Appendix C
Critical Reach Analysis (Airphoto Rectification and Feature Extraction Methodologies)

General Approach

Watersheds by their very nature, are dynamic systems that change over time The purpose of the following studies is to gain a better understanding of erosion, sedimentation and flooding problems in selected critical reaches within the Fountain Creek Watershed through time-series analysis of aerial photographs of the stream corridors.

Aerial photographic time-series analysis provides a better understanding of the relationships between each study area and the human and physical components affecting its stream corridor. Multiple years of photographs were acquired and rectified into the proper coordinate system using geographic information system (GIS) and remote sensing tools. Using the photographs as a backdrop, various features were then collected using GIS to provide a better understanding of erosion, sedimentation and flooding problems in a stream reach. These GIS data sets were subsequently used to compare changes in the channel and floodplain over time. Field investigations of the channels and floodplains were completed to observe fluvial landforms that reflect the condition of the streams and changes in stream geomorphology in the recent past.
Six critical Reaches have been analyzed so far in the Fountain Creek Watershed:

- Monument Creek, about 2½ miles, upstream of Monument Lake between the Towns of Monument and Palmer Lake
- Black Forest Tributary, about 1 mile, in the Gleneagle area just north of the Air Force Academy's auxiliary air field
- Cottonwood Creek, about 2 miles, from Union Blvd. to where Cottonwood Creek crosses under I-25
- Jimmy Camp Creek, about 1 ½ mile, from Fontaine Blvd. along Marksheffel Rd. to just upstream of Link Rd.
- Fountain Creek, about 3 miles, about 2 miles up and down from exit 151 (Pikes Peak Race Track).
- Fountain Creek. Pueblo Critical Area, about 4 miles above the confluence with Fountain Creek and Arakansas River.

A description of the analysis is available in a separate report entitled Fountain Creek Watershed GIS Critical Reach Analysis, which will be available on the Fountain Creek Watershed. This report is available on the Fountain Creek Watershed Webpage (www.fountian-crk.org) or by contacting PPACG at 719-471-7080.

Background

This study was conducted to gain a better understanding of erosion, sedimentation and flooding problems in the four selected critical areas through a time-series analysis of aerial photographs from 1955, 1983 and 1999 or 2001 of the stream corridors. GIS tools were used to extract features such as bank limits, meander belts, and rapidly eroding banks. Vegetation, transportation facilities (such as bridges crossing the stream reaches), and structures adjacent to streams were also analyzed. Field investigations were conducted to examine stream morphology, floodplains and channel corridors. These channel statistics were calculated for each of the three years of photographs that were analyzed.

The study examined features of the different stream reaches and how the stream channels have changed over time and in many places have become constrained by development. The result of this development is that the streams have changed from flowing in response to storm events to flowing year-round. This creates problems with sediment and ultimately flooding and channel degradation, which in turn can threaten buildings and infrastructure. The analysis of the aerial photographs demonstrates that floodplain maps can become outdated over time due to development, channel changes and a number of other factors. Preventative measures, such as watershed restrictions on well watering, reuse programs and identifying erosion-prone areas, may be necessary to prevent further damage. Information derived from aerial photography analysis, GIS tools and field investigations will supplement the information in floodplain maps and help to highlight problem spots for erosion. Analysis of historical movement of stream channels can also be used to estimate future movement.

Aerial Photograph Rectification Methodology

The project team researched two different aerial photography acquisition methods. The first method required flying the study area and generating ortho-rectified aerial photos through photogrammetric means. This method was eliminated from consideration because its cost was prohibitive. Instead, the team located existing sources of aerial photos. The project team learned that photos from various years were available from several sources including the U.S. Department of Agriculture (USDA)-Farm Service Agency Aerial Photography Field Office in Salt Lake City, Utah and other aerial-photograph vendors.

Aerial photos covering a specific time period were purchased for the study area and delivered in black/white, unrectified ".tif" image format or color geo-referenced .tif format. It was not necessary to obtain photos with complete stereo coverage. As a result, the USDA photos have approximately 20 percent end lap and 50 percent side lap (with side lap only in corners of the photos). The color .tif image was clipped from a larger data index to show only the study area. After the photo sets were acquired, the rectification process could begin. The following steps were followed to rectify the aerial photos.

Select which photo to rectify, and then identify ground control points from a known source to rectify the photos. URS chose to use U.S. Geological Survey (USGS) Digital Raster Graphic (DRG) data sets (digital USGS 1:24,000 topographic quads) as the source data because they were readily available and could be easily manipulated into the proper projection. Control points were chosen based on their presence on the DRGs and on all photo years to minimize efforts. A minimum of four control points was located on each photo and the corresponding DRG.

The photos were rectified using the control points selected. This procedure both rectified and projected the aerials into the proper projection. Each completed photo was then loaded into ArcMap® and displayed against the reference DRG to ensure both data sets adequately aligned with each other. Accuracies within the study areas typically range from approximately 10 feet to 150 feet in the x and y directions, with better accuracy generally found in the middle of the photo and along the stream segment to be studied. Aerial photo rectification errors are mainly caused by slight variations in photo scale within the image, especially near the edges. These errors are usually encountered in the rectification process and therefore were deemed minor and ignored.

Edge information such as fiducial marks and black "no-data" areas were eliminated from each USDA black/white aerial photo after the rectification process was complete. The aerials were loaded into ArcMap® and displayed to clearly determine the edge between the actual photo image and its extraneous edge information. This edge was digitized to form a closed square on the screen and saved. These digitized edges were then converted to ArcInfo® polygon coverages. The aerials were converted from .tif images into ArcInfo® GRID files. The GRID files of each aerial were then clipped with the polygon "edge" file to delete all GRID data beyond the clipping boundary. Finally, the photos were converted from GRIDs back to .tif files. The color .tif images were not modified because they did not have any "no-data" areas.

Feature Extraction Methodology

Once the aerials were rectified, each was loaded into ArcMap® to begin the process of extracting features from the photo and into a shapefile. A GIS database schema was developed to guide the feature extraction process. The schema outlines the individual features to extract and includes each feature's attribute definitions and ranges, and is included as part of the GIS data delivery.

Using the feature definitions and ranges from the database schema, shapefiles were created to receive the collected feature data. Data were collected from the rectified photos and placed in the proper ArcMap® themes by digitizing features directly on the computer screen. Features were collected within ArcMap® at a view scale of 1:3,000. This data scale displays all years' photos with enough detail to locate the required features. In many cases, ArcInfo® was also needed to help edit and process data, especially those data sets representing area features. Each feature and its extraction guidelines are outlined below.

Valley Length Reference Line

This feature was collected for quick and easy reference within GIS and provides a base to measure the sinuosity of the stream within each critical reach. The reference line was placed along the axis of the stream valley as determined from the most recent aerial photo.

Channel Centerline

This feature traces the center of the visible active flow area and indicates where the majority of the stream flow is located. The main channel was determined on the photos by simply locating the channel that is the largest and appears the most active. However, on many of the photos, stretches of channel could not be easily located because of dense streamside vegetation, steep narrow banks or a combination of these circumstances. In these cases, the centerline was approximately placed using streamside vegetation and other features as guides.

Left and Right Creek Banks

Identifying water within the channel and tracing each bank determined the creek banks. Many areas feature braided streams with multiple channels. In these cases, the creek banks were traced to include all the braided channels present. If only one channel was present, then the creek banks followed its edges exclusively. Where dry stretches occurred, the creek banks were assumed. Care, however, was taken to not include some features along the channel, such as point bars and beaches.

Critical Area/Reach Outline

These features were created as a reference for later feature collection within each study area. They are created using the northern and southern extents of the study area and a buffer of the most recent year's creek centerline.

Meander Belt

The meander belt is defined as the zone along the valley floor across which a meandering stream shifts its channel from time to time. This is important in determining the past and potential future channel changes during and after periods of flooding. Meander belt features were first identified on hard-copy prints of aerial photos by the team geomorphologist. Meander belt lines for each reach were then digitized on the screen with the aid of the photo backdrop, saved, created as polygons and attributed.

Prominent Scour and Deposition Areas

Where applicable, prominent scour areas and prominent deposition areas were collected for each critical reach. Scour areas are determined by the presence of exposed alluvium and sparse scrub-like vegetation immediately adjacent to channel edges. These locations are good indicators of recent channel movement during floods. Deposition areas are locations where alluvium have been deposited and typically occur in areas of decreasing stream gradient or upstream of channel obstructions. Scour and deposition areas were outlined on hard-copy prints by the team geomorphologist, digitized, created as polygons and attributed.

Vegetation

Vegetative cover was collected to help capture the human-induced changes within each critical reach. Data were collected only within the meander belt for a particular year, instead of the entire critical reach, to avoid costly time commitments and to focus attention on those areas immediately adjacent to streams.

General vegetation patterns were initially identified on hard-copy plots of each critical reach. From these, simple vegetation classes were developed. They include shrubland, forest, barren, potential wetlands, grassland, water, and riparian areas. A brief description of each vegetation class follows.

- Shrublands were identified by upland open-canopy forests with scrub-like vegetation such as oaks.
- Forest areas were identified as closed-canopy areas and were primarily pine trees or thick oak stands.

- Riparian areas consisted of willows, tamarisk and other vegetation immediately adjacent to stream banks.
- Barren areas were located within channels, had little to no vegetation and consisted of mainly sand and gravel.
- Grasslands were mainly located on dry upland areas and could be either prairies or pastures.
- Potential wetlands were collected for areas that were noticeably wet, but away from the channel.
- Water features were farm ponds and lakes.

These areas were then identified on-screen in ArcMap® and digitized within meander belts, saved, converted to polygons, and attributed. In addition, any transportation features or structures located within the meander belt were combined with the vegetation data and included as part of the final shapefile.

Unstable/Eroding Banks

These features represent locations within each critical reach where creek banks are either unstable or actively eroding. They are often near scour areas and edges of the meander belt. Active bank erosion features were first identified in the field, then correlations between field observations and recent aerial photographs were used to judge where the features are located on hard-copy prints by the team geomorphologist, digitized, and attributed within ArcMap®.

Transportation and Major Structures/Built-Up Areas

These features were collected to help document the important role humans play within each critical reach. Both feature sets were delineated directly within ArcMap® using the appropriate photos as backdrops and saved as polygons. All paved roads and railroads within each critical reach were identified, along with any gravel roads located within the meander belt. All major structures and built-up areas within each critical reach were also digitized. Groups of houses, entire neighborhoods and parking lots were aggregated as large polygons when possible.

Surficial Geology

The team was able to locate a hard-copy map of surficial geology that covered all study areas (Geologic Map of the Colorado Springs-Castle Rock Area, Front Range Urban Corridor, Colorado, USGS 1979, 1:100,000-scale). Unfortunately, this map was not readily available in a GIS format, so it was not included in the GIS analysis.

Other Data

Federal Emergency Management Agency (FEMA) Q3 digital floodplain data for El Paso County were obtained for the Fountain Creek Watershed Plan. When possible, each study area was clipped from the Q3 data and included with the GIS data deliverable. Additional data sets were collected if the team thought the effort would help explain a reach's geomorphology.