific size to accommodate scouring and erosion associated with high velocities and meandering bends throughout a channel. Contractors tend to be familiar with the installation of this material, however there are greater costs associated with hauling and placing the rock when compared to other options. When utilizing riprap consisting of larger rocks or boulders, void spaces must be properly filled and the use of a geotextile material should be used to prevent scouring. This material is usually not suitable for vegetation, and thus isn't able to acquire the aesthetic look associated with a natural channel design.

Example of a riprap revetment (armoring)

Inlet and Outlet Protection Blanket *(Bank Stabilization)*

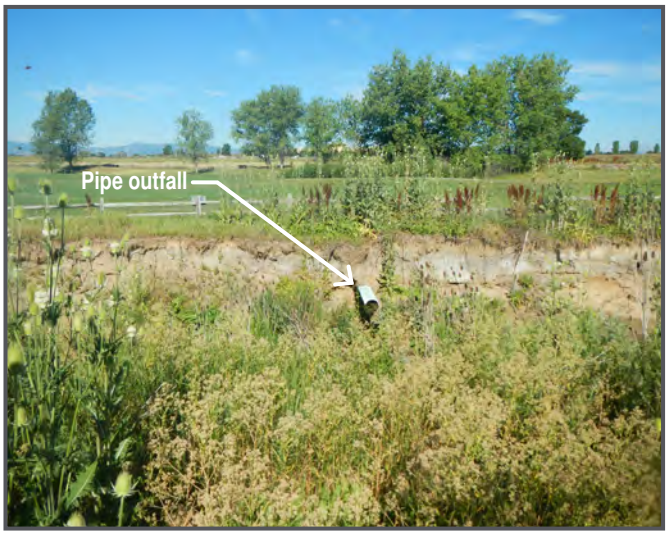
Cost per Unit: $90/CY

Problems Addressed:

- *Scour*
- *Sediment Control*
- *Flood Risk Reduction*
- *Outfall Protection*

There are many locations along Big Dry Creek where pipes outfall and other locations where the creek is conveyed through a pipe under a road or bridge crossing. At inlets to the pipe crossings, the creek is contracted through an area that is narrower than the creek itself, therefore causing increased velocity when entering and leaving the crossing. These increases in velocity due to constriction and then expansion can cause an increase in localized bank scour.

At inlet and outlet locations, a riprap protection blanket should be designed and installed to dissipate energy and provide protection for the pipe structure and the channel banks, as well as the embankments of the crossing. Some smaller culverts might not have the capacity to convey the entire storm runoff, so these culverts may overtop. The inlet and outlet protection blanket should also be designed to reduce failures caused by overtopping.



Bank erosion has caused this pipe outfall to be exposed with no protection

Although this outfall is stabilized with riprap, added vegetation will improve stability to the sides of the outfall

Flared End Section (FES) Headwall with Boulders *(Bank Stabilization)*

Cost per Unit: $2,000/ea

Problems Addressed:

- *Scour*
- *Sediment Control*
- *Stream Crossing*
- *Infall / Outfall Protection*
- *Conveyance*

In addition to inlet and outlet protection blankets, flared end sections should be used at pipe inlets and outlets. Flared end sections allow for a gradual tapering of the channel inlet and outlet so that the crossing embankment does not have to be as vertical. Flared end sections reduce the potential for erosion at both the upstream and downstream end of a culvert. On the upstream end, a flared end section provides protection against seepage; on the downstream end of the pipe, it predominantly protects against erosion and scour. Flared end sections are usually used in combination with an inlet and/or outlet protection blanket and can greatly reduce piping failures as well as overtopping issues.

Concrete flared end section

Pipe Headwall and Wingwall *(Bank Stabilization)*

Cost per Unit: $750/CY

Problems Addressed:

- *Scour*
- *Sediment Control*
- *Flood Risk Reduction*
- *Stream Crossing*
- *Outfall Protection*
- *Conveyance*

As an alternative to flared end sections, concrete headwalls and wingwalls can be used at pipe inlets and outlets. Pipe headwall and wingwalls act like flared end sections, but are used on generally larger structures. They are used in some instances where the vertical change in grade from the channel thalweg to the top of the crossing is too tight for a flared end section. In Big Dry Creek, attention should be focused to ensure the installation of these structures do not obstruct the bank geometry and do not negatively interfere with the base flow water surface elevation. Wingwalls should be constructed perpendicular to the thalweg of the receiving waters, reducing impact on the overbanks.

Pipe failure due to erosion on Big Dry Creek

Pier and Bank Protection *(Bank Stabilization)*

Cost per Unit: $90/CY

Problems Addressed:

- ***Scour***
- ***Sediment Control***
- ***Flood Risk Reduction***
- ***Stream Crossing***

At some crossings, piers must be used to support the crossing structure, and therefore must be protected within the channel from erosion. Where applicable, pier and bank protection should be assessed based on the configuration and location of the piers. Considering scour potential is required in designing protection for these crossing elements with detailed hydraulic modeling used to perform a scour analysis. Additional protection should also take place on the bank within the crossings. As water is conveyed through these crossings, its velocity is increased due to the contraction of the channel through the crossing. Where possible, the use of piers is not recommended. Riprap can often be used to armor areas around and adjacent to crossing structure abutments. Riprap should be designed to resist anticipated flow and scour potentials and should transition into natural channel design away from the structure(s).

Abutments failing

3. Channel Complexity

Channel complexity refers to channel features that contribute to geomorphically effective bedforms as well as to habitat quality and diversity. Channel complexity is as simple as breaking up the monotony of a straight channel with features that increase variation throughout a given reach while allowing for fluctuation in flow velocity, depth and sinuosity. Channel complexity can occur in the form of structures both inside or outside of the channel, such as log toes, boulder toes, cross vanes or drop structures. Habitat and biodiversity can be increased by utilizing a diverse palette of vegetative cover and species and by fluctuating the width and slope of the channel cross sections.

Big Dry Creek has little channel complexity, with very little variation in channel velocities, depths, and shaping. This is evident with the relatively tranquil and low velocity flows throughout the corridor. These complexities help support life within the creek by adding elements to the channel to allow for greater ecosystem diversity. Channel complexities could be added along straight sections of the creek to provide some variation in the flow and placed at locations where erosion is evident or at locations where a scour hole could form to provide aquatic refuge.

Following are tools to create channel complexity that could be used as part of the Big Dry Creek floodplain restoration.

Section of Big Dry Creek lacking sinuosity and creek edge variation

Section of Big Dry Creek with good channel complexity; sinuosity, variation in type of channel edge and vegetation types

Boulder Clusters *(Channel Complexity)*

Cost per Unit: $1,000/ea

Problems Addressed:

- ***Aquatic Habitat/Fish Passage***

Boulders clusters are groups of boulders based in the bottom of the low flow channel to provide cover and create scour holes or areas of reduced velocity. They can be used to break up a tranquil section of stream by providing changes in hydraulics to promote fish habitat and encourage aquatic species. Boulder clusters are great places for aquatic organisms to live and provide additional depth to allow for fish passage. The creation of these environments also provides opportunities for recreational fishing. Boulder clusters should not be placed near the banks of the creek, because increased velocities around the boulders can cause scour and bank erosion. While the boulders need to be sized to resist typical base and bankfull flows, it is understood that some might move under greater flood events.

Boulder clusters installed

Boulder Clusters *Plan View*

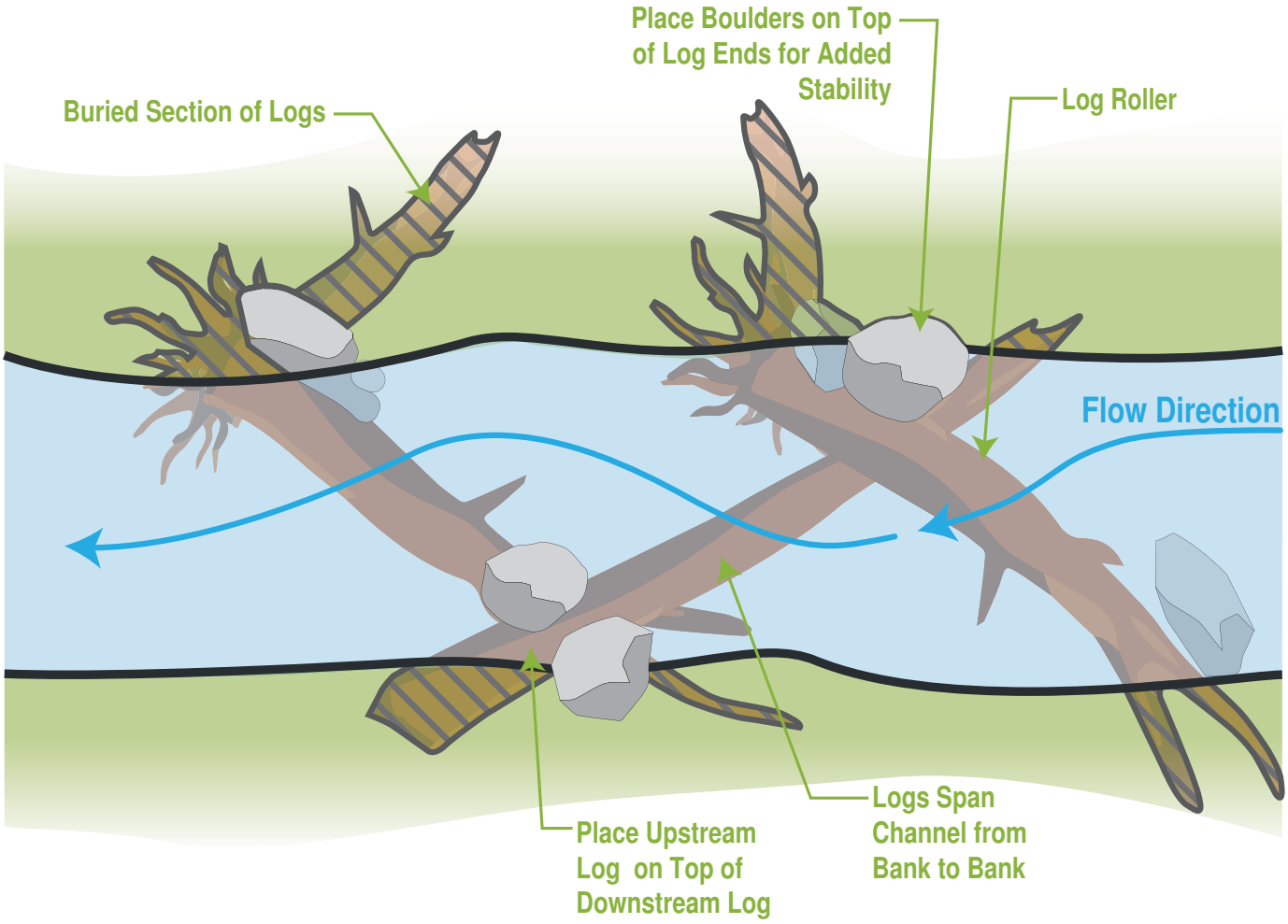
Log Roller *(Channel Complexity)*

Log rollers are large, crisscrossed trees spanning the channel from bank to bank. Constructed such that the upstream end of the downstream-facing log is buried in the bank under the log upstream, log rollers dissipate flow energy, reduce bank erosion, and protect against headcuts. These logs promote low flow channel sinuosity and channel complexity on a small scale. Additionally, log rollers can add increased habitat and cover for aquatic species.

Cost per Unit: $2,000/ea

Problems Addressed:

- ***Channel Stability***
- ***Scour***
- ***Sediment Control***
- ***Aquatic Habitat/Fish Passage***



Log Roller *Plan View*

4. Grade Control Strategies

Maintaining a stable slope is a critical component of stream restoration. In order to achieve this, grade control structures may play an essential role. While the creek has established its own grade control via its meander pattern, grade control structures can be used to reduce vertical degradation of the channel bed. These structures provide significant vertical drop in a fairly short length of stream to allow erosive velocities to pass through the project area without causing damage to the channel, making them primarily appropriate for use at road and/or utility crossings. The required size and number of these structures should be evaluated on a case by case basis and minimized when possible.

Grade control structures through Big Dry Creek could be used for multiple reasons, including the following:

- To stabilize a certain reach of a creek in an unstable system
- To demark a project's limits by using grade control at the most upstream and downstream ends of a creek restoration project to ensure that the design isn't influenced greatly by unstable conditions up and down stream
- To naturally bring the channel thalweg and bankfull elevation closer to the floodplain bench to allow for floodplain connectivity which would also reduce the amount of fill required to meet the desired design intent
- At crossing locations to provide greater conveyance through the crossing by increasing the vertical separation between the creek thalweg and the bottom of the crossing, such as at Washington Street and East 144th Avenue
- When straightening a section of creek upstream of a crossing, such as at 156th Avenue
- At confluences with tributaries to Big Dry Creek
- In any area where Big Dry Creek meanders are becoming very close to one another, and an oxbow is about to form

Following are grade control structure tools that could be used as part of Big Dry Creek's floodplain restoration.

If the channel's meander is straightened out, the water will be falling the same height over a shortened length, increasing the creek's slope and resulting in the need for grade control structures

Failed grade control

Cross Vanes *(Grade Control)*

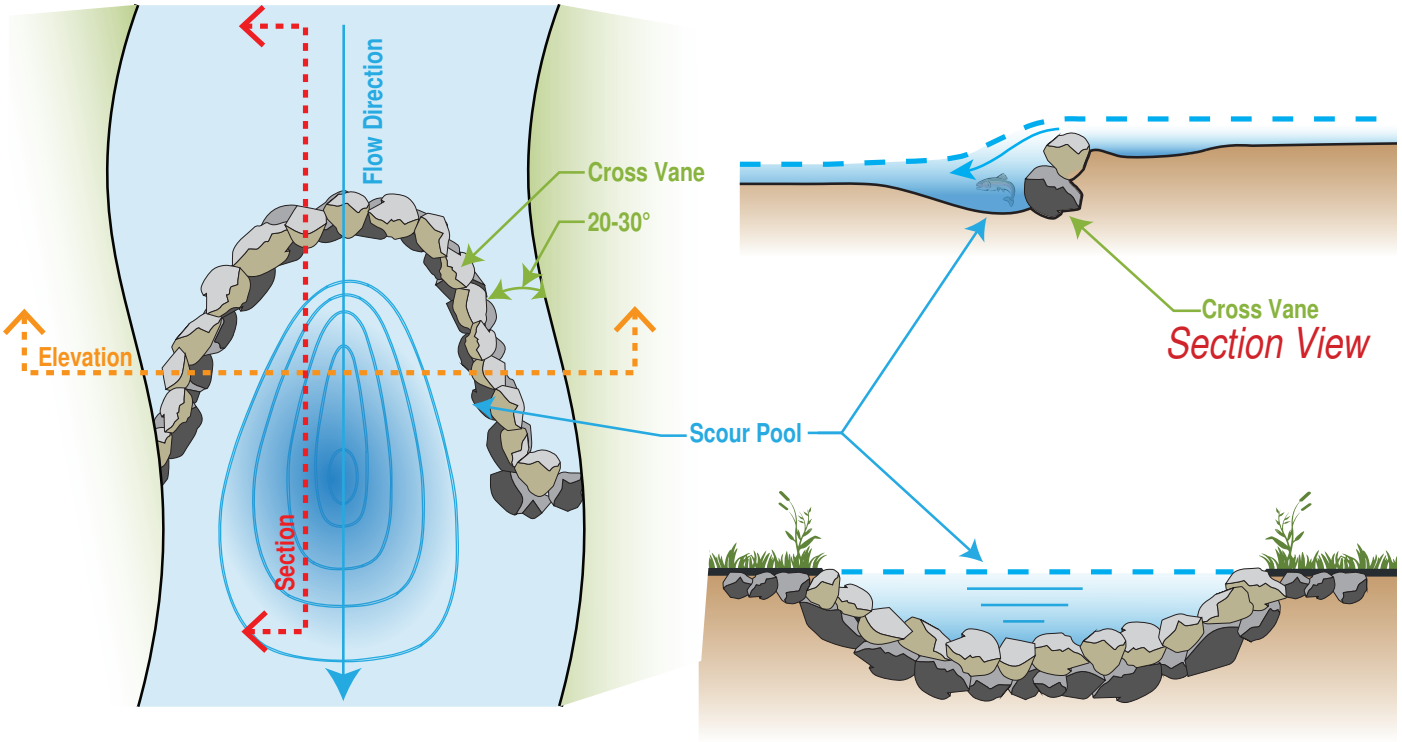
Cost per Unit: $15,400/ea
$280/LF

Problems Addressed:

- *Channel Stability*
- *Scour*
- *Sediment Control*
- *Flood Risk Reduction*
- *Stream Crossing*
- *Aquatic Habitat/Fish Passage*

Cross vane example

Cross vanes are a natural way to modify channel slope and the channel width-to-depth ratios. They work by conveying the flows towards the center of the channel, therefore removing stress on the banks. These structures can also be effective at transporting excess bed material, reducing bank erosion, reducing the potential for headcuts to migrate upstream, and promoting bank stabilization. Cross vanes can be used in combination with other tools to accomplish multiple goals, including diversion, bridge protection and stabilization. They can also increase stream habitat by creating pool areas and providing a resting place for aquatic species during high flows. Variations of cross vanes can be constructed with either boulders or logs and can be integrated into a number of other natural stream design features such as a bankfull bench.



Cross Vane *Plan View* *Elevation View*

Constructed Riffles *(Grade Control)*

Riffles consist of channel-wide accumulations of larger cobbles and small boulders, and they typically transition into either a shallower slope or directly into a pool to provide grade control. Water depth is relatively shallow over the riffle, and the slope is steeper than the average channel slope. At low flow, water accelerates over the riffle, mobilizing finer sediments, keeping interstitial spaces in the channel substrate clean, and oxygenates the water. Energy is dissipated through tumbling flow and grain roughness. Riffles are typically installed on steeper, straight reaches of creek to provide additional vertical drop. The riffle sequences are expected to stabilize the longitudinal bed slope and dissipate instream energy, which ultimately reduces erosive forces on the banks. In addition to their grade control function, constructed riffles provide channel complexity and habitat for smaller aquatic species.

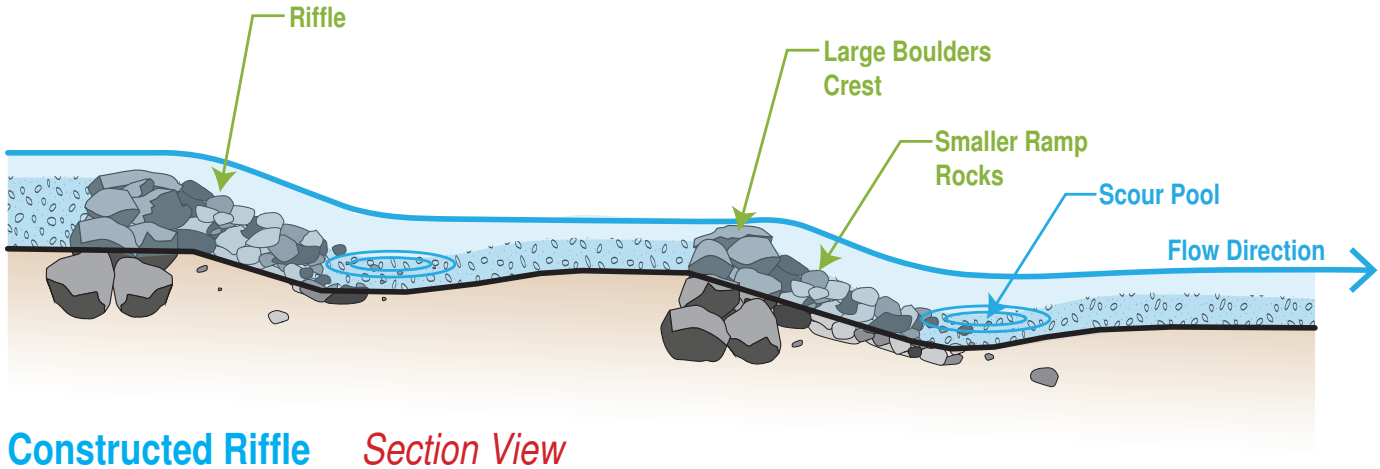
Cost per Unit: $110,000/ea
$2,000/LF

Problems Addressed:

- *Channel Stability*
- *Scour*
- *Sediment Control*
- *Bank Terracing*
- *Aquatic Habitat/Fish Passage*

Water flowing over a constructed riffle

Riffle structure during construction with geotextile fabric along the banks



Constructed Riffle *Section View*

Sills *(Grade Control)*

Sills can be constructed to provide grade control in channels and floodplains that have a high degree of susceptibility to erosion that may result in an unacceptable risk to adjacent infrastructure, private property or wetlands. These features disperse flow over a wider section of the channel or floodplain and limit erosion potential. Sills can be used directly as grade control or as an extension of a cross vane. Sills consist of coarse rock or boulders embedded into the channel or floodplain such that the top of the rock is flush with the final grade. They can create a pool habitat and promote sediment disposition upstream. Downstream scour pools should be anticipated with the installation of sills and accounted for in the placement and design of these structures.

Cost per Unit: $2,750/ea
$50/LF

Problems Addressed:

- ***Channel Stability***
- ***Scour***
- ***Sediment Control***
- ***Aquatic Habitat/Fish Passage***

Example of an in-stream concrete sill

Drop Structures *(Grade Control)*

Cost per Unit: $55,000/ea
$1,000/LF

Problems Addressed:

- ***Channel Stability***
- ***Scour***
- ***Sediment Control***

Drop structures are necessary when narrow channel widths, high shear stresses, increased velocity or unstable slopes do not readily allow for natural channel design applications. Drop structures allow for an increased vertical change in channel slope to tie in grades up and downstream of an area. Drop structures usually range in height anywhere from 1 foot to 5 feet in vertical change. These structures are usually designed by creating a slope of grouted boulders or sculpted concrete. Alternatively, wood and stone can be used in areas where velocity shear stresses permit. Fish ladders should be considered wherever possible to provide passage for aquatic organisms around larger drop structures. The Urban Drainage and Flood Control District (UDFCD) provides detailed guidance for the design of drop structures in Volume 2 of their Criteria Manual.

Drops structures along Big Dry Creek could be developed using various design techniques. The more traditional way to construct drop structures is using boulders that are placed in the channel to provide a stable slope and then grouting between the boulders to prevent the bedding and subsequent surface material from being eroded away. It is recommended due to the smaller sediment size that these drops be grouted, but in a situation where fish passage is more necessary it can be advantageous to leave the grout out. Drop structures can also be constructed using sculpted concrete which can be massaged into unique configurations to fit the channel dimensions. These drops structures can also be outfitted with planting locations so that they appear more natural. The sculpted concrete drops structures usually cost more than grouted boulders due to the preparation work.

Example of a constructed drop structure that is also designed as a low-water crossing

Environmental Recommendations

The following section contains detailed recommendations for the environmental conditions observed on-site. These recommendations are organized by parcel and the facing page contains an Environmental Recommendations Matrix which summarizes the recommended actions. Many of the parcels have very similar existing conditions and therefore have similar recommendations. Common environmental recommendations include:

Weed control (manual or chemical removal): Spot spray patches of weedy grass and herbaceous species or use boom spraying in heavily affected areas. Spot spraying could occur in riparian areas and on the edges of wetlands, using aquatic-approved herbicides. Boom spraying allows for complete weed eradication before soil amendment, seeding, planting and mulching activities would commence. Weed control would likely continue annually at least two to three years until desirable plant species had established.

Soil sampling: Soil samples should be taken to a laboratory for soil nutrient analysis. Necessary soil amendments should then be added and tilled into the soil before revegetation.

Russian olive removal: Russian olive is a Colorado Department of Agriculture B List invasive and noxious weed. Removing Russian olive will improve the overall health and stability of Big Dry Creek and allow more riparian vegetation to establish in the floodplain area. Existing Russian olive should be cut out and stumps treated with herbicide to prevent future growth.

Prairie dog monitoring and/or mitigation: Prairie dog colonies should be monitored over time in case they become so large as to outbalance existing conditions and warrant some prairie dog relocation and/or treatment. Control is warranted in particular areas before weed control and replanting activities take place. Prairie dogs could be treated over winter months when the burrowing owl is not present, or following a burrowing owl field survey if work is conducted between March 15 and October 31. Once the prairie dogs are reduced and/or removed, the weed control and replanting activities will be more successful. On city of Thornton properties, Prairie Dog Ordinance #2628 must be referenced and followed prior to disturbing the land.

Sharp meander in Parcel V; if the meander is cut off to protect infrastructure, the previous channel and the inner bend area can be converted into a healthy and productive oxbow wetland

Environmental Recommendations Matrix

TREATMENTS

	WEEDS	WILDLIFE	SOILS	WILDLIFE & ENVIRONMENTAL MONITORING	REVEGETATION
Parcel I **Adams County** **48.79 Acres**	> Spot weed control as needed throughout. > Spray weedy areas with an approved herbicide. > Russian olive removal and stump treatment. > Boom spray or spot weed control in subplots 11, 13, 14, and 16 – 19.	> Prairie dog relocation and/or treatment in selected areas with required burrowing owl survey if treatment occurs between March 15 and October 31.	> Soil samples taken for soil amendment nutrient analysis and working soil amendments into soil. > Soil nutrient analysis and necessary amendments followed by native seeding and mulching in subplots 11, 13, 14, and 16 – 19.	> Follow-up spot weed control, spot seeding, and mulching as needed. > Continued irrigation of planted upland trees and shrubs on a scheduled basis. > Wetland monitoring, oil/gas well monitoring.	> Spot seeding and mulching of native grasses and herbaceous species. > Native tree/shrub plantings, staking, mulching, and irrigation. > Expand diversity of wetland and riparian plantings to support wildlife habitat in subplots 10 and 15.
Parcel II **Thornton** **24 Acres**	> Spot spray or larger-area boom spray weed control as needed throughout. > Spray weedy areas with an approved herbicide. > Russian olive removal and stump treatment.	> Observe prairie dog town located in northern portion of subplots 21 and 25 and determine if relocation or treatment becomes necessary. > Wetland creation with High Priority Reach (HPR)* 2, subplots 20 and 21.	> Soil samples taken for soil amendment nutrient analysis and working soil amendments into soil.	> Follow-up spot weed control, spot seeding, and mulching as needed. > Continued irrigation of planted upland trees and shrubs on a scheduled basis. > Wetland monitoring.	> Spot seeding and mulching of native grasses and herbaceous species. > Native tree/shrub plantings, staking, mulching, and irrigation. > Expand diversity of wetland and riparian plantings to support wildlife habitat in subplots 21 and 22.
Parcel III **Thornton** **59.29 Acres**	> Spot weed control as needed throughout. > Spray weedy areas with an approved herbicide. > Russian olive removal and stump treatment. > Boom spray in subplots 39 and 46.	> Prairie dog relocation and/or treatment in subplots 25, 39, and 46, if necessary, with required burrowing owl survey if treatment occurs between March 15 and October 31. > Wetland creation with HPR 3, subplots 30 and 34. > Preserve subplots 22, 29, 39 and 46 for wildlife habitat.	> Soil samples taken for soil amendment nutrient analysis and working soil amendments into soil. > Soil nutrient analysis and necessary amendments followed by native seeding and mulching in subplots 39 and 46.	> Follow-up spot weed control, spot seeding, and mulching as needed. > Continued irrigation of planted upland trees and shrubs on a scheduled basis. > Wetland monitoring, oil/gas well monitoring.	> Spot seeding and mulching of native grasses and herbaceous species in subplots 32, 33, 36, 37, 38, 40, and 47-50. > Native tree/shrub plantings, staking, mulching, and irrigation.
Parcel IV **Thornton** **41 Acres**	> Spot weed control as needed throughout. > Spray weedy areas with an approved herbicide. > Russian olive removal and stump treatment. > Boom spray in subplots 52 and 62.	> Prairie dog relocation and/or treatment in selected areas (particularly subplots 56, 58 and 62) with required burrowing owl survey if treatment occurs between March 15 and October 31.	> Soil samples taken for soil amendment nutrient analysis and working soil amendments into soil.	> Follow-up spot weed control, spot seeding, and mulching as needed. > Continued irrigation of planted upland trees and shrubs on a scheduled basis. > Oil/gas well monitoring.	> Spot seeding and larger-area seeding in subplots 52 and 62 and mulching of selected native grasses and herbaceous species > Native tree and shrub plantings, staking, mulching, and irrigation.
Parcel V **Thornton** **25.54 Acres**	> Spot spray or larger-area boom spray weed control as needed throughout. > Spray weedy areas with an approved herbicide. > Russian olive removal and stump treatment.	> Prairie dog relocation and/or treatment in selected areas (particularly subplots 66, 68 and 73) with required burrowing owl survey if treatment occurs between March 15 and October 31. > Oxbow wetland creation within HPR 7.	> Soil samples taken for soil amendment nutrient analysis and working soil amendments into soil.	> Follow-up spot weed control, spot seeding, and mulching as needed, especially subplot 56. > Continued irrigation of planted upland trees and shrubs on a scheduled basis. > Oil/gas well monitoring.	> Spot seeding and mulching of native grasses and herbaceous species. > Native tree and shrub plantings, staking, mulching, and irrigation.
Parcel VI **Thornton** **44.08 Acres**	> Spot spray or larger-area boom spray weed control as needed throughout. > Spray weedy areas with an approved herbicide. > Russian olive removal and stump treatment.	> Prairie dog relocation and/or treatment in selected areas with required burrowing owl survey if treatment occurs between March 15 and October 31. > Wetland expansion opportunities with HPR 8, subplots 74, 75, 76, 76A, 79, 84 and 90. > Preserve wildlife habitat in subplots 80, 83 and 87.	> Soil samples taken for soil amendment nutrient analysis and working soil amendments into soil.	> Follow-up spot weed control, spot seeding, and mulching as needed. > Continued irrigation of planted upland trees and shrubs on a scheduled basis. > Oil/gas well monitoring.	> Spot seeding and mulching of native grasses and herbaceous species. > Native tree/shrub plantings, staking, mulching, and irrigation. > Expand diversity of wetland and riparian plantings to support wildlife habitat with 156th Avenue widening.
Parcel VII **Thornton** **34 Acres**	> Spot to larger-area boom spraying weed control as needed throughout, especially subplots 93, 95, and 100 with an approved herbicide.	> Consider prairie dog relocation and/or treatment in subplots 93 and 100 with required burrowing owl survey if treatment occurs between March 15 and October 31. > Wetland expansion opportunities around subplot 96 and HPR 9 when impacted by 156th Avenue widening.	> Soil samples taken for soil amendment nutrient analysis and working soil amendments into soil.	> Follow-up spot weed control, spot seeding, and mulching as needed. > Continued irrigation of planted upland trees and shrubs on a scheduled basis. > Oil/gas well monitoring.	> Spot to larger-area seeding and mulching of native grasses and herbaceous species, especially subplots 93, 95, and 100. > Native tree/shrub plantings, staking, mulching, and irrigation. > Expand diversity of wetland and riparian plantings to support wildlife habitat with 156th Avenue widening.
Parcel VIII **Thornton** **16 Acres**	> Spot weed control as needed throughout. > Spray weedy areas with an approved herbicide. > Russian olive removal and stump treatment.	> Consider prairie dog relocation and/or treatment in subplots 113 and 114 with required burrowing owl survey if treatment occurs between March 15 and October 31.	> Soil samples taken for soil amendment nutrient analysis and working soil amendments into soil.	> Follow-up spot weed control, spot seeding, and mulching as needed. > Continued irrigation of planted upland trees and shrubs on a scheduled basis.	> Spot seeding and mulching of native grasses and herbaceous species. > Native tree and shrub plantings, staking, mulching, and irrigation.

***High Priority Reach (HPR)**

Revegetation, ranging from riparian, to wetland to upland species: Following successful weed control and appropriate soil amendment, native trees, shrubs, grasses and herbaceous species found in Appendix H: Environmental Recommendation Items (Tables A to C) could be planted, staked, mulched and irrigated in locations as desired. The seeding and planting of additional native species along the creek will create diverse wildlife habitat, significantly increase biodiversity of both flora and fauna and allow for greater overall creek health. Increased riparian and wetland plantings will create crucial wildlife habitat necessary for over half of the bird species and a majority of the mammalian, amphibian and reptile species found in Colorado. Follow-up irrigation would be needed on a scheduled basis until plants had established. Plant material snags and brush piles could be preserved or created for wildlife perches and habitat. Adequate landscape and site mitigation should be provided to buffer oil and gas operations.

Wetland and wildlife habitat creation/expansion: Grading back of steep vertical banks create additional benching for wetland and riparian native plant establishment. When sharp creek meanders are lost due to future hydraulic improvements, oxbow wetlands could be created in place of the meanders. Upland pockets adjacent to wetland areas could be excavated to enlarge the area and create additional habitat for small mammals, birds, reptiles, amphibians and insects. Further wildlife and habitat protection could be achieved by isolating specific areas as a wildlife refuge.

Routine monitoring of wildlife, wetlands and vegetation: Consistent and timely monitoring is a critical tool to help manage and protect resources. By assessing the condition and function of wildlife, wetlands and vegetation over time, monitoring provides data to support decision-making and planning processes.

These recommended actions address a variety of issues that can be completed on their own, but can, and should, be incorporated into other projects such as recreational, infrastructure or floodplain restoration projects. For example, if a section of Big Dry Creek is straightened to protect infrastructure, the existing meander can be converted into a productive and healthy oxbow wetland. Not only will this replicate the natural progression of creeks, but it will also help mitigate the negative wetland and riparian impacts of straightening a section of creek. Another example would be using proper soil amendments, seed mixes and plants to revegetate an area following an underground utility project or repair.

Prairie dog burrows and over-grazing of vegetation in Parcel I

By applying these environmental recommendations to corridor projects, the natural wildlife habitats and vegetative communities within the Big Dry Creek open spaces can continue to thrive and grow. In turn, the overall health and stability of the corridor will improve. More riparian vegetation will result in more stable banks, resulting in less sediment being released into the creek, thereby improving water quality. Riparian and wetland habitats are of particular importance in the corridor. While they make up a small percentage of the overall area, they contain the far majority of the biodiversity in the corridor. In order to conserve and progress the environmental conditions along Big Dry Creek, the recommended actions set forth in this Master Plan should be used for all projects within the corridor.

Parcel I Environmental Recommendations

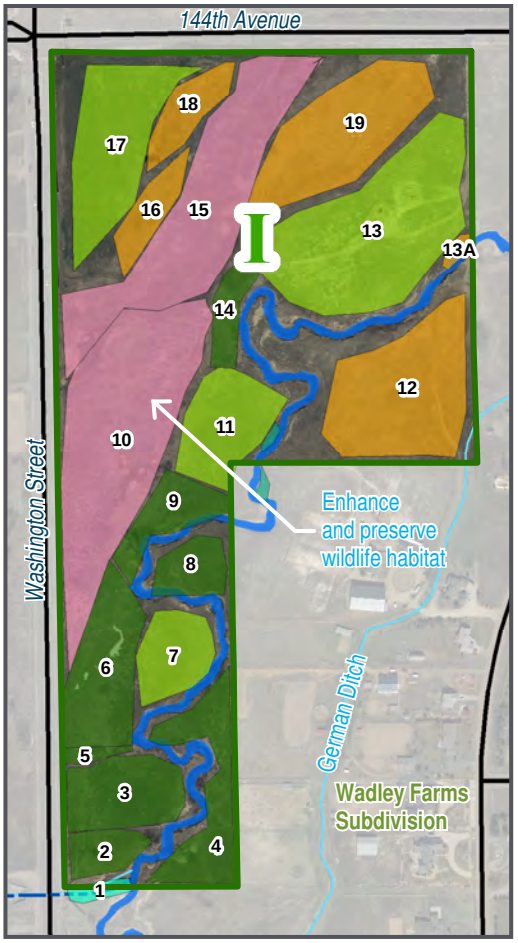
Uplands: The uplands located in the southern half of Parcel I (subplots 2, 3, 4, 6, 8 and 9) have good native and non-native grass establishment. However, there are minor weed and Russian olive tree establishment issues. Therefore, management recommendations include spot weed control and seeding with desired grass species after appropriate soil analysis and amendment. Existing Russian olive trees should be cut out and stumps treated with herbicide to prevent future growth.

Some prairie dog control may be necessary in subplot 7, especially if the existing prairie dog town starts to expand. Subplot 7 could then have spot weed control, amendment, seeding and mulching.

Upland native trees and shrubs could be planted, staked and mulched in the southern half of Parcel I. Irrigation of planted trees and shrubs would continue on a scheduled basis until plants had established.

Uplands located in the northern half of Parcel I vary from good grass establishment with some active prairie dogs and minor weed issues (subplots 13, 14 and 19) to heavy active prairie dog and heavy weed growth (subplots 11, 12, 16, 17 and 18).

Management recommendations for the northern upland areas vary from spot weed treatment to boom weed spraying in the heavily affected areas. However, prairie dog control in subplots 11, 16, 17 and 18 is warranted before weed control and seeding activities take place.



Parcel I Subplot map

Russian olive removal and treatment on upland areas along the creek in subplots 11 and 13 is necessary before revegetation. Well site environmental impacts should be monitored.

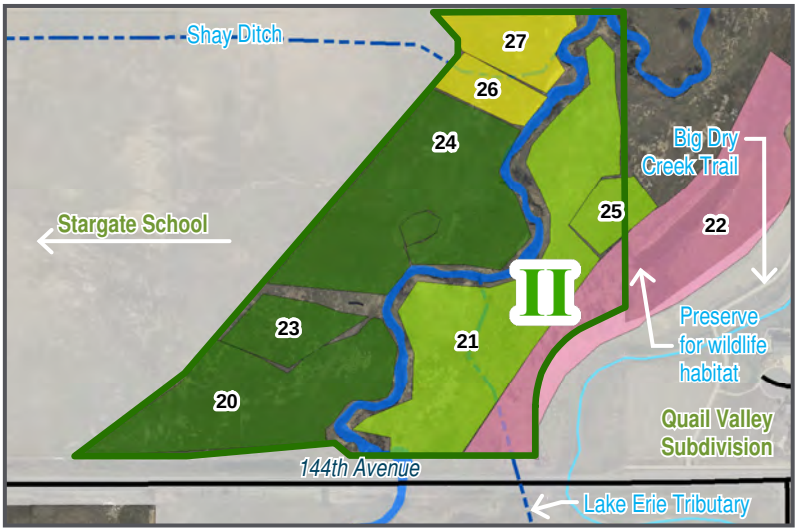
Riparian: There are some steep vertical banks located along Big Dry Creek throughout Parcel I. These banks should be graded back to create additional benching for wetland and riparian native plant establishment. The planting of additional native trees and shrubs along the creek will allow for greater riparian plant diversity and overall creek health. Russian olive trees should be removed and weedy grass and herbaceous species should be spot sprayed with aquatic-approved herbicides before revegetation.

Wetlands: Wetlands located in Parcel I include small drainages located in the southern portion of the parcel that drain from the west into Big Dry Creek. These drainages are relatively stable and establishing with wetland plants.

A larger wetland complex is located in subplots 10 and 15. Weeds could be spot treated. Any establishing Russian olives should be removed and wetland plant material added to create better plant species diversity. This wetland area creates excellent wildlife habitat for small mammals, birds, reptiles, amphibians, and insects due to its larger size and close proximity to Big Dry Creek.

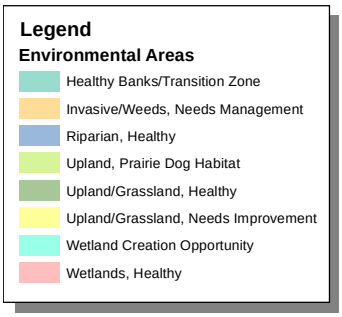
Parcel II Environmental Recommendations

Uplands: Uplands located west of Big Dry Creek vary from well-established uplands (subplots 20 and 23 and part of subplot 24) to more bare uplands (part of subplot 24 and subplots 26 and 27). Some weedy patches are evident throughout. Recommendations include spot weed control followed by soil sampling, incorporation of appropriate amendment and revegetation. A larger weed control and seeding effort over time is warranted in the northern portion of subplot 24 and subplots 26 and 27.



Parcel II Subplot map

Uplands located east of Big Dry Creek vary from fairly well-established uplands (southern part of subplot 21) to moderately well-established uplands (portions of subplot 21 and subplot 25). Weed control is needed throughout, followed by revegetation. A larger weed control and seeding effort is warranted in the northern portion of subplot 21 and subplot 25. A prairie dog colony located in the northern portion of subplot 21 and in subplot 25 should be monitored over time in case it becomes larger and warrants some prairie dog relocation and/or mitigation. However, the existing prairie dog town appears to be in balance with the existing conditions.



Riparian: There are some steep vertical banks located along Big Dry Creek throughout Parcel II. These steep banks should be graded in locations to create additional benching for wetland and riparian native plant establishment. An oxbow riparian/wetlands area could be created in subplot 21 when creek migration is addressed. Russian olive trees should be removed before the weed control and revegetation process begins.

Wetlands: Existing wetlands along Big Dry Creek may need some spot weed control. A wetland complex is located in subplot 22 that could be isolated and preserved for wildlife. Weeds could be spot treated in and around this wetland area, Russian olives should be removed then the area revegetated. This wetland complex creates excellent wildlife habitat due to its larger size and relative proximity to Big Dry Creek.

Parcel III Environmental Recommendations

Uplands: Uplands located west of Big Dry Creek in subplot 31 are in great condition and require no management at this time. The uplands located west of Big Dry Creek in subplots 39 and 46 have some weed establishment and large bare areas with little vegetation at all. But the general upland area in Parcel III provides excellent wildlife habitat due to its good vegetated condition, relative isolation and presence of all three habitat types and might be a good natural area to protect for wildlife use. Management recommendations include weed control, Russian olive removal and revegetation. Environmental impacts from the well areas should be monitored.

Prairie dog relocation and/or mitigation is necessary in subplots 39 and 46 before weed control and revegetation.

Subplots 32, 33, 36, 38, 40 and 47 – 50, located west of Big Dry Creek in Parcel III have some good upland grass establishment with some weedy patches and bare areas. These subplots have evidence of abandoned prairie dog homes, but active prairie dogs were not observed. There are few trees and shrubs located in subplots 47 – 50. After weed control, planting and mulching of upland

trees and shrubs would increase cover and shade in these subplots. Raptor perches could be installed. The trees and shrubs should be irrigated on a scheduled basis until established.

Uplands located east of Big Dry Creek in Parcel III vary from good grass establishment with limited to no prairie dogs and minor weed issues (subplots 25, 28, 37 and 51) to heavy weed growth, mowed grasses and many bare areas (subplots 42 – 45). Subplots 25, 28 and 37 provide excellent wildlife habitat due to its good vegetated condition and could be isolated as a natural area for wildlife use.

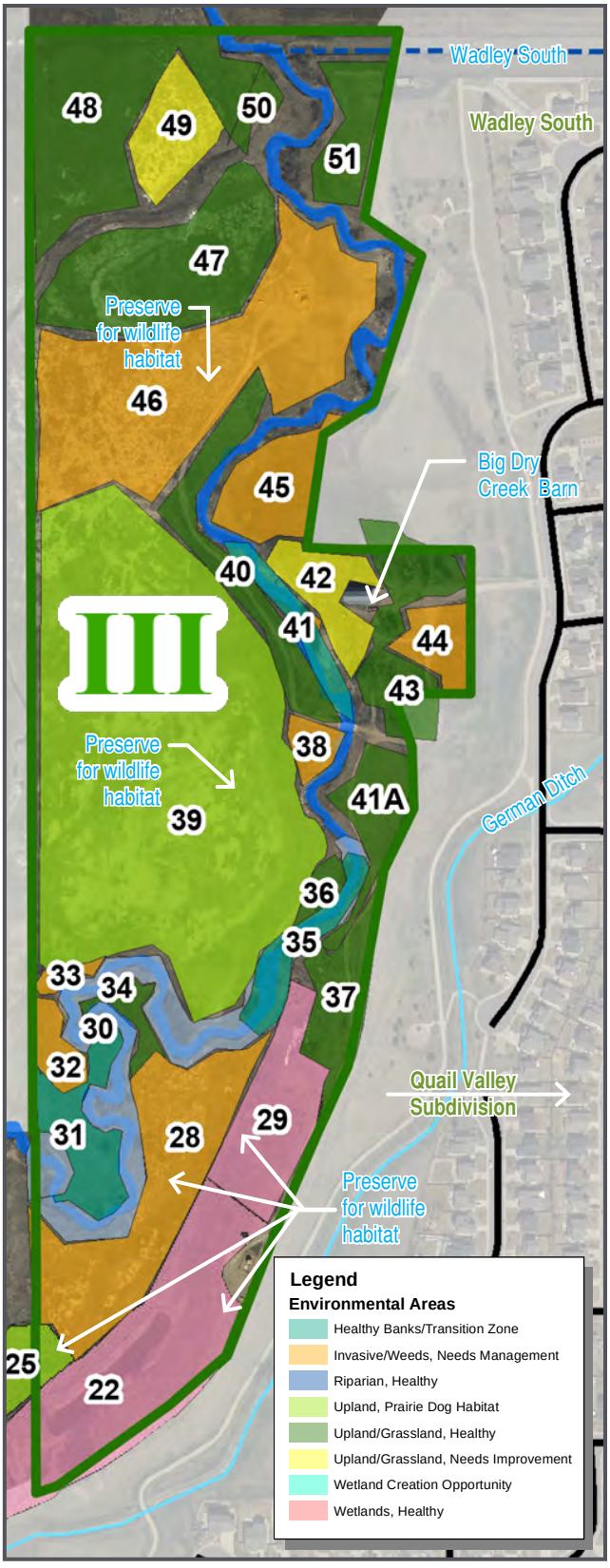
Management recommendations for these uplands include weed control and revegetation. Prairie dogs should be observed in subplot 39 in case relocation or mitigation of the prairie dog town becomes necessary.

Russian olive trees are abundant in this parcel, and removal is necessary.

Riparian: The riparian area located in the southern third of Parcel III is a good reference for all parcels in this report in terms of number and species of native riparian trees and shrubs present. This section of creek has excellent riparian tree and shrub establishment and creates excellent wildlife habitat.

There are some vertically eroded banks located along Big Dry Creek in Parcel III that should be graded back to create additional benching for wetland and riparian native plant establishment. Oxbow riparian/ wetlands could be created in subplots 30-34 (High Priority Reach 3) when floodplain restoration work occurs. Russian olive trees are a problem in Parcel III and should be removed from riparian areas, followed by additional weed control and revegetation.

Wetlands: A larger wetland complex is located in subplots 22 and 29 in Parcel III and could be preserved as a wildlife refuge. Weeds could be spot treated and Russian olive removed. The wetland vegetation located in subplots 22 and 29 is fairly diverse and well established. Subplot 34 contains a fairly healthy meander; if this meander is lost due to future hydraulic improvements, an oxbow wetland can be created in place of the meander. This would add beneficial wildlife habitat.

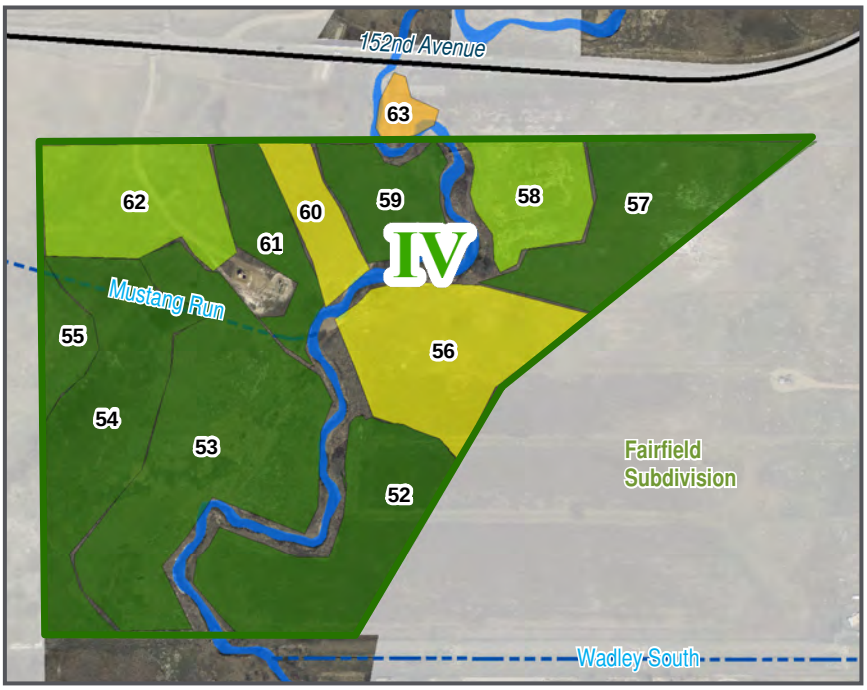


Parcel III Subplot map

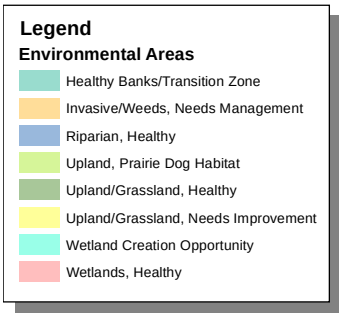
Parcel IV Environmental Recommendations

Uplands: Uplands located west of Big Dry Creek in Parcel IV (subplots 53, 54, 59 and 61) have good native and non-native grass establishment. However, there are minor weed and bare area issues. Therefore, management recommendations include spot spraying of weed patches and spot seeding with desired grass species.

Subplots 55 and 62 will require more weed control due to more weed growth. Some prairie dog control may be necessary in subplots 55 and 62, especially if the existing prairie dog towns start to expand. Upland native trees and shrubs could be planted, staked and mulched in any subplots west of Big Dry Creek as desired.



Parcel IV Subplot map



Uplands located east of Big Dry Creek in subplot 52 have good grass establishment with few to no prairie dogs and only minor weed issues. Management recommendations for subplot 52 include spot weed control and spot seeding/mulching. Subplot 56 had been graded due to development in the parcel at the time of this survey and should be monitored for weed growth. The uplands located in subplots 57 and 58 should be watched for increased prairie dog population growth over time, which may warrant some relocation and/or mitigation. For now, these subplots need some spot weed control, seeding and mulching. Some Russian olive removal and treatment on upland areas along the creek may be necessary before revegetation. Selected upland native trees and shrubs could be planted, staked, mulched and irrigated as desired within subplots 52, 57 and 58. Environmental impacts on the well site should be monitored.

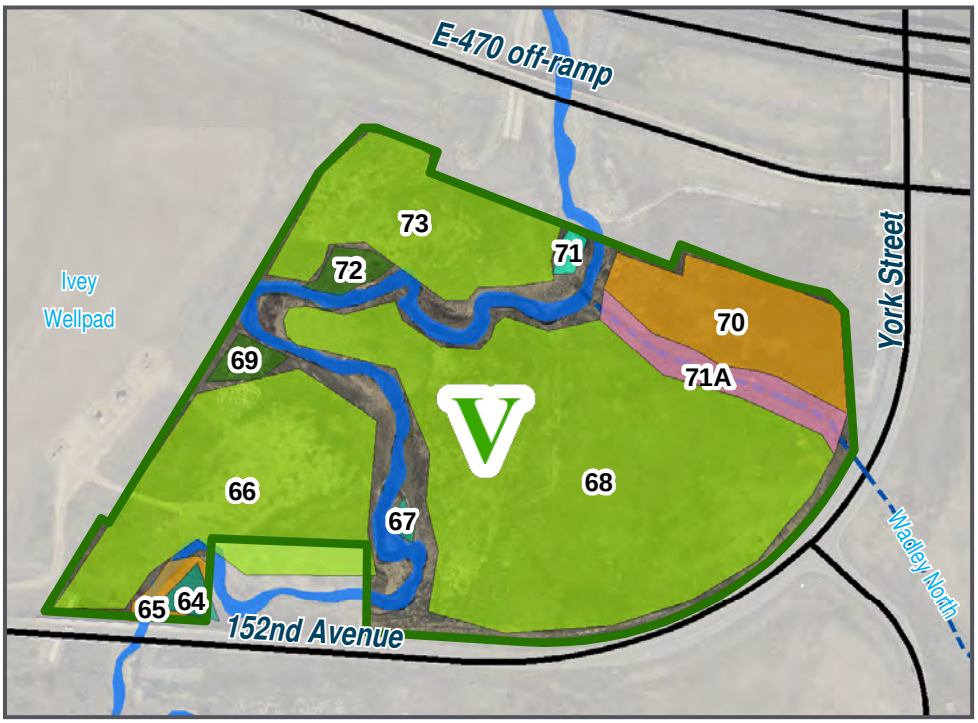
Riparian: There are some steep vertical banks located along Big Dry Creek throughout Parcel IV that should be graded back to create additional benching for wetland and riparian native plant establishment. Russian olive trees should be removed and additional native riparian trees and shrubs planted along the creek. This planting would provide greater riparian plant diversity for overall creek health. Irrigation of these planted species would be required.

Weed control is necessary before revegetation.

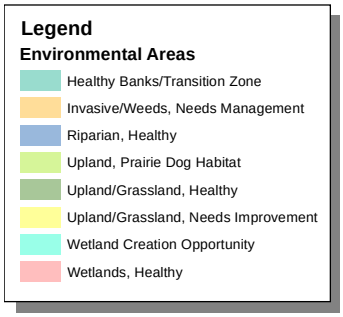
Wetlands: The only wetland area located in or near Parcel IV is located to the north and is mapped as subplot 63, in the 152nd Avenue right-of-way. Russian olive tree removal is the main management recommendation for this wetland area.

Parcel V Environmental Recommendations

Uplands: The uplands located west of Big Dry Creek (subplots 66 and 73) have poor to moderate grass establishment with substantial weed and prairie dog issues. Management recommendations include some prairie dog control and treatment, especially if the existing prairie dog towns start to expand. Following prairie dog reduction, subplots 66 and 73 need weed control and revegetation. Subplots 69 and 72 look slightly better and may only require spot weed control and spot seeding. All areas will likely need weed control and seeding annually for two to three years before the desirable grasses and herbaceous species are able to establish. Existing Russian olive trees should be removed before revegetation.



Parcel V Subplot map



Uplands located east of Big Dry Creek (subplots 68 and 70) are similar to subplots located west of Big Dry Creek. Management recommendations are similar, including prairie dog mitigation, weed control, Russian olive removal and revegetation.

Riparian: The riparian area located along Big Dry Creek in Parcel V is generally well vegetated with less areas of steep vertical banks and erosion than in some of the other parcels. This riparian habitat provides excellent wildlife habitat due its diverse vegetation establishment. The few steep vertical banks can be graded back to create additional benching for wetland and riparian native plant establishment.

Russian olive trees should be removed and Canada thistle treated in this parcel before revegetation. Follow-up irrigation on a scheduled basis would be needed over time for the trees and shrubs.

Parcel V contains some very sharp creek meanders that provide wildlife habitat but also threaten infrastructure (152nd Avenue near subplots 64, 65 and 67 and subplot 69 adjacent to the Ivey Wellpad). If/when these meanders are lost due to future hydraulic improvements, oxbow wetlands should be created in place of the meanders to add beneficial wildlife habitats.

Wetlands: There are wetlands located on the fringe of riparian benching throughout this parcel. This benching sometimes creates wetland conditions, which may need some spot weed control and appropriate planting.

A well-established wetland channel from Wadley North enters Parcel V from the east into Big Dry Creek. The approximately 50-foot-wide channel is dominated by cattails with wetland shrubs, grass and herbaceous species establishment. Some spot weed control may be necessary on the perimeter and Russian olive trees need removal. Overall, this channel has good wetland plant establishment and creates excellent wildlife habitat for small mammals, birds, reptiles, amphibians, and insects due to its larger size and merging with Big Dry Creek.

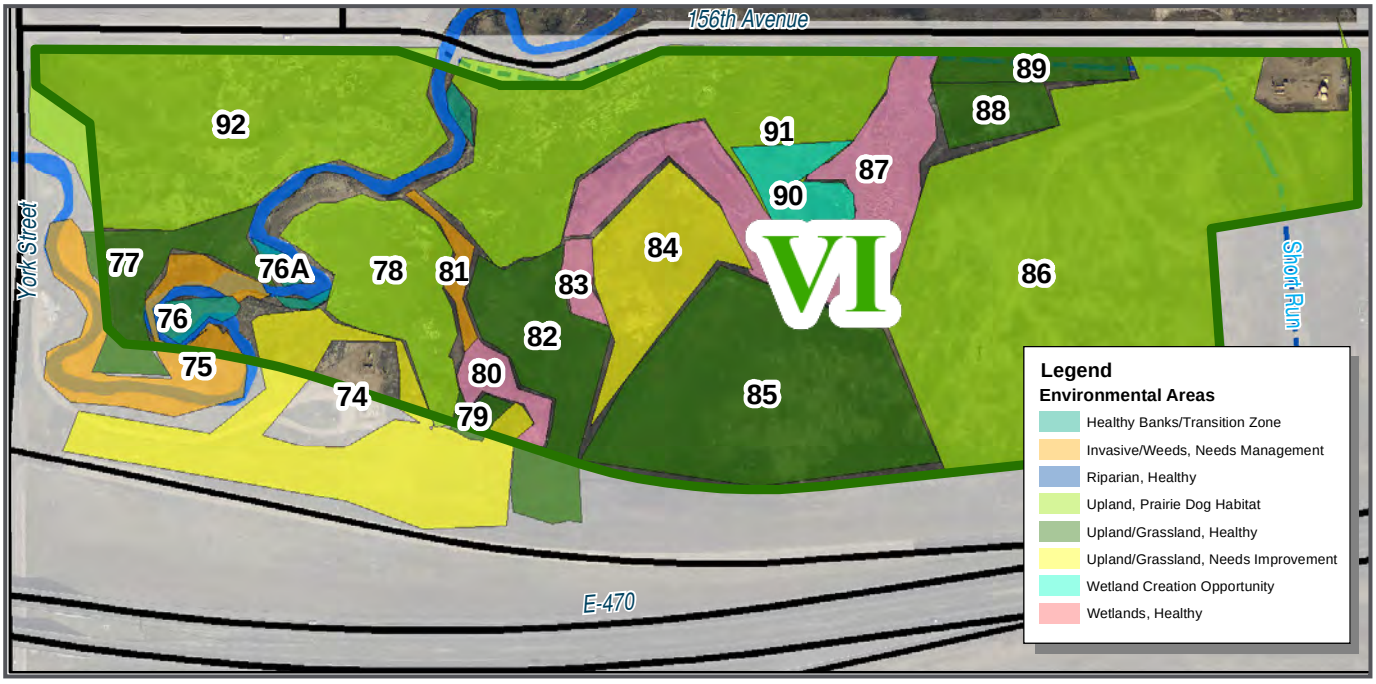
Parcel VI Environmental Recommendations

Uplands: The uplands located west of Big Dry Creek (subplots 77 and 92) have moderate native and non-native grass establishment with weedy and bare patches and moderate presence of prairie dogs. Management recommendations include some prairie dog control, especially if the existing prairie dog towns start to expand. These subplots could then have weed control, Russian olive removal and replanting. When High Priority Reach 8 is addressed, oxbow riparian/wetland areas could be created in subplots 74, 75 and 76.

Uplands located in the eastern portion of Parcel VI vary from good grass establishment with minor prairie dog, weed, and bare patch issues (subplots 74, 79, 82, 84, 85, 88, 89 and 90) to heavy active prairie dogs and heavier weed growth (subplots 78, 86 and 91). Management recommendations for these subplots vary from spot weed treatment to boom weed spraying in the heavily affected areas. Prairie dog relocation or mitigation in subplots 78, 86 and 91 is warranted before weed control and revegetation activities take place. Russian olive removal on upland areas along the creek is necessary, followed by native tree and shrub planting. The well sites' environmental impacts should be monitored.

Riparian: Big Dry Creek winds through Parcel VI with good riparian tree, shrub, grass and herbaceous species establishment. There are some steep vertical banks located along this stretch of creek that should be graded back to create additional benching for wetland and riparian native plant establishment. Russian olive and weedy grass and herbaceous species should be controlled before revegetation.

Wetlands: There are two established wetland areas in the middle of Parcel VI which are dominated by cattails and other wetland species (subplots 80, 83 and 87). Upland pockets such as part of subplots 74, 79, 84 and 90 could be excavated to enlarge the wetland areas to create excellent wildlife habitat due to its larger size and relative proximity to Big Dry Creek. This wetland is established in a remnant oxbow of Big Dry Creek and provides a good opportunity for further wildlife protection by isolating the area as a wildlife refuge. Weeds and Russian olive should be controlled and native wetland shrubs could be planted on the edges to create better plant species diversity. Other existing wetlands along Big Dry Creek may also need some spot weed control and revegetation.



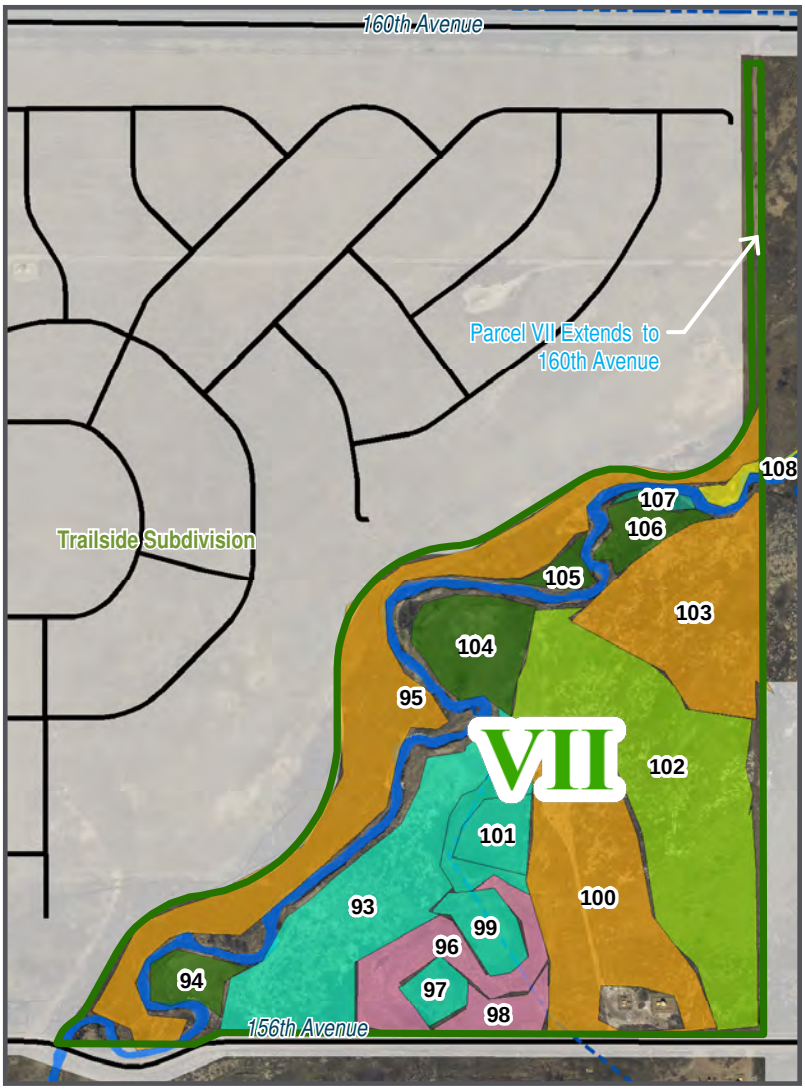
Parcel VI Subplot map

Parcel VII Environmental Recommendations

Uplands: Uplands located west of Big Dry Creek (subplot 95) are heavily infested with weeds. There is slightly better grass establishment in subplot 105. Management recommendations include weed control, Russian olive removal and revegetation, with irrigation of plant material on a scheduled basis until plants have established.

Uplands located east of Big Dry Creek vary from good grass establishment with some active prairie dogs and minor weed issues (subplots 97, 99, 101 – 104 and 106) to heavy active prairie dog and heavy weed growth (subplots 93 and 100). Management recommendations for these subplots include weed control, Russian olive removal and revegetation. However, prairie dog mitigation in subplots 93 and 100 is warranted before these activities take place. Environmental impacts at the well site should be monitored.

Riparian: The riparian area is less incised through this parcel, and therefore has better grass and herbaceous plant establishment along the banks. Any existing vertical banks should be graded back to create additional benching for wetland and riparian native plant establishment. Russian olive trees and weedy grass and herbaceous species should be controlled before areas are replanted.



Parcel VII Subplot map

Legend
Environmental Areas
- Healthy Banks/Transition Zone
- Invasive/Weeds, Needs Management
- Riparian, Healthy
- Upland, Prairie Dog Habitat
- Upland/Grassland, Healthy
- Upland/Grassland, Needs Improvement
- Wetland Creation Opportunity
- Wetlands, Healthy

Wetlands: There is an established wetland oxbow located in the middle of Parcel VII which is dominated by cattails and other wetland species (subplot 96). This wetland area creates excellent wildlife habitat for small mammals, birds, reptiles, amphibians and insects. The wetland is established in a remnant oxbow of Big Dry Creek and provides a good opportunity for further wildlife protection if isolated as a wildlife refuge. Uplands within subplots 97, 98 and 99 could be excavated to enlarge the wetland area. Weed control and Russian olive removal should occur before replanting.

Other existing wetlands along Big Dry Creek may also need weed control and replanting. When the 156th Avenue bridge is reconstructed, restoration of the creek can provide opportunities for riparian and wetland creation and expansion.

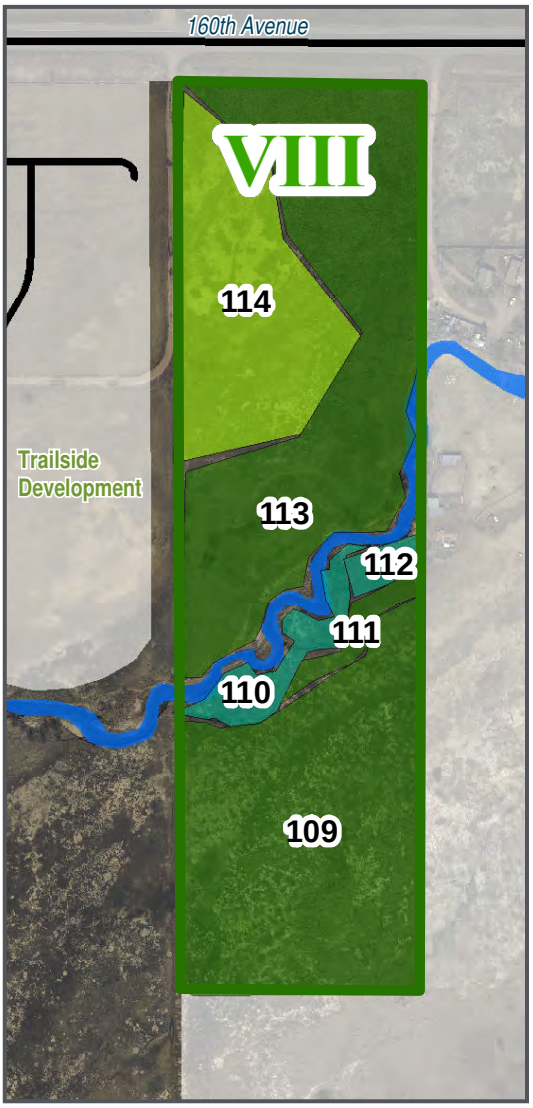
Parcel VIII Environmental Recommendations

Uplands: Uplands located north of Big Dry Creek in Parcel VIII have a balance of prairie dog activity and good native and non-native grass establishment with some weedy and bare patches. Prairie dogs should be monitored over time in subplots 113 and 114 in the event that population growth warrants prairie dog relocation or treatment. Weedy patches and Russian olive should be removed before the replanting process begins. Uplands located south of Big Dry Creek in subplots 109 and 111 are more established with upland grasses but still have some bare and weedy patches. Weed control and replanting would improve upland vegetated conditions in these subplots.

Both upland areas north and south of Big Dry Creek would benefit from weed control, Russian olive removal and upland tree and shrub planting.

Riparian: Big Dry Creek is less incised through this parcel with only a few stretches of vertical eroding banks that could be graded back to create benching for wetland and riparian native plant establishment. After weed control and Russian olive removal, the planting of additional native riparian trees and shrubs along the creek would allow for greater riparian plant diversity and overall creek and wildlife habitat health. Follow-up irrigation would be needed over time for the trees and shrubs.

Wetlands: Existing wetlands along Big Dry Creek in Parcel VIII may require some spot weed control. These areas could then be planted with wetland and riparian shrubs and trees.



Riparian area within Parcel VIII

Permitting

Typically, any activity that could have an adverse impact on a wetland or riparian area, including clearing vegetation, disturbing ground or conducting work near a sensitive area requires permits. Restoration projects such as those along Big Dry Creek may require the appropriate permits to be acquired prior to beginning work. Standard documents that are often required when working in proximity to creeks or wetlands include **Section 404 of the Clean Water Act (CWA) Permits** issued by the U.S. Army Corps of Engineers and **Floodway/Floodplain Permits**, issued by the Federal Emergency Management Agency (FEMA), as well as standard jurisdictional development permitting that will be required for any proposed structures and trailheads.

Section 404 Clean Water Act Permitting

In general, any work involving fill material added below the ordinary high water mark (OHWM) will necessitate permitting by Section 404 of the Clean Water Act (404 permitting) through the U.S. Army Corps of Engineers. Much of the floodplain restoration work that needs to be done along Big Dry Creek will involve work within the channel, and specifically, work below the OHWM. The criteria for whether a project fits under a Nationwide or Individual 404 permit is defined by the Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers. For projects that fall within this category, there are two types of 404 permits: Nationwide and Individual.

Nationwide 404 permits can be applied for instances when a project will have only ***minimal adverse effects*** that fall into a general category. In many cases, projects along Big Dry Creek will be able to fall under the general Nationwide 404 permit as opposed to a site specific permit. For example, Nationwide Permit 13 (NWP13) allows for bank stabilization projects less than 500 feet along the bank and less than 1 cubic yard per running foot.

Individual 404 permits are required for projects that will have a ***significant impact*** within the channel. Individual 404 permits require longer review and preparation, thereby causing an increase to permitting costs as well as project completion time.

Projects with major channel impacts such as cutting off an existing meander to create an oxbow wetland are likely to require an Individual 404 permit

Floodway/Floodplain Permitting

Some of the Big Dry Creek projects will impact the Federal Emergency Management Agency (FEMA) floodways and floodplains, and will therefore require floodplain permitting. Any project along Big Dry Creek ***that will alter the floodway and/or floodplain*** should undergo a hydraulic analysis to determine the impacts of the proposed improvements. Based on the outcome of the analysis, the project will either need to pursue a **No-Rise Certification** or a **Conditional Letter of Map Revision (CLOMR).**

In cases where there is no incursion into the floodway, or in cases where the work in the floodway will result in a zero-rise or decrease in base flood elevations, it may be feasible to forego the step of the CLOMR. In these instances where the hydraulic analysis can show that a project will not cause a rise in the floodplain, the project should aim to achieve a **No-Rise Certification.** The local Floodplain Administrator has discretion in whether a CLOMR is required in these cases. Foregoing the CLOMR step saves the CLOMR review fee ($6750) and a three to six month review period.

However, when projects will have a negative effect on the floodway or floodplain levels (a rise), they will have to undergo a CLOMR process and receive FEMA's comments regarding the impacts of a potential project. A CLOMR presents FEMA with the projected floodway/floodplain impacts of a project. An as-built survey must be produced after construction, from which a new hydraulic analysis is created. The new hydraulic analysis is submitted to FEMA in the form of a **Letter of Map Revision (LOMR).** Once accepted, the official FEMA Flood Insurance Rate Map (FIRM) Flood Boundary and Floodway Map (FBFM), or both, are updated by FEMA to reflect the new floodway/floodplain conditions. For some cases in which a no-rise certificate is achieved but the floodway and/or floodplain is significantly affected, the local floodplain administrator may require a LOMR process after construction.

Development Permitting

As the majority of the land within the Big Dry Creek open spaces is floodplain, pavilion and trailhead building projects will require floodplain development permitting through the city of Thornton and/or Adams County. Deviation from conservation easements that are in place on many of the parcels must be also approved, since these easements dictate the size, type and location of improvements such as parking, trailheads and restrooms.

While this discussion identifies the most likely permits for Big Dry Creek recreation and floodplain restoration projects, all applicable agencies should be contacted during the early phases of design for each project. When in doubt, contact the appropriate party and discuss the project to determine if further coordination is required.

Chapter 5 - Prioritization

Project Prioritization

In many cases, the prioritization of the projects within the Big Dry Creek Master Plan will depend on the timing of other nearby projects and developments. The recreational improvements, in particular, will be closely tied to the timing of other projects. For example, the Big Dry Creek Trail will be installed as a sidewalk along the north side of 144th Avenue; as the widening of 144th Avenue is already funded and planned, it makes sense to install this section of trail, as well as connections to this trail at the same time or soon after the 144th Avenue widening project.

However, the High Priority Reaches of Big Dry Creek are definable projects that can be prioritized. The Prioritization Decision Matrix on the facing page evaluates each of the High Priority Reaches for how well they meet criteria such as the immediate risk to infrastructure, the complexity of permitting required, potential funding opportunities, the projects ability to fulfill multiple objectives and other important criteria. By completing this evaluation process, the High Priority Reaches were 'scored' and assigned priorities. High Priority Reach 7 (Parcel V) received the highest priority ranking (Immediate) and this was one of the factors that resulted in Parcel V being selected as the pilot project site (more information on the pilot project can be found in Chapter 6, and on page 145). Following the Immediate priority ranking, four High Priority Reaches ranked as First Priorities, four as Second Priorities and two as Third Priorities. On a regular schedule, the city and county should re-evaluate this Prioritization Decision Matrix, including reviewing the High Priority Reaches/projects that should be listed, the criteria that are important and 'scoring' the projects to identify Priority Rankings. This will ensure that Thornton has an up-to-date plan of which items are of the utmost concern and have the most potential for implementation in the near future. It should be noted that all of the High Priority Reaches should be designed in a fashion to be in line with UDFCD Maintenance Eligibility guidelines.

In addition to the High Priority Reaches, there are a number of smaller projects within the Corridor. These projects are small enough that evaluating them alongside the High Priority Reaches does not produce realistic results. On page 139 is a Small Project List which identifies the projects, as well a brief discussion of the type of work that needs to occur at each location. On page 138, there is a map which shows the locations of all eleven High Priority Reaches, as well as all 5 Small Projects.

In order to implement projects along the Big Dry Creek corridor, this Master Plan has taken the approach of developing a toolbox of recreational, hydraulic and floodplain restoration and environmental improvements, as well as a framework of where the recreational and environmental improvements should be installed. This, combined with descriptions of how to determine where to install the floodplain restoration improvements, provides a full set of strategies that gives the city of Thornton and Adams County the flexibility to design and install projects based on available funding, applicable grants, upcoming adjacent development, recent storm damage and community needs.

Most importantly, this strategy gives Thornton and Adams County the ability to combine recreational, hydraulic and floodplain restoration and environmental improvements into the same project. This is an opportunity that is often missed because funding sources are typically separated by categories. For example, a utility project would typically be led by an engineering department and would therefore only be funded through engineering or infrastructure dollars. However, if that utility project is within the Big Dry Creek corridor, there could be possibilities to combine the project with invasive plant management, revegetation strategies and floodplain restoration and creek improvements. By creating a multi-use project with multiple objectives and goals, the project can be opened up to funding from not only the engineering department, but also parks and open space, floodplain management, water quality, community development and most importantly, outside funding sources such as recreation grants, Urban Drainage and Flood Control District programs and conservation groups. Multi-faceted projects will help the city of Thornton and Adams County achieve the desired vision and goals for the Big Dry Creek corridor more quickly than trying to construct individual projects that only address a single problem or constraint.

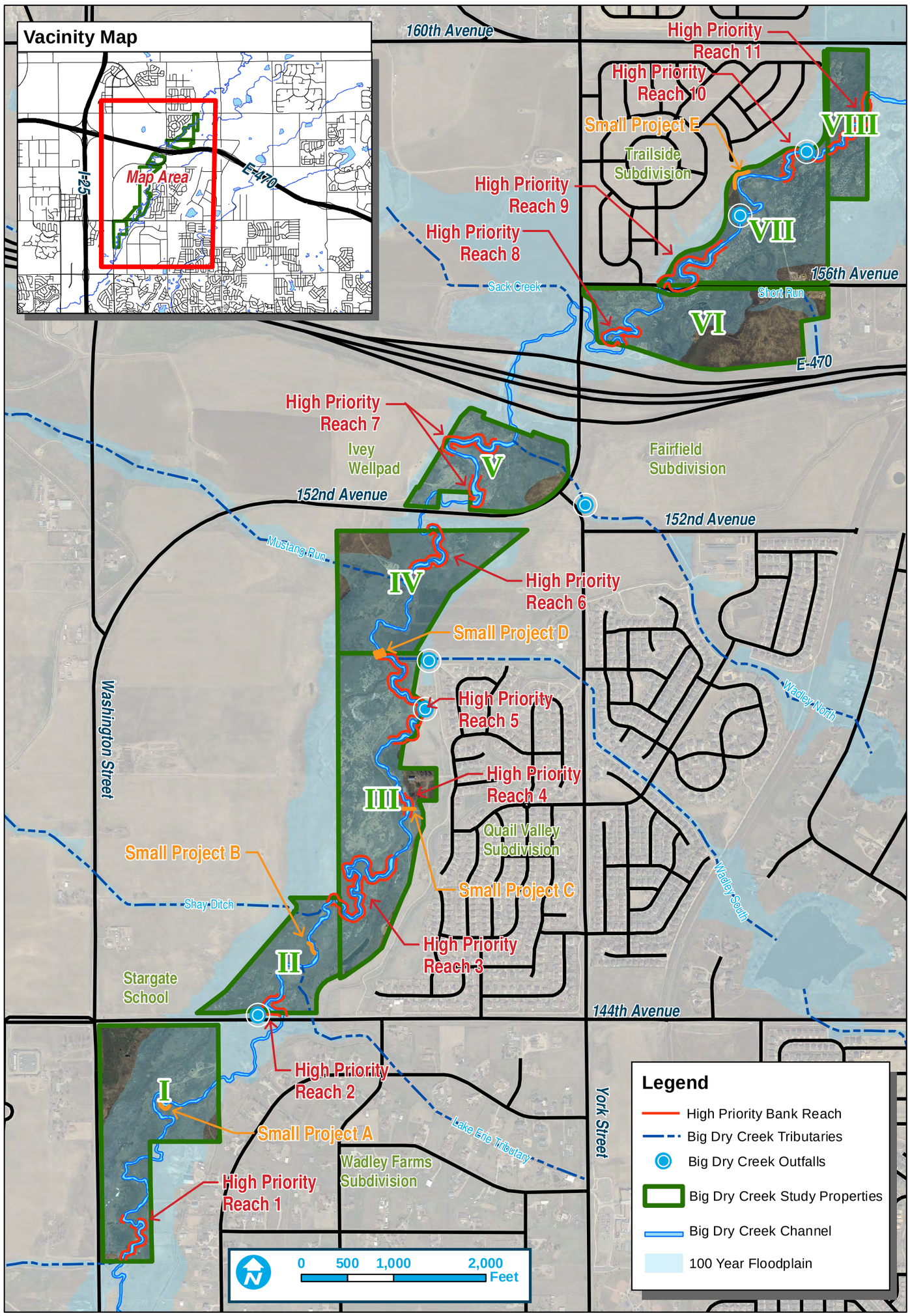
Priorization Decision Matrix

	Satisfies Criteria Fair (1 pt)	Satisfies Criteria Better (2 pts)	Satisfies Criteria Best (3 pts)

This matrix, the criteria and the projects listed within it should be re-evaulated on a regular basis in order to maintain an up-to-date priority ranking

High Priority Reach	Prioritization Decision Criteria							Priority Ranking (score)
	Existing conditions threaten public infrastructure, welfare and safety (roads,bridges, utilities, buildings, exposed gather lines, etc.)	Simplicity of permits required for the project	Project has the potential to garner public support and momentum	Project can tie into and/or build upon a planned project or an in-progress project	Project achieves multiple objectives (such as floodplain restoration, flood hazards, water quality, wildlife habitat, invasive plants and recreation)	Project has potential funding partners or is grant eligible	Project will immediately connect to existing recreational amenities and/or neighborhoods	First, Second or Third Priority. All projects on this spreadsheet are a high priority, but this ranking gives a further level of priority detail.
High Priority Reach 1 (southern end of Parcel I)	Improvements in this reach have the potential to decrease the likelihood of the creek migrating onto private properties to the east.	Would require floodplain and 404 permits (likely a Nationwide)	Project would impact the immediate neighbors to the east, but does not provide much opportunity for public engagement	No	Floodplain restoration, water quality. Areas surrounding the creek are in a relatively healthy state from an environmental perspective.	Adams County	No	**Third (10)**
High Priority Reach 2 (southern end of Parcel II)	This reach threatens 144th Ave. in its current condition.	Would require floodplain and 404 permits (could potentially be an Individual)	Not much public engagment, but the project would be very visible from the road.	Yes, could potentially tie into the 144th Ave. widening project.	Floodplain restoration, flood hazards, water quality, prairie dog management, could include part of the BDC regional trail along 144th Ave.	Yes, if combined with other projects	Potentially, yes	**First (17)**
High Priority Reach 3 (southwest end of Parcel III, flowing in from Parcel II)	Improvements in this reach will decrease the likelihood of the creek migrating onto private property to the west.	Would require floodplain and 404 permits (could potentially be an Individual)	Project is near the Quail Valley Subdivision, so it would have some visibility.	No	Floodplain restoration, flood hazards, water quality, wetland creation opportunity, invasive plants, could possibly integrate a wildlife viewing area with interpretive signage	If recreation is included, yes	If a wildlife viewing area is integrated, it could connect to the existing BDC regional trail.	**Second (13)**
High Priority Reach 4 (near concrete bridge at white barn)	Existing bridge is in poor condition and could create liability issues for either Thornton or the oil/gas operator who is in charge of maintaining the bridge.	Could require both floodplain and 404 permits (likely a Nationwide) depending on the exact scope of work	Bridge is currently used by many people who walk the trails in this area and could gather momentum and support from these people.	No	Floodplain restoration, flood hazards, water quality, recreation	Yes, oil/gas company and possibly recreation grants	Yes, would tie into the existing oil/gas access road which is widely used as a trail.	**First (17)**
High Priority Reach 5 (northern end of Parcel III, including area near playground)	This long reach currently threatens to migrate to the east, which would threaten the HOA property, including the playground. This reach includes multiple upended and rusting culverts that could be addressed as part of the overall High Priority Reach, or on their own.	Would require floodplain and 404 permits (likely a Nationwide)	Yes, it is adjacent to the playground, so it could gather support from the neighborhood. Culverts could garner public support as it could be advertised as a clean-up effort	No	Floodplain restoration, flood hazards, water quality, wildlife habitat (through re-vegetation), invasive plants	Recreational grant opportunities. Potential for oil/gas access lines that could prompt funding/partnership with oil/gas operator.	No	**Second (14)**
High Priority Reach 6 (northern end of Parcel IV, leading up to 152nd Ave. crossing)	This reach is currently threatening to migrate towards 152nd Ave.	Would require floodplain and 404 permits (likely a Nationwide)	Not much public engagment, but the project would be very visible from the road.	No	Floodplain restoration, flood hazards, water quality, wildlife habitat (through re-vegetation), invasive plants, recreation. This project has the potential to also create a required creek crossing for the BDC regional trail.	Yes, particularly if the project includes the trail/crossing improvements. Potential for oil/gas access lines that could prompt funding/partnership with oil/gas operator.	Yes, if the project includes the creek crossing for the BDC regional trail, it would tie directly into the existing trail along the eastern edge of the property, as well as possibly connecting to the existing underpass under 152nd Ave.	**First (16)**
High Priority Reach 7 Pilot Project Site	Big Dry Creek is threatening to migrate towards 152nd Ave, as well as to the west onto the Adams County property currently slated for the Ivey Wellpad	Would require floodplain and 404 permits (likely a Nationwide)	Yes, the project would involve a trailhead, trails and educational signage. It is also nearby neighborhoods and very visible from E-470 and 152nd Ave.	The project could potentially have some engagement with the Ivey Wellpad in the form of partnering to move/armor the creek to protect the wellpad, and/or creating screening between the wellpad and the open space parcel.	Floodplain restoration, flood hazards, water quality, wetland creation opportunity, invasive plants, trailhead, trails and interpretive signage.	Yes, potentially the oil/gas operator for the Ivey Wellpad, and/or Adams County. Would likely be eligible for GOCO grants for recreation, possibly CWCB grants for creek improvements.	Yes, it would tie directly into the existing underpasses under E-470 and 152nd Ave.	**Immediate (18)**
High Priority Reach 8 (Southwest corner of Parcel VI, near oil/gas access road)	Existing conditions threaten the oil/gas access road, as well as posing some threat to York Street.	Would require floodplain and 404 permits (could potentially be an Individual)	Project could include boardwalks and interpretive signage; otherwise it is not likely to gather much public support	No	Floodplain restoration, flood hazards, water quality, wetland creation opportunity, invasive plants, could integrate boardwalks with interpretive signage	Yes, particularly if the project includes the trail/crossing improvements. High potential for oil/gas access lines that could prompt funding/partnership with oil/gas operator.	No	**Second (14)**
High Priority Reach 9 (Southwest corner of Parcel VII, should be mostly corrected with 156th Ave. bridge project)	Currently, the creek channel is migrating into 156th Ave.	Would require floodplain and 404 permits (could be Nationwide or Individual depening on scope of channel re-alignment)	Yes to some extent. It will be visible from the road.	Yes, the 156th Ave. bridge project (by private developer) should address this reach	Floodplain restoration, flood hazards, water quality, invasive plants and possibly recreation if underpass is included. There are also opportunities to add boardwalks and wildlife viewing areas	Project should be largely completed by private developer	No	**First (16)**
High Priority Reach 10 (Northeast corner of Parcel VII)	Existing alignment threatens the new Trailside neighborhood	Would require floodplain and 404 permits (likely a Nationwide)	Yes to some extent. It will be visible from the neighborhood.	No	Floodplain restoration, water quality, wildlife habitat (through re-vegetation), invasive plants. Could tie into a wildlife viewing area along the existing Big Dry Creek regional trail.	Most likely for wildlife viewing area	Yes, if wildlife viewing area is integrated into the project.	**Second (14)**
High Priority Reach 11 (Entirety of BDC through Parcel VIII)	Creek is entrenched, but is not threatening infrastructure	Would require floodplain and 404 permits (could be Nationwide or Individual depening on scope of channel re-alignment)	Yes to some extent. It will be visible from the neighborhood.	No	Floodplain restoration, water quality, wetland creation opportunities, opportunity to build boardwalks.	None known, but possible for boardwalk creation	Yes, if boardwalks are built they can connect to the existing Big Dry Creek regional trail	**Third (12)**

Big Dry Creek High Priority Reaches and Small Projects



Small Projects:

Small Project A: This eroding bank in Parcel I has a highly active vertical cut bank on the outer bend. It is in close proximity to an upstream meander and if it continues to erode, it could cutoff the meander resulting in an oxbow. While the oxbow could provide beneficial wetlands, it would reduce the length of creek, thereby increasing the creek's slope and causing headcuts. This bank should be stabilized (ideally with re-grading to meet the recommended cross section) and the inner bend can be revegetated to create a more connected floodplain.

Small Project B: This eroding bank in Parcel II has vertical cut banks that are depositing sediment into the river. The outer bank should be stabilized (ideally with re-grading to meet the recommended cross section) and the inner bend can be revegetated to create a more connected floodplain.

Small Project C: This project is the existing oil/gas access bridge near the Big Dry Creek Barn in Parcel III. While this bridge is included in High Priority Reach 4, it could be repaired/improved independently from the rest of the High Priority Reach. The bridge itself requires repair or replacement to improve the abutment and embankment conditions, as well as the capacity/conveyance under the bridge. Currently the bridge has corrugated metal sheets hanging off of the bottom of the bridge into Big Dry Creek. In addition to the bridge repairs, hydraulic conditions need to be improved downstream. Currently the creek channel makes a sharp 90˚ turn, resulting in a scour pool that is deteriorating the outer bank.

Corrugated metal hanging off of the bottom of the bridge at Small Project C

Small Project D: This area contains multiple up-ended and rusting culverts that likely used to be a crossing of Big Dry Creek. The culverts are now causing major hydraulic and safety issues along the creek. The culverts should be removed and it is likely that grade control will need to be installed to avoid/minimize head cutting in the up and downstream reaches of Big Dry Creek. This area is within High Priority Reach 5, but it can be completed independently of the High Priority Reach improvements.

Small Project E: This highly active erosional bank is in Parcel VII and could potentially threaten the Trailside Neighborhood. In order to prevent further migration towards the neighborhood, the bank should be stabilized and the eroded areas should be revegetated to create wildlife habitat and provide additional stabilization.

Funding/Partnership Opportunities

Thornton and Adams County may be able to leverage a variety of grants or funding partners to support stream channel and recreation improvements. Suggestions include:

1. **Great Outdoors Colorado (GOCO)** (*http://www.goco.org/grants*): Multiple grants are available, including:
   - > Local Park and Outdoor Recreation (LPOR) grants (up to $350,000 per project) and mini grants (up to $45,000 per project costing $60,000 or less) fund new park development, enhancing existing park facilities, park land acquisition and environmental education facilities. Applicants must provide at least 25% of the total project cost in matching funds, at least 10% of which must be a cash match.
   - > Habitat Restoration grants are for projects that improve and restore Colorado's rivers, streams, wetlands, and critical habitat. The program offers $500,000 in available funding each grant cycle.
   - > GOCO's Connect Initiative will invest $30 million over the next five years to increase access to the outdoors in communities across the state. The grant will focus on connecting existing trail gaps, constructing new, highly demanded trail systems, and providing better walkable and bikeable access for youth and families to existing outdoor recreation opportunities. The maximum Connect Initiative grant request is $2 million, with a minimum match of 25% of the total project cost, of which a minimum of 10% must be cash.
2. **Colorado Water Conservation Board (CWCB)** (*http://cwcb.state.co.us/LoansGrants/colorado-watershed-restoration-grants/Pages/main.aspx*): Senate Bill 16-174, passed by the 2016 Colorado General Assembly, establishes funding for watershed restoration, which includes projects and plans designed to protect or restore watershed health and stream function. This may include projects and plans designed to stabilize perennial, ephemeral, and intermittent stream

Small Project D contains blown out culverts that need to be removed from Big Dry Creek

channels, provide habitat for aquatic and terrestrial species, re-vegetate riparian areas, reduce erosion in upland and riverine environments, improve recreational opportunities, provide fish passage, and improve channel/floodplain connectivity. CWCB funds from the Colorado Watershed Restoration Program shall not exceed 50% of the total cost of the individual plan or project.

3. **Urban Drainage and Flood Control District (UDFCD)** (*http://udfcd.org/5-year-cip*): The design and construction of master-planned projects is carried out through the Five Year Capital Improvement Plan (CIP). This plan forms the basis for District participation in design and construction projects. Work included on the CIP must meet the following requirements:
   - > Proposed improvements must be master planned
   - > District funds must be matched by local governments
   - > Local governments must agree to own the completed facilities and must accept primary responsibility for their maintenance.
4. **U.S. Department of Agriculture Natural Resources Conservation Service (NRCS)** (*https://www.nrcs.usda.gov/wps/portal/nrcs/main/co/programs/financial/*): The NRCS offers voluntary programs to eligible landowners and agricultural producers to provide financial and technical assistance to help manage natural resources in a sustainable manner. Through these programs the agency approves contracts to provide financial assistance to help plan and implement conservation practices that address natural resource concerns or opportunities to help save energy, improve soil, water, plant, air, animal and related resources on agricultural lands and non-industrial private forest land. Eligibility requirements for NRCS grants should be evaluated on a case by case basis since they primarily target agricultural producers.
5. **Section 319 Grants through Colorado Department of Public Health and Environment** (*https://www.colorado.gov/pacific/cdphe/nonpoint-source-funding-opportunities*): The Nonpoint Source Program (NPS Program) of the Colorado Department of Public Health and Environment, Water Quality Control Division (CDPHE, WQCD) funds nonpoint source projects to help achieve its two overarching objectives of restoring and protecting waterbodies from nonpoint source pollution impacts. Non-federal matching funds equal to at least 40% of the total project cost are required. The match can be cash and/or in-kind. Because 319 grants are federal funds, there can be year-to-year uncertainty regarding the amount and timing of available funds. The Big Dry Creek Watershed Association has completed a Watershed Plan under the 319 program that identified stream stabilization as a need in the watershed.
6. **Colorado Parks and Wildlife** (*http://cpw.state.co.us/aboutus/Pages/GrantPrograms.aspx*): Colorado Parks and Wildlife has several grant programs ranging from Fishing is Fun to Habitat Partnership Programs. Other grant programs include the Non-Motorized Trails Grant Program, Outdoor Classroom Grants and Wetlands Partnerships. All of these grant programs would be applicable to many of the projects recommended in this Master Plan.

Other sources of grants may include private foundations such as the **Gates Family Foundation** and organizations such as the **Trust for Public Lands**.

Chapter 6 - Pilot Project

Pilot Project Location and Goals

As part of the Big Dry Creek Master Plan, a location and goals for a pilot project were chosen. The purpose of this pilot project is to showcase how the Master Plan floodplain restoration strategies and recommendations can be implemented along Big Dry Creek and develop more public interest and momentum behind the overall development of the Big Dry Creek corridor. The success of the pilot project can also be used as leverage to garner additional funding for future Big Dry Creek projects.

During the Master Planning process, Parcel V was chosen as the pilot project location for a number of reasons:

Site Selection

1. Address multiple issues at once:

- *Floodplain Restoration*
- *Channel Migration*
- *Bank Stabilization*
- *Invasive Weeds*
- *Increase Vegetation*
- *Increase Habitat*

2. High visibility from roads

3. Existing regional trail connections

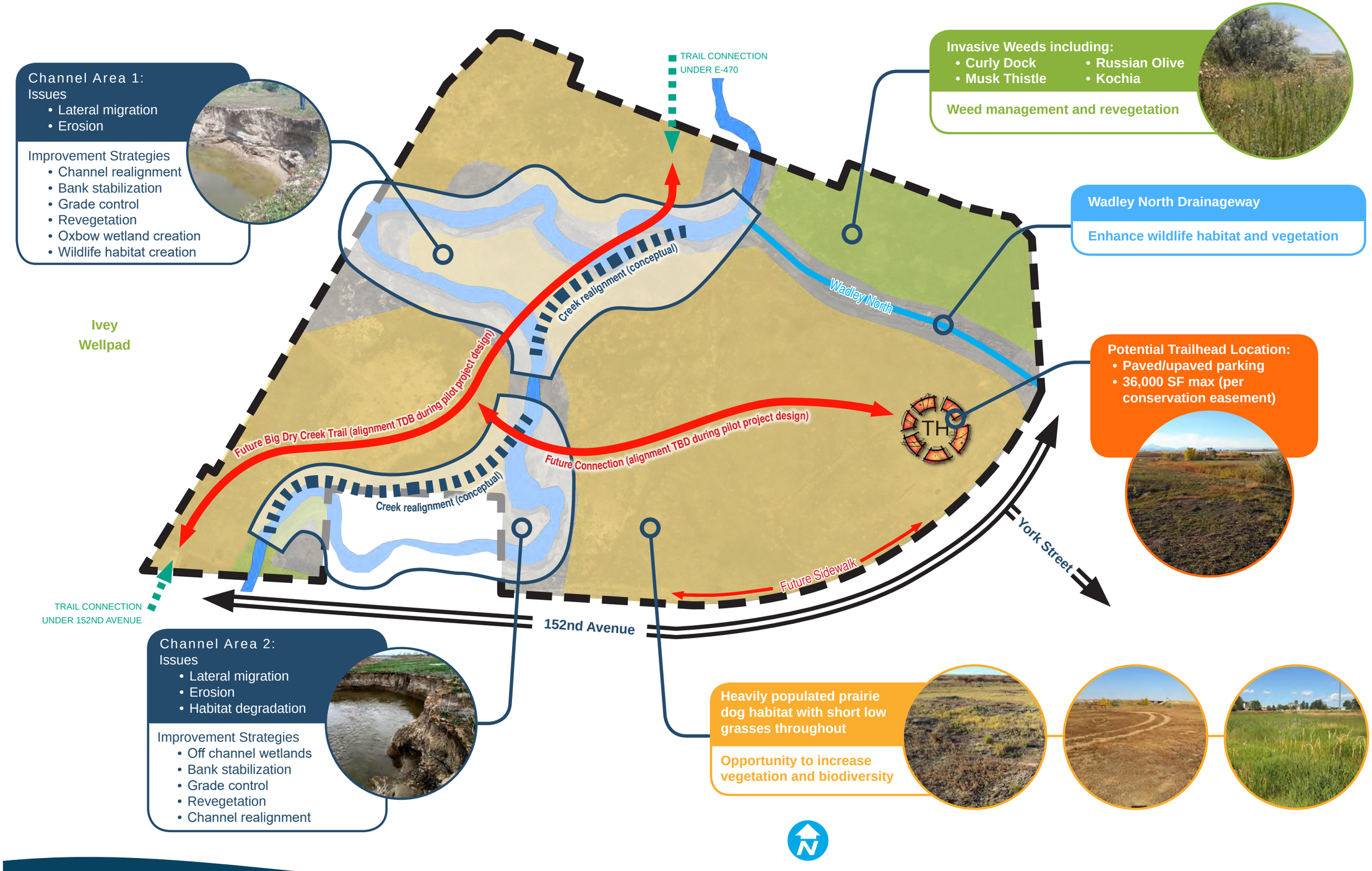
4. Easily accessed by vehicular traffic

5. Centrally located on the corridor

Pilot Project Recommendations

Parcel V is an area of Big Dry Creek, between 152nd Avenue and E-470, that has been hydrologically impacted in negative ways and is a prime candidate for a number of improvements. Hydraulically, the straightening of the channel under both 152nd Avenue and E-470 has caused the creek to search for additional space to meander. The creek has sharp bends, steep cut banks and lateral migration almost off of the property. Channel Area 1 in the Pilot Project Conceptual Plan on the facing page contains a large oxbow that is creating very deep vertical cut banks and extensive erosion. The channel has migrated almost onto the Adams County parcel to the west. Channel Area 2 also displays strong lateral migration, with Big Dry Creek doing a U-turn that directs the channel back towards 152nd Avenue. The channel then runs parallel to 152nd Avenue before turning north into Channel Area 1. For both of these areas, multiple options should be explored, but they both offer the opportunity to re-align the channel and cut off the sharp oxbows. If this is done, overflow wetlands can be created between the new channel and the previous channel area. As this would increase the slope of the creek significantly, appropriate grade control measures would need to be installed.

Aerial view of the pilot project site looking north towards E-470; Big Dry Creek is migrating laterally and causing heavy bank erosion due to the straightening of the channel on both the north and south sides of the site


Channel Area 1:
Issues
• Lateral migration
• Erosion
Improvement Strategies
• Channel realignment
• Bank stabilization
• Grade control
• Revegetation
• Oxbow wetland creation
• Wildlife habitat creation
Invasive Weeds including:
• Curly Dock
• Musk Thistle
• Russian Olive
• Kochia
Weed management and revegetation
Wadley North Drainageway
Enhance wildlife habitat and vegetation
Potential Trailhead Location:
• Paved/upaved parking
• 36,000 SF max (per conservation easement)
TRAIL CONNECTION
UNDER E-470
Ivey
Wellpad
Creek realignment (conceptual)
Wadley North
Future Big Dry Creek Trail (alignment TDB during pilot project design)
Future Connection (alignment TBD during pilot project design)
TH
Creek realignment (conceptual)
York Street
Future Sidewalk
TRAIL CONNECTION
UNDER 152ND AVENUE
152nd Avenue
Channel Area 2:
Issues
• Lateral migration
• Erosion
• Habitat degradation
Improvement Strategies
• Off channel wetlands
• Bank stabilization
• Grade control
• Revegetation
• Channel realignment
Heavily populated prairie dog habitat with short low grasses throughout
Opportunity to increase vegetation and biodiversity
N

Big Dry Creek running parallel to 152nd Avenue

Dramatic sharp turns and vertical cut banks on Big Dry Creek on the pilot project site

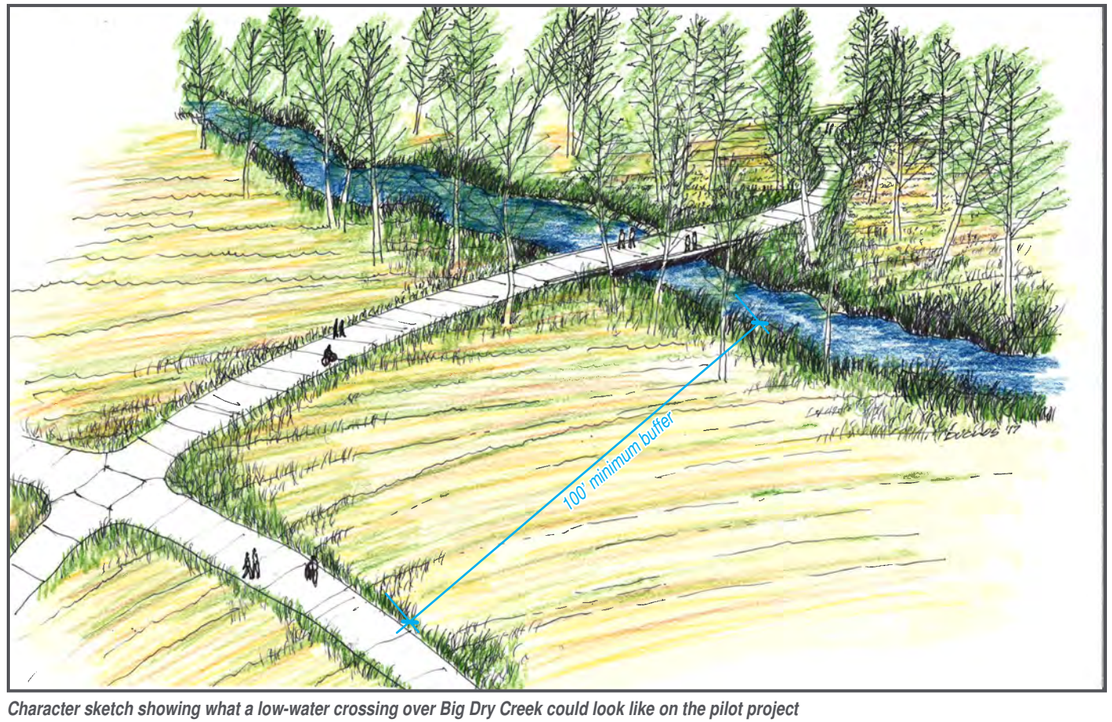
As discussed in Chapter 5, it is recommended that multiple objectives be combined into single projects. For the pilot project, Parcel V also offers a great opportunity to install a trailhead with parking, soft surface trails, a portion of the Big Dry Creek Trail, Heritage Trail signage and a creek crossing. The trailhead access will be directly across from the York Street and 152nd Avenue intersection. This location will result in the need for a crossing of Big Dry Creek that matches the city design standards.

The portion of the Big Dry Creek Trail through Parcel V should connect to the existing underpass trails under both 152nd Avenue and E-470. As part of the pilot project, the opportunity to continue the trail north of E-470 to the York Street and 156th Avenue intersection should be investigated.

In addition to the planned floodplain restoration work, the pilot project can also make environmental improvements to Parcel V. Much of Parcel V is over-populated with prairie dogs, likely due to the site being confined on three sides by road. This has resulted in the upland grasses and vegetation being over-grazed. The pilot project can implement prairie dog management strategies as well as removing invasive plants and re-vegetating the area with upland grass seed, tree and shrub plantings and the appropriate riparian and wetland communities along the creek. The project can also create, enhance and improve wetland and riparian conditions along both Big Dry Creek and the Wadley North Drainageway. The pilot project will likely realign portions of Big Dry Creek while re-grading the banks and areas around it. This presents a unique opportunity to create and expand oxbow wetlands in the parcel.

Implementation

Construction documents for the pilot project will begin following the completion of the Master Plan. At this time, funding for implementation is only available for floodplain restoration work on the pilot project, although funding is budgeted for trail construction and Heritage Trail amenities design in future years. In order to install all of the improvements together, the city is researching applicable grants. If the Ivey Wellpad moves forward, Thornton can also engage the wellpad operator about partnering opportunities as the re-alignment of the creek will benefit the flood resiliency of their site.



Character sketch showing what a low-water crossing over Big Dry Creek could look like on the pilot project

Chapter 7 - Process

Project Kickoff

The Big Dry Creek Recreation and Floodplain Restoration Master Plan began in July of 2016 after the city of Thornton and Adams County selected the THK team for the project. The kickoff meeting was held in late July, and background research began immediately. The city and county provided large amounts of background data, including:

- Conservation Easement documents
- Property acquisition documents
- Ownership documents
- Plats and subdivision maps
- Surveys of some of the open space parcels
- Relevant utility plans
- Most recent Thorncreek Golf Course improvement plans from UDFCD
- Pictures and examples of the other Heritage Trails in Thornton

All of these documents, as well as additional ones such as Thornton's Parks and Open Spaces Master Plan, Adams County's Open Space, Parks and Trails Master Plan and the Big Dry Creek Watershed Master Plan, were reviewed by the team for relevance to the project. Thornton also provided THK with their full GIS data library. This library gave the team access to the following databases:

- Address Points
- Buildings
- Parcels
- Existing Land Use
- Parks
- Trails (existing and proposed)
- Zoning
- Urban Growth Area 2035
- City Boundaries
- Utilities
- High resolution aerial imagery

This GIS data was used to evaluate existing conditions and for base maps for planning charrettes, public meetings and final map graphics. The project team also created existing condition maps from this data to use during site visits.

Site Visits

While reviewing and gathering background documents, the project team also visited all of the Big Dry Creek open space parcels. The team visited the parcels at multiple points throughout the project but the first major visit was in August 2016, walking portions of the corridor from I-25 to 160th Avenue. During these visits, they cataloged descriptions of the issues and conditions observed, as well as gathered geolocated photographs, many of which are shown in this Master Plan. The team also explored the surrounding areas in order to gather information about the surrounding context and potential trail connections.

The next major site visits were conducted in the beginning of October. During this multi-day set of site visits, detailed notes and geolocated pictures on both the existing environmental conditions, as well as recommended actions for each of the Big Dry Creek open space parcels were gathered.

Team members taking inventory on Parcel IV

Hydraulic/Geomorphic Research

The hydraulic and geomorphic recommendations were developed utilizing a variety of background documentation and on site observation of Big Dry Creek within the master plan project area. The following sections provide a sequential summary of the steps used to arrive at the recommendations:

Desktop Review

The project team collected and complied relevant background information and data associated with Big Dry Creek via a desktop review of available documents, and data from various public sources such as UDFCD, Colorado State University, and United States Geological Survey (USGS). A brief description of the data source and how it was utilized is provided as follows:

- **2012 Big Dry Creek Major Drainageway Plan Conceptual Design Report:** Information from this report, which was prepared for UDFCD, was utilized to map channel reaches into low, medium, and high priority channel restoration reaches based on the assessment that was performed in 2012. This report was also reviewed to provide specific recommendations for road crossing and outfall improvements within the master plan area. All of this information was mapped onto field maps that were utilized during field visits to confirm or change reach priorities based on visual observations.
- **2012 Flood Hazard Area Delineation (FHAD) – Big Dry Creek:** The hydraulic model (HEC-RAS) associated with this report was used to model water depths under various flow conditions in the master plan area.
- **Communication with Roderick Lammers, Colorado State University:** Roderick (Rod) Lammers, a PhD student at Colorado State University researching the geomorphology of Big Dry Creek, was consulted for input on various geomorphic characteristics of the creek. Additionally, Rod provided a mapped assessment of highly erosional areas in Big Dry Creek. This assessment compared 1993 aerial imagery of Big Dry Creek with imagery from 2014. By comparing the two images, a summary of specific channel locations where a high degree of lateral erosion and migration of the channel had occurred over time was analyzed. Information was mapped onto field maps which the team utilized during field visits to confirm or change reach priorities based on visual observations.
- **Streamflow gage data from USGS gage 06720820 Big Dry Creek at Westminster, CO:** The project team collected and complied streamflow data from this USGS gage station located approximately 4 miles upstream of the master plan project area. Data from this gage was used as a basis for quantifying hydraulic and hydrologic characteristics of Big Dry Creek through the project area.
- **Big Dry Creek Annual Water Quality Summary for 2015 (from BDC Watershed Association):** Information from this report was utilized to gain insight into the water quality concerns associated with Big Dry Creek. This report also provided a summary of typical wastewater treatment plan effluent discharge rates into and water rights diversions out of Big Dry Creek for use in adjusting streamflow values recorded at the USGS stream gage.

Hydraulic/Geomorphic Site Visits

The project team visited the Big Dry Creek open space parcels multiple times throughout the course of the project. Below is a more detailed summary of the hydrologic and hydraulic findings of the site visits:

- Big Dry Creek, through the master plan project area, has experienced widespread incision, or bank erosion, which has resulted in a deeper, more confined channel.
- The incision appears to have slowed or halted in many areas due to artificial or natural grade controls. These grade controls include road crossings and some intentional grade control structures. In some locations, the channel has incised through alluvium and encountered a naturally occurring clay layer which has prevented the channel from becoming further incised.

- The channel has begun to adjust its course primarily through bank erosion and lateral migration.
- Based on these observations, the project team agreed that the majority of the channel is in the bank wasting stage of its channel evolution, a process which allows the channel to eventually form a terraced, stable floodplain within the incised channel extents.
- The need for recommended restoration or stabilization projects specifically identified in the 2012 Big Dry Major Drainageway Plan were assessed. Some of the recommendations within this master plan's project area had already been completed, while others were still necessary.
- The project team also used this opportunity to refine the extents of low, medium, and high priority channel restoration reaches within the master plan project area.

Design Process

Throughout the project, the project team (including Thornton and Adams County staff) met every other week for a progress meeting. During these meetings, various city staff and consultants attended to contribute their respective expertise to the project. Each meeting had specific agendas and objectives intended to progress the design of the Master Plan and keep the project on schedule. Many of these meetings involved making design decisions and discussing options for how to proceed with specific elements of the Master Plan.

In between these progress meetings, the consultant team worked collaboratively on progressing design ideas and possibilities. Often, the entire consultant team (consisting of THK, WWE, Matrix, IRIS and CSU) would meet for an internal design charrette session, during which the attendees marked up and discussed base maps, proposed designs and less defined project ideas. This free-flowing and collaborative approach resulted in a wealth of ideas and options for the team to consider as the project progressed.

Public Engagement

A key piece of the master planning process was to engage the community to introduce them to the project and to gather input about what they would like to see in the Big Dry Creek corridor. The first public open house took place on the evening of October 5, 2016 at the Margaret W. Carpenter Recreation Center. Prior to the open house, the project team released an online survey to residents that was open for responses from September 28, 2016 to November 17, 2016. The survey consisted of 31 questions and 358 respondents filled it out. A family version of the survey was also distributed to schools for children to fill out with their parents. The children's survey results were compiled separately from the adult survey. Full survey results can be found in "Appendix A: Full Survey Results". The survey was also available at the open house, and many people completed it there.

Welcome Board from Open House #1

At the beginning of the first open house, the design team outlined the background of the project, described the team's approach to the project and explained the format of the public meeting. The meeting was formatted to create an open platform in which community members could share their ideas with the design team and the design team could answer questions for the community. Each member of the team was stationed at a different area in the room according to their discipline and project input boards were provided to give more information on the project, existing conditions and potential design elements.

Survey Results: Current Use

Between September 28, 2016 and November 17th, 2016 the **city of Thornton** and **the Big Dry Creek Design Team** released a public survey to gather input on ways people currently use the corridor and how they would like to use it in the future. The following are notable results of that survey:

31 *Questions*

358 *Participants*

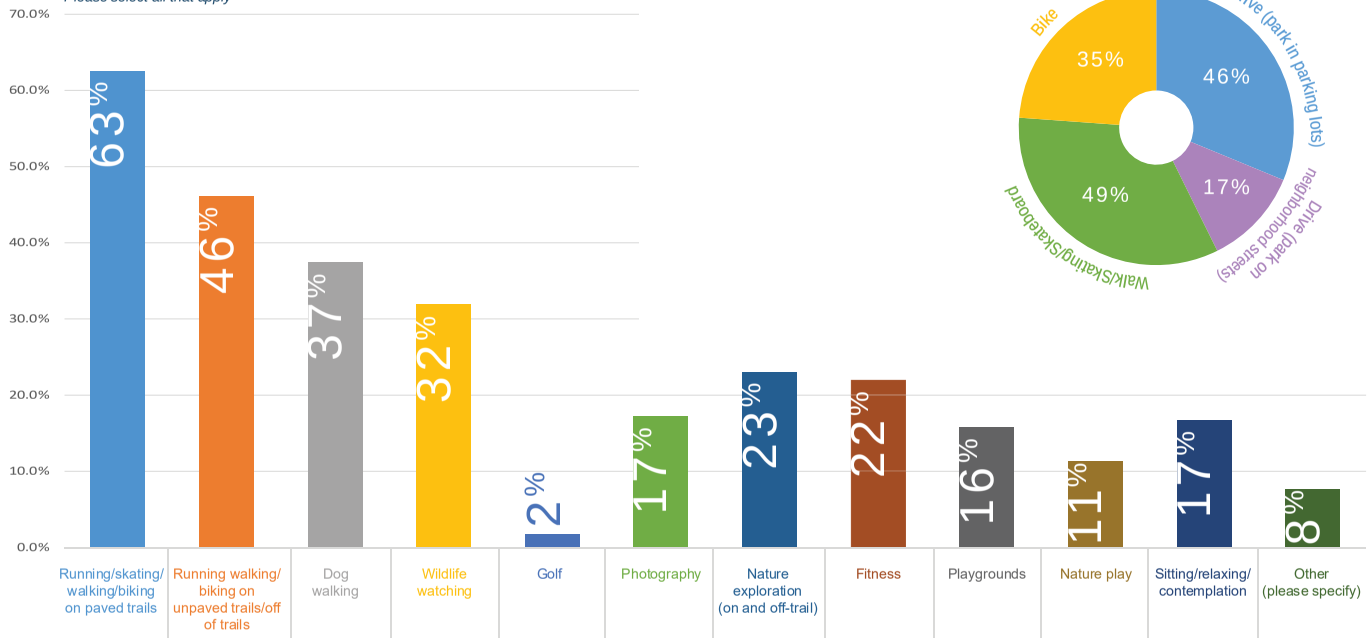
74% *of respondents live in the Thornton city limits*

87% *of respondents know of BDC open space areas that are open to the public*

70% *of respondents believe there are currently no or not enough recreational opportunities*

How do you CURRENTLY use the Big Dry Creek open space areas?

Please select all that apply



How do you typically access Big Dry Creek open space areas?

Please select all that apply

Other responses included:

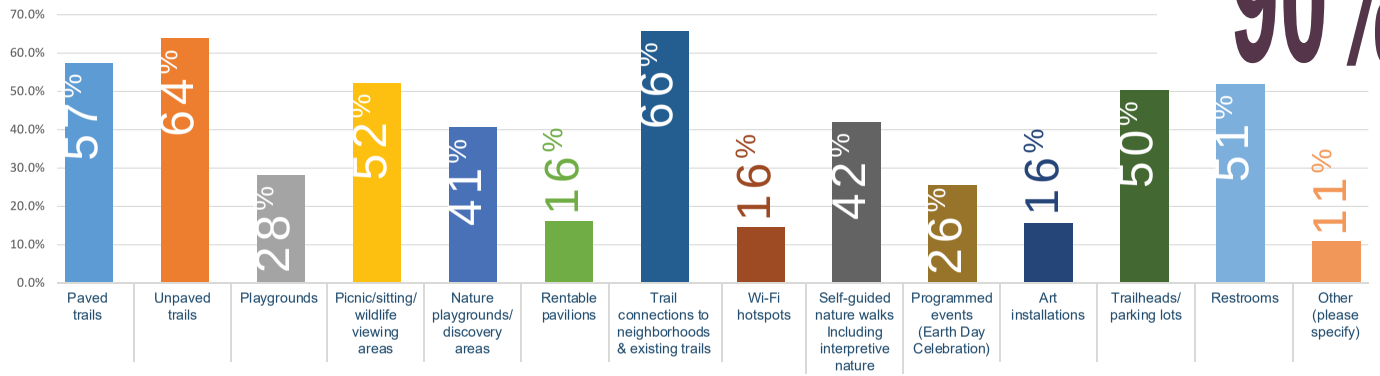
- Swimming
- Saving Animals
- No use
- Viewing open space while driving
- Playing Frisbee
- Event Production
- Bird Watching

Partial survey results showing responses to questions about how people currently use Big Dry Creek open spaces

Survey Results: Desired Use

Which of the following features would you like to see incorporated into the Big Dry Creek Corridor?

Please select all that apply

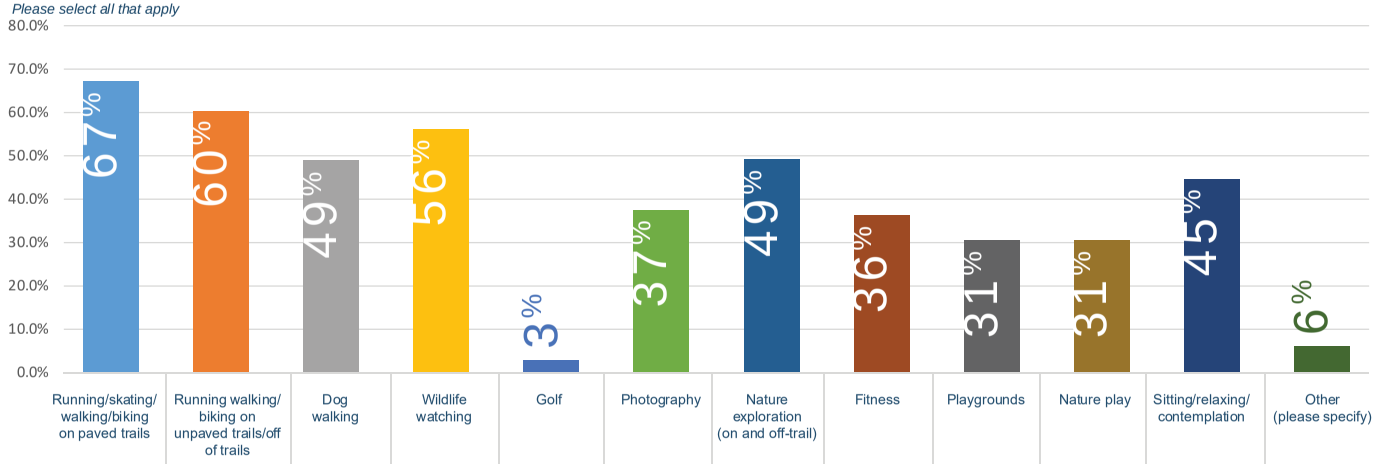


Over **90%** *of respondents believe that it is IMPORTANT for natural open space areas to-include year-round recreational opportunities with trails, wildlife viewing areas, shade shelters, benches, etc.*

Other responses included:
- Climbing facilities (walls, rocks, ropes)
- Soccer
- Keep it natural!
- Facilities for dogs (waste bins, dog parks)
- External trail connections
- Water fountains
- Exercise facilities (equipment, places for passive exercise such as yoga)

Which activities would you like to do at Big Dry Creek open space areas?

Please select all that apply



Other responses included:
- Swimming
- Soccer
- Kids play
- Games
- Disc golf
- Picnic
- Sledding
- Tent camping
- Dog park
- Fishing
- Bike park
- Adult workout stations

Partial survey results showing responses to questions about how people would like to use Big Dry Creek open spaces

Members of the public were encouraged to interact with the team and contribute to the following design process via:

- **Comment Sheet**
- **Public Input Survey**
- **Existing Conditions Map** – Community members discussed the existing conditions of the corridor with the design team and marked items such as future developments, future light rail stops, their homes, potential trail connections, etc.
- **Project Input Boards** – Community members were asked to share their input on each of the following boards and mark the items they liked using green dots and items they disliked with red dots.
  - **Recreation Features such as:**
    - Outdoor Education
    - Natural Play
    - Regional Trails
    - Neighborhood Trails
    - Access Trails
    - Creek Access
    - Fitness Stations
    - Outdoor Art
  - Stream Improvement Examples such as:
    - Existing Conditions
    - Improved/Built Stream Systems
    - Examples of Restoration Techniques
    - Vegetation and Habitat types
    - Riparian Habitat
    - Upland Habitat

'Dot-exercise' on a Project Input Board from Open House #1

The first open house attracted more than 50 attendees and overall resulted in positive project feedback from the community members, engaging conversations about existing conditions and substantive recommendations for future goals and usage of the corridor.

The second open house took place on the evening of November 30, 2016 at Fire Station No. 5 in Thornton. Approximately 60 people attended. The purpose of the meeting was to update the public on project progress, present the proposed pilot project site, as well as the proposed Big Dry Creek Trail alignment and gather input on both.

A brief update of the project's progress was given along with a summary of the public input survey results. The transparent overlays that were used for the Big Dry Creek overlay charrettes (discussed on the following pages) were explained, showing the information on each overlay and how they related to each other, including the preliminary proposed trail alignment. The pilot project board outlined objectives of the project site, as well as existing conditions and the reasons this site had been chosen.

Throughout the presentation, the design team answered questions before splitting into three groups. Each group had a copy of the Big Dry Creek DRAFT Trails Master Plan map rolled out onto a table and team members circulated with the groups to answer questions, address concerns and take input. Comments and input were recorded by writing and drawing on the maps. Below is a list of some of the feedback heard at the public meeting:

- Concerns whether active recreation or development would occur on the Big Dry Creek open space areas. Attendees were very happy to hear that the goal of the Master Plan was to preserve the open space areas while adding trails and passive recreation.
- Questions about timing and funding were asked.
- Some of attendees were concerned if the Master Plan would propose trails or changes on their private property. The Master Plan will not recommend changes or projects on private property.
- As the Ivey Wellpad site (directly west of the pilot project site) had recently held its first public meeting, there were a number of questions about the Ivey site. Since the site is in Adams County, there is little that Thornton can control.
- A number of people asked if equestrians could use the Big Dry Creek trails. Thornton Code does not allow horses on undocumented equestrian city of Thornton trails, but Adams County does allow that use. Further discussions were held with Thornton about creation of a variance.
- Many attendees asked about how stream restoration would be done, types of materials used, if floodplains would be negatively impacted, etc.

Overall, the Big Dry Creek open house #2 resulted in positive project feedback from the community members and productive conversations about what residents would like to see in their Big Dry Creek open spaces.

The team also presented to the Thornton Parks and Open Space Advisory Commission (POSAC) to discuss progress of the Master Plan, as well as goals and potential uses of the open space areas. The project and progress was well received and the POSAC members provided valuable feedback that was incorporated into the Master Plan.

Open House #2

Big Dry Creek Design Overlay Charrettes

The Big Dry Creek Master Plan is a complex project with many intertwined aspects. These include recreation, community connections, geomorphology, hydrology and hydraulics, wildlife habitat, vegetation and nearby development. In order to effectively capture and address all of these items while developing designs, the project team took a unique approach of creating a set of clear overlay base maps. Each 'layer' contained information from a certain subset (such as recreation, environmental, hydraulics, etc.). The top overlay sheet was a clear piece of acetate with just the open space parcel boundaries printed on it on which the team could draw. Through a series of charrettes, the design of the Big Dry Creek Master Plan was laid out and developed. During the charrettes, the team was able to add and remove layers in order to understand how they interacted/conflicted and where there were opportunities to combine projects. For example, the original routing for a trail was often changed once the environmental layer was overlaid, showing the trail going through healthy riparian or wetland habitat. Instead, the trail was rerouted through an area that was less sensitive. Another example is creek crossings being re-located to align with areas that require major channel work. This way, a channel improvement project could be designed to also fulfill recreational needs.

Overlays allowed the team to add and remove different layers of information

Possible trail alignments and improvements drawn on top of the overlay maps created a clear depiction of the layers of information needed to be analyzed throughout the design process.

Development of Hydraulic and Geomorphic Recommendations

Obtained from the desktop review, site visits, progress meetings and overlay charrettes, the project team assessed the feasibility of reconnecting Big Dry Creek with its historic floodplain, based on existing channel geometry and an assessment of the hydraulic conditions within the project area.

In order to assess the feasibility of reconnecting the creek with its historic floodplain, a typical channel cross section for each project area parcel was developed. These typical cross sections were created by generating channel cross sections every 100 feet through the master plan project area parcels using LiDAR data from the 2012 Big Dry Creek Master Drainageway Plan report. Each cross section was placed on top of one another relative to the channel centerline and invert of the channel. A typical cross section was then created by visually averaging channel bottom widths, depths, side slopes and top width. More details on the recommended cross sections can be found in Appendix G.

A hydraulic analysis was then performed to size a recommended design bankfull channel cross section. This hydraulic analysis combined data from the USGS gage 06720820 Big Dry Creek at Westminster, CO, wastewater treatment plant effluent discharge, and water rights diversions in order to estimate a baseflow and bankfull discharge through the Big Dry Creek channel reaches in the project area.

Based on the results of this analysis, the project team found that reconnecting Big Dry Creek with its historic floodplain is feasible, and only minor filling of the existing channel will be required to facilitate this reconnection. Following and in combination with the development of the recommended cross-sections, the project team developed a set of Toolbox Strategies for Thornton and Adams County to use as methods of achieving the recommend cross-section.

Master Plan Document

As the recommendations for the recreation, environmental and hydraulic issues came together, the project team began organizing all of the elements into the Master Plan document. This document is meant to catalog not only the recommendations of the project team, but also the process of how the team came to those recommendations. In addition, the document needed to make recommendations on funding, prioritization and implementation. The document was submitted to the city of Thornton and Adams County for review.

Following review, the Master Plan was revised based on comments received and was submitted for a final review. Comments were taken on this ‘final draft’ and revisions were made to arrive at the final Big Dry Creek Master Plan.