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CITY OF COLORADO SPRINGS
PLANNING, DEVELOPMENT AND FINANCE DEPARTMENT

Monument Creek Drainage Basin Planning Study

Volume I
Report

Prepared by
CH2M HILL

in association with
Kiowa Engineering Corporation
Thomas & Thomas
Urban Edges

Monument Creek
Drainage Basin Planning Study

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Executive Summary

Purpose

The purpose of the Monument Creek Drainage Basin Planning Study was to develop a preliminary plan of stream improvements along a 10-mile study reach extending from Fountain Creek to the U.S. Air Force Academy (USAFA). The preliminary plan was developed with the active involvement of a number of City and County departments, State and Federal agencies, interest groups, the public at large, and a team of consultants comprised of planners, landscape architects, engineers, and biologists.

Scope

The study included an inventory of riparian flora and fauna, aquatic habitat, and cultural resources along the study reach and an assessment of problems related to flood capacity, stream stability, and habitat quality. The study formulated various stream alternatives and evaluated them on the basis of construction and maintenance costs, impacts on riparian vegetation, and a number of qualitative factors. After the preferred alternatives were selected, the preliminary plan was developed.

Study Reach Constraints

Constraints and problems evident along the study reach of Monument Creek (extending from the confluence with Fountain Creek to the south boundary of the USAFA) are highlighted below:

- Much of the natural floodplain channel has been filled in over the years to gain developable land. This fill has raised flood levels, reduced riparian vegetation, and increased flood velocities and bank erosion risk.
- High sediment loads supplied to the study reach downstream of Woodmen Road have created a wide, braided base flow channel, reducing riparian vegetation and impairing aquatic habitat and water quality.
- Dumping of trash and rubble down the banks of the channel in the area upstream and downstream of Garden of the Gods Road poses a concern regarding public safety, water quality, and aesthetics.
- Storm runoff is expected to increase in peak discharge, volume, and frequency as the Monument Creek watershed continues to develop, further exacerbating stream capacity and erosion problems.

- The potential exists for out-of-channel flooding of a number of industrial and residential structures upstream of Polk and Fillmore Streets for 100-year future development conditions.

- Significant long-term erosion in the Monument Creek channel is anticipated, endangering public infrastructure and further impairing habitat and water quality.

Stream Resources

Even with the problems described above, the existing Monument Creek corridor serves as an extremely valuable resource. The continuous streamflows and the large areas of remaining riparian vegetation provide important habitat for a diverse array of mammals, amphibians, reptiles, and birds. The portion of the study reach upstream of Woodmen Road still has a relatively natural, undisturbed physical geometry that provides productive aquatic and terrestrial habitat and an unconstricted floodplain. Finally, access to and enjoyment of the Monument Creek corridor on the part of Colorado Springs residents and visitors is increasing as new trails and recreational areas are constructed.

Alternative Formulation

A set of goals and objectives was formulated to guide the study. A full range of conceptual alternatives was refined into three to four workable stream improvement alternatives for seven different stream reaches of Monument Creek (designated M1 on the downstream end to M7 on the upstream end). The study goals, objectives, and improvement alternatives were formulated with the assistance of a project study group comprised of City of Colorado Springs representatives, resource agencies, and the public at large.

Alternative 1 was consistently a no action alternative. The purpose of Alternative 1 was to provide a baseline condition from which to compare the other alternatives.

Alternative 2 generally represented a reactive strategy, similar to past practices related to Monument Creek. In the reactive strategy, action would be oriented toward protecting existing infrastructure. For instance, drop structures would be constructed downstream of bridges and utility crossings to protect the structures against the impacts of bed degradation.

Alternative 3 in Reaches M3, M5, and M7 featured stabilization over the length of the respective reach using conventional drop structures and bank channelization. The drop structures would typically be constructed of concrete or grouted boulders with drop heights greater than 3 feet. The channelization work would be designed to increase flood capacity and confine the 100-year future development condition floodplain to the area between the top of channel banks.

Alternative 3 in the other portions of the creek (in Reaches M1, M2, M4, and M6) would utilize "riffle drops" and enhanced riparian vegetation to stabilize the channel against erosion. Alternative 4 in Reaches M3, M5, and M7 would also use this concept. Riffle drops are small (1 to 3 feet high) cobble (rock) drops frequently spaced along the streambed. The riffle drops would be designed to emulate the riffle/pool sequence found in many natural streams and would control downcutting of the channel as the equilibrium slope decreases over time. The drops would be used to promote a narrower, meandering baseflow channel geometry as the expected long-term decrease in sediment supply causes this shift in regime to take place.

Overbank flooding in the riffle drop alternatives would be addressed through a nonstructural strategy of flood insurance, flood proofing, and "passive" floodplain acquisition. Opportunities would be sought to remove some of the fill material that has been placed adjacent to the channel. This would open up a wider floodplain and enable riparian vegetation to be increased, decreasing flow velocities and lateral bank erosion during extreme floods.

Alternative Evaluation

The alternative stream improvement plans were evaluated based on how well they achieved the goals and objectives identified for the stream corridor. The evaluation included both qualitative and quantitative aspects. Included were quantitative comparisons of present value costs and areal impacts on riparian vegetation. Qualitative evaluation ratings were assigned to alternative plans based on 30 different corridor objectives.

Selection of Preferred Alternatives

The riffle drop alternatives (Alternative 3 in Reaches M1, M2, M4, and M6, and Alternative 4 in Reaches M3, M5, and M7), featuring enhanced riparian vegetation and floodplain acquisition, comprised the stream improvement plan recommended by the study team and study group for refinement during the development of the preliminary plan. The riffle drop alternatives were judged to best achieve the goals and objectives identified for the corridor, while offering the lowest present value cost. Implementing a proactive stream improvement plan based on the riffle drop alternatives (providing full stabilization and a variety of other benefits) is more economical than doing nothing and trying to fix creek corridor problems after they occur.

Preliminary Plan

The selected stream improvement alternatives were refined during the development of the preliminary plan. Additional detail was provided and the type, location, and approximate geometry of each of the improvements identified. Plan view and profile drawings of the improvements were prepared at a scale of 1 inch equals 200 feet.

The preliminary plan generally consists of the following elements:

- A series of sloping boulder riffle drops for grade control, protection of infrastructure, and other benefits
- Creation of vegetated bench areas adjacent to the base flow channel to retard flow velocities and enhance the stability of channel banks
- Regrading and revegetating steep, eroding channel banks to reduce erosion potential and improve public safety
- Repair of undermined riprap or gabion slope protection structures
- Installation of grouted rock energy dissipators at several locations
- Installation of fencing at the top of steep bedrock banks
- Planting of screening vegetation to soften the appearance of existing concrete or rock bank protection

Probable construction costs for the plan total $25.7 million, exclusive of right-of-way acquisition and engineering, permitting, and administrative costs. The actual costs of the plan will be less if all of the improvements are not built. For example, if actual degradation of the creek is less than the amount planned for in this study, fewer riffle drops would be required. The actual costs of the plan will depend on a variety of other factors, including the schedule of plan implementation, the final project design and scope, and the actual labor and materials costs at the time of construction.

1.0 INTRODUCTION

1.0 Introduction

1.1 Authorization

This study, entitled "Monument Creek Drainage Basin Planning Study" (Monument Creek DBPS), was authorized by the City of Colorado Springs (the City) on April 30, 1991. Specific study tasks were performed in accordance with the terms of Agreement Number 91C-2026 and subsequent amendments. The study was prepared for the City Engineering Division of the Planning, Development, and Finance Department by a consultant team led by CH2M HILL, Denver, Colorado.

1.2 Purpose and Scope

The purpose of the Monument Creek DBPS was to develop a stormwater management plan along the study reach of Monument Creek. The management plan was based on an inventory of riparian flora and fauna, aquatic habitat, cultural resources, and an assessment of problems related to flood capacity, stream stability, and habitat quality. The study formulated alternative plans to address problems and enhance resources and developed a recommended plan to guide future activities and improvements along the creek.

The Monument Creek DBPS focuses on an important receiving stream adjacent to the City, draining a watershed area of 250 square miles. The study reach of Monument Creek extends from its confluence with Fountain Creek near State Highway 24 to the corporate limit of Colorado Springs just south of the U.S. Air Force Academy (USAFA). The study reach of Monument Creek is approximately 10 miles long.

Monument Creek represents an extremely complex natural system. The creek provides for the movement of surface runoff and sediment from upstream watershed areas to downstream areas, and features specialized bed and bank material, geometry, and vegetation. Like all creeks, the system is dynamic, continually responding to changes in the quantity of in-flowing runoff and sediment and to human-induced changes to its geometry and vegetation. Flood events, though rare, can result in major damage and shifts in channel form and vegetation, especially when human activities have constrained the natural ability of a creek to convey large floods.

This study recognizes the complex, dynamic nature of Monument Creek and seeks to understand some of the impacts the creek has on the community and the impacts the community has on the creek. The study was undertaken with a comprehensive scope, which considered the following:

- The need to assess cumulative impacts of multiple tributaries and diverse watershed land use practices on the Monument Creek corridor

- The need to balance the multiple, often competing, objectives for the stream corridor

- The need for interaction and cooperation between various local governments, resource agencies and the public at large responsible for the quality of the stream corridor

The scope of this study included the tasks shown in Table 1-1.

The purpose of this report is to document the completed tasks and to assist the City, County, resource agencies, and public in implementing the preliminary plan of selected stream improvements. This report is organized in three volumes:

- **Volume I** summarizes the methods, results, and conclusions of the Monument Creek DBPS. Volume I summarizes essential study elements and findings.

- **Volume II** consists of 41 drawings. The drawings depict stream corridor resources, floodplain boundaries, stream improvement alternatives, and the preliminary plan of selected stream improvements.

- **Volume III** contains appendices, consisting of detailed information that supports Volume I. Volume III identifies parties who participated in the public involvement process, shows hydraulic model results, documents costs and present value analyses for the alternatives evaluated, and provides a detailed preliminary plan cost opinion. In addition, Volume III contains the *Drainage Facility Inventory* (December 1992) and the *Baseline Hydrology Report* (May 1992). These reports were prepared by Kiowa Engineering Corporation under subcontract to CH2M HILL. The reports document Task 3 and the hydrologic analysis portion of Task 4, described in Table 1-1.

1.3 Related Studies

The Monument Creek DBPS is being performed concurrently with the following related studies:

1. Fountain Creek Drainage Basin Planning Study—This study is being prepared for the City Engineering Division of the Planning, Development, and Finance Department and has the same purpose and scope as the Monument Creek DBPS. The study reach along Fountain Creek extends from the corporate limit of Colorado Springs south of Circle Drive upstream to the city limit east of Manitou Springs. The study reach is approximately

Table 1-1 Study Tasks	
Task	Description
1.	Collect and review existing information pertaining to current and planned land use, topographic mapping, drainage studies/plans, flood plains, vegetation, wildlife, geology, water resources, cultural resources, flooding complaints, etc.
2.	Compile aerial topographic mapping of the study reach corridor.
3.	Use the inventory available from the City Engineering Division of the existing drainage system/ facilities along the study reach of Monument Creek, supplement it as necessary, and analyze the system along the main stem including all drainage structures and facilities that discharge into the creek. Prepare a drainage facility inventory for the study reach.
4.	Develop 10-year and 100-year flood hydrology for existing and estimated future development conditions in the drainage basin and perform necessary hydraulic computations to define the 100-year floodplain in the study reach.
5.	Identify drainage/flooding problems and opportunities for improvement of the drainageways along the main stem of Monument Creek.
6.	Incorporate a public input and information process along with input/review from various resource agencies into the design of the study.
7.	Perform an environmental inventory within the basin along the main stem of Monument Creek to include such items as riparian flora and fauna, aquatic habitat, and cultural resources.
8.	Coordinate the project with related planning and engineering studies and provide ongoing project management and communication tasks.
9.	Identify opportunities for preserving or enhancing recreational facilities, parks, and open space along the creek corridor.
10.	Develop a comprehensive list of alternative concepts with input from the City, County, public, and resource agencies to address the major drainage system. Analyze the concepts and select three practical alternatives for detailed evaluation.
11.	Conduct a detailed evaluation of the three alternatives identified above to include such factors as construction costs, land acquisition costs, maintenance and operation costs, engineering feasibility and constructibility, environmental impacts, socioeconomic/land use impacts, and recreational/open space impacts.
12.	Recommend a preferred alternative drainage plan with input from the City, County, public, and resource agencies.
13.	Prepare preliminary design drawings showing the concepts and intent of the selected plan.
14.	Develop opinions of probable cost for the selected plan and address financing and implementation issues.
15.	Prepare a draft drainage basin planning study report and technical appendices and assist the City in the approval and adoption process.
16.	Revise the draft study as necessary, obtain approval and adoption of the study, and prepare and submit the specified number of copies of the final study to the City.

8 miles in length. The study reach is comprised of 4 miles of lower Fountain Creek below the confluence with Monument Creek and 4 miles of upper Fountain Creek above the Monument Creek confluence.

2. The Pikes Peak Greenway Master Plan—This study is being prepared for the Comprehensive Planning Division of the Planning, Development, and Finance Department and is closely linked to the Monument Creek and Fountain Creek DBPSs. The purpose of the project is to develop a Master Plan for the Monument Creek/Fountain Creek/I-25 Corridor through central Colorado Springs which offers:

   - An urban corridor vision
   - Planning goals and objectives for the future character of the corridor
   - A multi-objective greenway design theme
   - Specific recommendations including a master site plan

   The study is to interrelate drainageway management, expansion of I-25, central city development, flood control, and water quality engineering objectives with preservation and enhancement of the corridor's assets as a major aesthetic, recreational and wildlife habitat amenity. Finally, the study is to initiate an ongoing marketing and implementation process that ultimately results in realization of the plan's vision, goals, objectives, and recommendations.

The design teams for the Monument Creek DBPS, the Fountain Creek DBPS, and the Monument Creek/Fountain Creek Corridor Plan have worked closely together and have met in joint working meetings and public meetings in order to maintain a high level of teamwork and coordination in preparing the alternative stream improvement plans.

1.4 Project Team

The project team for the three concurrent studies consists of representatives from the following firms:

- Monument Creek DBPS
  - CH2M HILL—Lead Engineer
  - Kiowa Engineering Corporation—Hydrologic and Hydraulic Analyses

- Thomas and Thomas—Resource Inventories
- Urban Edges—Multi-objective Planning

The City's Project Manager for the Monument Creek DBPS is Ken Sampley, Civil Engineer Supervisor, with the City Engineering Division.

- Fountain Creek DBPS

  - Muller Engineering Company—Lead Engineer
  - Thomas and Thomas
  - Obering, Wurth and Associates
  - Aquatic and Wetland Consultants
  - CTL/Thompson

  Ken Sampley also serves as the City's Project Manager for the Fountain Creek DBPS.

- Pikes Peak Greenway Master Plan

  - Urban Edges—Lead Planner
  - Thomas and Thomas
  - Erik Olgersen

  The City's Project Manager for the Monument Creek/Fountain Creek Corridor Plan is Craig Blewitt, Senior Planner with the Comprehensive Planning Division.

Other studies relating to Monument Creek have been undertaken in previous years, such as flood insurance reports by the Federal Emergency Management Agency (FEMA). These studies are referenced in the applicable sections of this report.

1.5 Public Involvement

A public involvement program was initiated to involve resource agencies and the public at large in the three related studies. The public involvement program was initially coordinated with a Letter of Permission (LOP) process. The LOP process was sponsored by the U.S. Army Corps of Engineers (COE) in cooperation with local governments to provide for early consideration of 404 permit issues. After coordinating the LOP process for the first 20 months of the study, the COE indicated in early 1993 that limitations in their staff resources precluded the continuation of the LOP process for these studies and other DBPSs in progress for the City.

The public involvement program for the three studies consists of the following elements:

- Holding an initial public meeting
- Developing a project mailing list
- Making periodic mailings of project newsletters and meeting notices
- Holding regular meetings of a project study group
- Holding a public meeting to obtain input on alternative concepts and the recommended plan

More than 30 individuals representing at least two dozen public interest groups, agencies, departments, project consultants, and resource groups participated in the study group. The group provided valuable reviews of interim study results and offered input and recommendations regarding alternative improvement plans.

Individuals who participated in the project study group meetings are listed in Appendix A. A copy of the comprehensive project mailing list and copies of project newsletters are also provided in Appendix A.

2.0 STUDY AREA DESCRIPTION

2.0 Study Area Description

2.1 Topography and Physiography

2.1.1 Project Area

Monument Creek is located along the eastern slope of the Rocky Mountains in El Paso County, Colorado. The Monument Creek basin drains approximately 250 square miles of area upstream of the confluence with Fountain Creek. The study reach for the Monument Creek DBPS project is located in the City of Colorado Springs, Colorado (the City), extending from the south boundary of the U.S. Air Force Academy (USAFA) to the confluence with Fountain Creek. Figure 2-1 shows the Monument Creek basin and study reach in relationship to Fountain Creek.

2.1.2 Principal Landforms

Principal landforms in the Monument Creek basin include the Front Range of the Rocky Mountains (Dawson Formation), Hogback Ridge, and the Colorado Piedmont. The Front Range is located in the western part of the basin and is composed predominantly of granite. Hogback Ridge, situated immediately east of the Front range, is formed by a band of steeply tilted sedimentary rocks. The Colorado Piedmont is located immediately east of Hogback Ridge and is characterized by the following:

1. Upland areas consisting of bench and valley topography in the vicinity of the USAFA and low, rolling land east of the creek.

2. Lowland areas consisting of floodplains, terraces, and lowlands covered by alluvial and wind deposits along the downstream reach of Monument Creek.

The watershed drops dramatically from the western ridgeline of the Front Range (elevation 9200 to 9700 feet above mean sea level [MSL]) to the study reach of Monument Creek (elevation 5940 to 6300 feet MSL). The eastern ridgeline of the watershed (elevation 6600 to 7600 feet MSL) provides a somewhat lower, but still relatively steep, drainage gradient toward Monument Creek.

2.1.3 Land Change Activities

Agriculture was the predominant land use in the basin during the late 1800s and early 1900s. In the 1950s, urban development began to replace agricultural land use in the vicinity of Colorado Springs and has been steadily expanding outward from the historic center of the City. Urbanization has increased the peak rate and volume of storm water runoff in the southern portion of the watershed, contributing to channel erosion in the

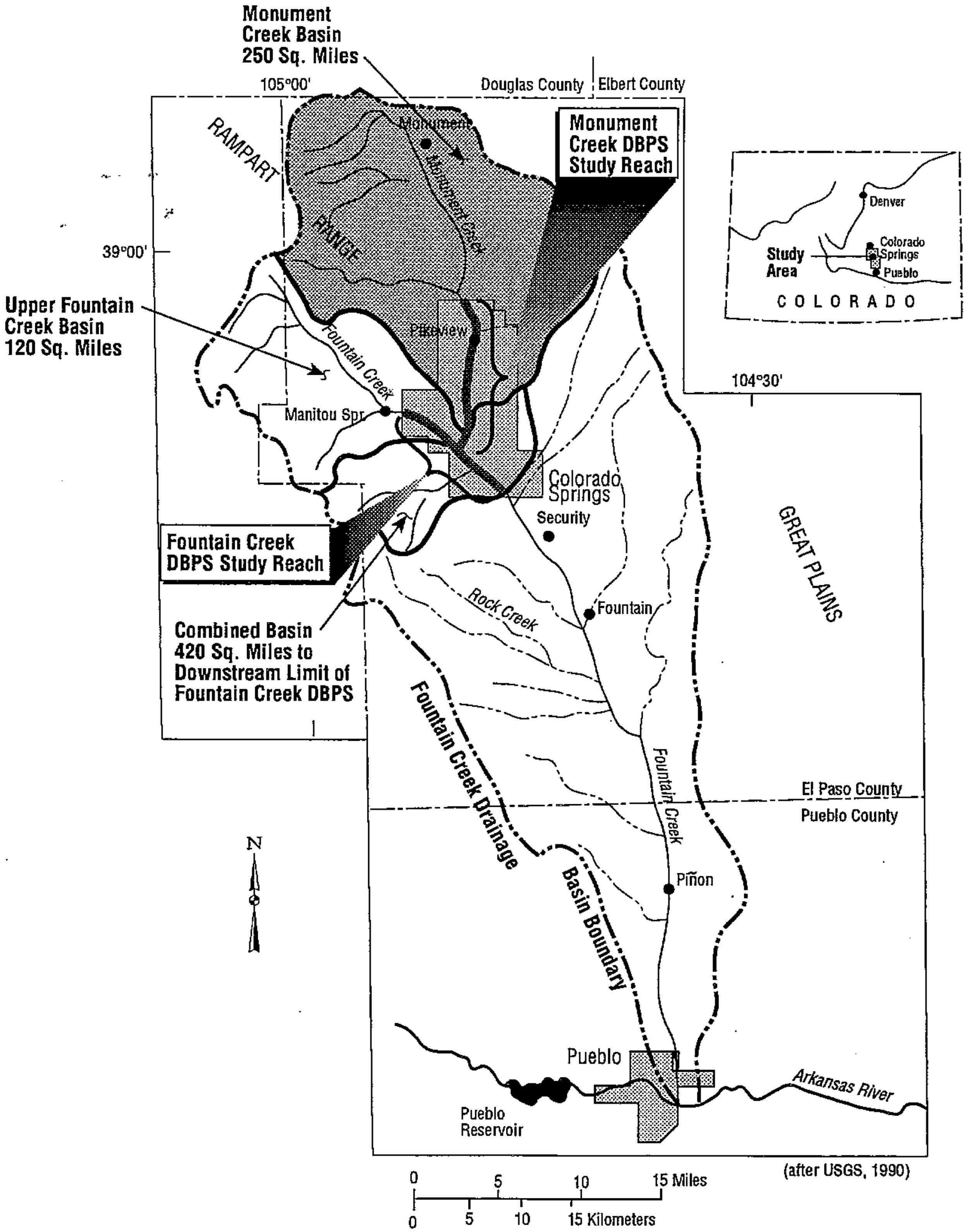


Figure 2-1
STUDY AREA

drainageways leading into Monument Creek. Tributary channel erosion has contributed a high sediment load to the study reach of Monument Creek.

2.2 Geology

2.2.1 Alluvial Deposits

Alluvial sediments in the basin are characterized as colluvial or landslide, fluvial terrace/channel, and windblown deposits (Hillier and Hutchinson, 1980). Figure 2-2 shows a generalized west-to-east cross-section illustrating the occurrence of these deposits. Colluvial deposits consist of loose, poorly sorted deposits with limited weathering. Fluvial deposits consist primarily of well sorted sands and gravels overlain by finer grained overbank deposits of silt with some clay. Windblown deposits consist of loess and dunes of fine to coarse sand.

2.2.2 Bedrock Formations

Within the vicinity of the study area, Precambrian granites are found to the west along the mountain front, sedimentary units of the Denver Basin are encountered to the north and east, and erodible shale units are found to the south. Specific formations occurring immediately beneath Monument Creek, between the USAFA and the confluence of Monument Creek with Fountain Creek, include (Hillier and Hutchinson, 1980):

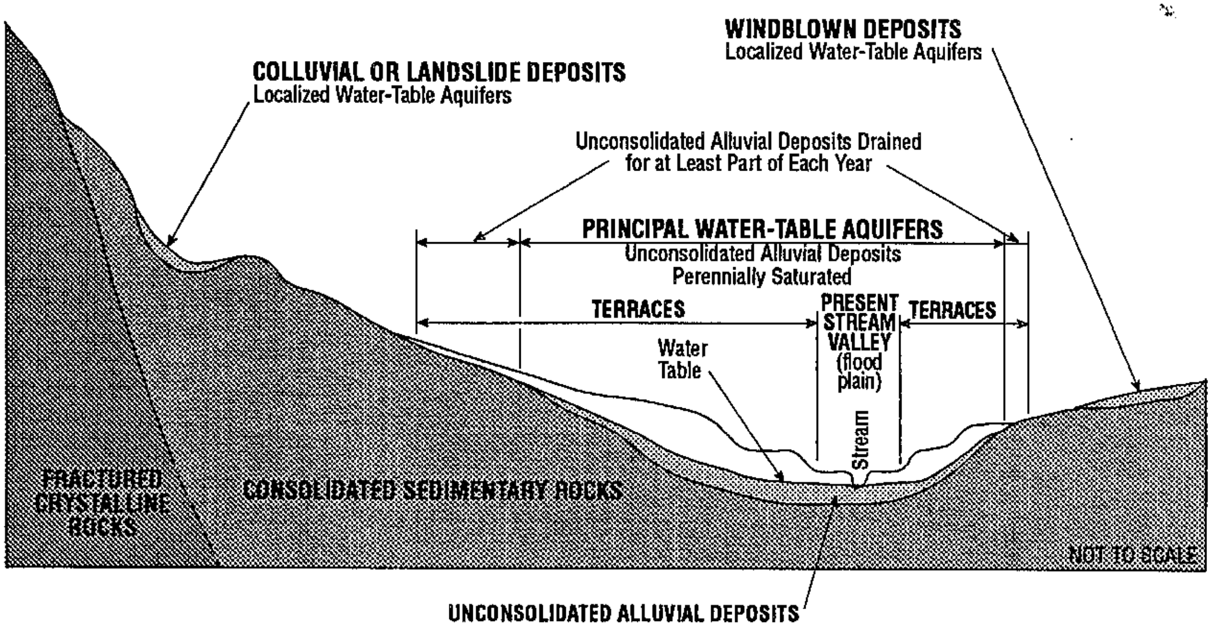
- Denver Sandstone
- Arapahoe Sandstone
- Laramie Fox Hills Sandstone
- Pierre Shale

In general, units overlying the Precambrian basement dip easterly at a high angle along the Front Range and more gently eastward and northward further to the east beneath the plains. In general, the bedrock underlying the alluvial deposits encourages groundwater movement toward and along Monument Creek and other surface drainages. In a number of locations along the Monument Creek study reach, bedrock formations have been exposed on the stream bottom providing some localized resistance to downcutting of the channel. Bedrock outcroppings in the stream bottom are shown on the geomorphology information drawings (sheets 3 through 6) in Volume II.

2.3 Soils

2.3.1 Hydrologic Soil Groups

To characterize the relative runoff potential of soils, four general soil classifications have been developed by the U.S. Soil Conservation Service (SCS, 1981). These four



(after Hillier and Hutchinson, 1980)

Figure 2-2
GENERALIZED GEOLOGIC CROSS SECTION

hydrologic soil groups, defined below, are based on infiltration and transmissibility capacities.

Group A. (Low runoff potential.) These soils consist of deep, well-drained to excessively well-drained sands and gravels. The infiltration and transmissibility capacities of these soils are high.

Group B. (Moderately low runoff potential.) These soils consist of moderately deep to deep soils with moderately fine to moderately coarse material. The infiltration and transmissibility capacities are moderate.

Group C. (Moderately low runoff potential.) These soils consist of moderately fine to fine material and have slow infiltration and transmissibility capacities.

Group D. (High runoff potential.) These soils consist primarily of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay layer at or near the surface, and shallow soils over nearly impervious material. The infiltration and transmissibility capacities in these soils are very low.

Table 2-1 indicates the approximate distribution of hydrologic soils groups in the Monument Creek watershed. This distribution was measured from watershed mapping based on information shown in the El Paso County Soil Survey (SCS, 1981).

Table 2-1
Distribution of Hydrologic Soils Groups

Group	Percentage of Basin Area
A	11
B	52
C	3
D	34

A map of the hydrologic soils groups is shown in Figure 2-3 of the Baseline Hydrology Report (Kiowa, 1992a), contained in Volume III.

In general, the soils in the Monument Creek watershed have a moderate runoff potential. This information was subsequently factored into the hydrologic modeling of the watershed to estimate peak rates and volumes of runoff generated by a series of design rainfall events.

Specific soil types along the Monument Creek study reach corridor are shown in the geomorphology drawings (sheets 3 through 6) in Volume II.

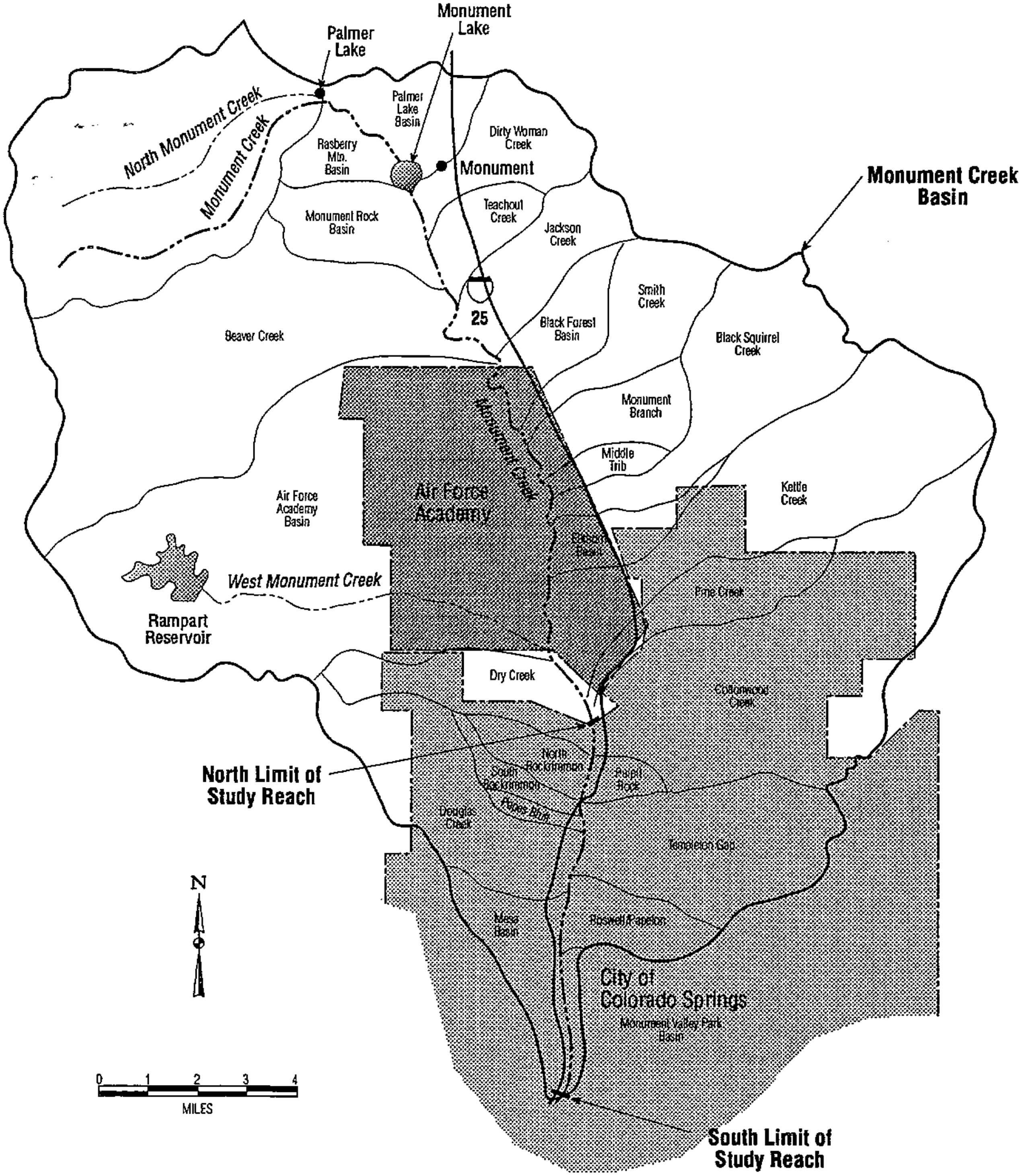


Figure 2-3
MAJOR DRAINAGE
BASINS

2.3.2 Soil Erodibility

Several factors that indicate the susceptibility of soil erosion by wind and water were characterized by the U.S. Soil Conservation Service in the 1981 Soil Survey of El Paso County (SCS, 1981). These factors are as follows:

- **Erosion factor K** indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is based on the percentage of silt, sand, and organic matter; the soil structure; and the permeability. Possible values of K range from 0.10 to 0.64, with the higher values indicating greater susceptibility to erosion.

- **Erosion factor T** represents the maximum average annual rate of soil erosion by wind or water (tons/acre/year) that can occur without affecting crop productivity over a sustained period.

- **Wind erodibility groups** define soils in cultivated areas with similar resistance to wind erosion. The wind erodibility groups indicate the susceptibility of soil to wind erosion and the amount of soil lost. Soils are grouped according to the following distinctions:

  1. Sands, coarse sands, fine sands, and very fine sands. These soils are generally not suitable for crops. They are extremely erodible, and vegetation is difficult to establish.

  2. Loamy sands, loamy fine sands, and loamy very fine sands. These soils are very highly erodible. Crops can be grown if intensive measures to control wind erosion are used.

  3. Sandy loams, coarse sandy loams, fine sandy loams, and very fine sandy loams. These soils are highly erodible. Crops can be grown if intensive measures to control wind erosion are used.

  4. Calcareous loamy soils that are less than 35 percent clay and more than 5 percent finely divided calcium carbonate. These soils are erodible. Crops can be grown if intensive measures to control wind erosion are used.

  5. Clays, silty clays, clay loams, and silty clay loams that are more than 35 percent clay. These soils are moderately erodible. Crops can be grown if measures to control wind erosion are used.

  6. Loamy soils that are less than 18 percent clay and less than 5 percent finely divided calcium carbonate, and sandy clay loams

and sandy clays that are less than 5 percent finely divided calcium carbonate. These soils are slightly erodible. Crops can be grown if measures to control wind erosion are used.

7. Loamy soils that are 18 to 35 percent clay and less than 5 percent finely divided calcium carbonate. These soils are very slightly erodible. Crops can easily be grown.

8. Silty clay loams that are less than 35 percent clay and less than 5 percent finely divided calcium carbonate. These soils are very slightly erodible. Crops can easily be grown.

9. Stony or gravelly soils and other soils not subject to wind erosion.

The majority of the soils in the Monument Creek drainage basin have an erosion factor K ranging from 0.10 to 0.15, an erosion factor T of 5, and consist of wind erodibility groups 2, 3, and 8. These values indicate that the soil is somewhat susceptible to sheet and rill erosion by water and highly susceptible to wind erosion.

The erodibility of watershed soils plays an important role in the quantity of sediment flowing into the Monument Creek study reach, which in turn, impacts the physical and biological characteristics of the creek. The response of Monument Creek to the inflowing sediment load is discussed in Section 5.

2.4 Surface Water Resources

2.4.1 Major Drainage Basins

For the purpose of organizing watershed studies and establishing drainage fees, the City and El Paso County staff have identified major drainage basins tributary to Monument and Fountain Creeks. A total of 28 major drainage basins have been identified within the Monument Creek watershed, as shown in Figure 2-3.

Many of the major drainage basins tributary to Monument Creek have been the subject of detailed drainage basin planning studies and are subject to drainage fees.

The drainage fees represent the equitable share of the cost of drainage improvements to be constructed in major drainage basins and is expressed in dollars per acre of unplatted land in the basins. The drainage fee is the total drainage improvement cost divided by the unplatted acreage.

The drainage fee is a one-time charge to the developer and is collected at the time of the final plat recording. However, the developer may be required to construct drainage improvements in lieu of paying drainage fees. If the improvement costs are higher than the fees for a development, the developer is eligible to be reimbursed by the basin fund for those costs in excess of the appropriate drainage fees.

Drainage fees assessed for major drainage basins do not normally include the cost of stream improvements which may be required on the mainstream reaches of Monument and Fountain Creeks. Therefore, costs for stream improvements recommended in this report must be covered by other sources. Estimated costs of alternative improvement plans for the Monument Creek study reach are shown in Section 7.

2.4.2 Stream Characteristics

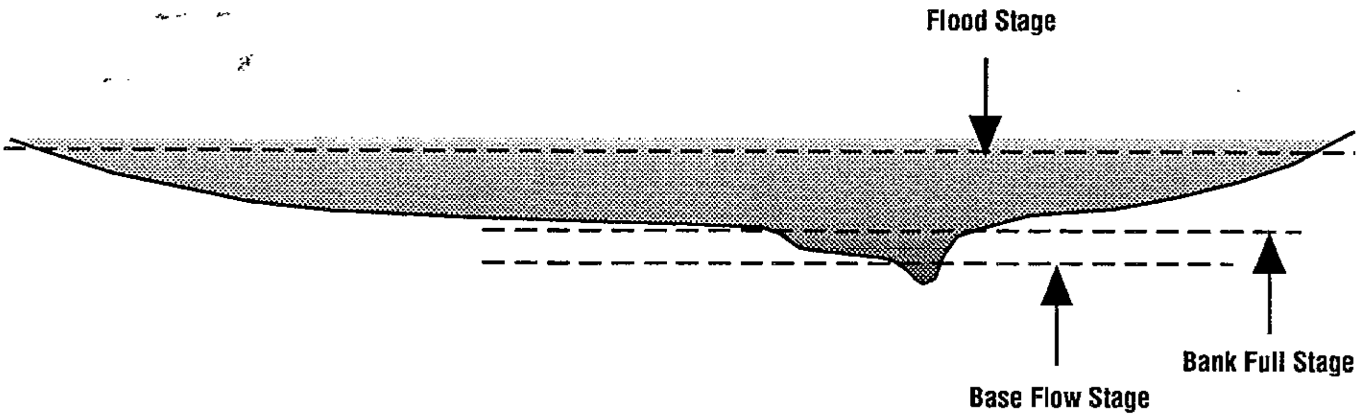
Monument Creek is a perennial stream that originates in the Front Range of the Rocky Mountains and flows eastward towards the City of Palmer Lake and the Colorado Piedmont areas. At Palmer Lake, the creek alignment shifts southward and flows parallel with the Front Range until it joins Fountain Creek on the southwest side of downtown Colorado Springs.

The physical character of Monument Creek within the study reach has been altered from its natural, predevelopment configuration. These alterations are of a lesser magnitude for the portion of the study reach upstream of Woodmen Road than for the reach downstream of Woodmen Road.

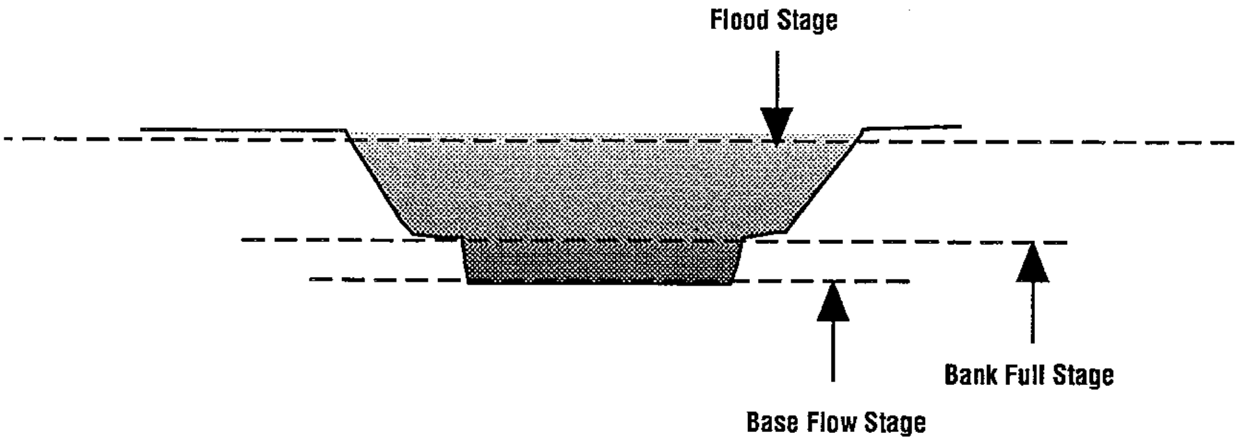
The physical geometry of the upstream reach resembles the natural stream cross section illustrated in Figure 2-4. The creek cross section in the upstream reach features a relatively deep and narrow meandering base flow channel and a wide, vegetated floodplain channel. This natural channel cross section enhances the stream's ability to provide a range of important functions such as support of biological habitat, maintenance of water quality, transport of sediment, and stable conveyance of flood waters.

The upstream reach features a meandering pool and riffle base flow channel with bed and bank material consisting of course sand, gravel, and cobbles. The base flow depth in this reach is 1/2 to 2 feet and the unvegetated channel width varies between 20 and 35 feet. Sediment transport in the upstream reach appears to be low during base flow conditions. Some streambank and streambed erosion is evident along the upstream study reach. The physical geometry of the majority of the Monument Creek study reach downstream of Woodmen Road resembles the disturbed stream cross section shown in Figure 2-4. Much of the historic floodplain channel has been filled to increase developable land area adjacent to the creek. The baseflow channel has taken on a wide, shallow, braided form in response to a large sediment inflow from Cottonwood Creek and other tributaries.

The unvegetated channel width in the reach downstream of Woodmen Road ranges from 30 to 200 feet. The base flow depth is generally only a few inches. Sediment transport during base flows appears high, with a significant sediment contribution evident from Cottonwood Creek and other tributaries to Monument Creek. Sediment transport in the



NATURAL STREAM CROSS SECTION



DISTURBED STREAM CROSS SECTION

Figure 2-4
NATURAL AND DISTURBED STREAM CROSS SECTIONS

downstream reach during base flows consists primarily of bed load (sand and fine gravel particles rolling and bouncing downstream along the streambed). Significant streambank and streambed instability is evident along most of the study reach downstream of Woodmen Road.

The channel downstream of Woodmen Road is characterized by shallow flow depth, fine, mobile bed sediments and lack of riparian vegetation. These factors can reduce biological diversity and water quality during base flow periods by elevating temperature, lowering dissolved oxygen, and physically impairing habitat. The narrow floodplain channel and lessened hydraulic roughness due to reduced riparian vegetation and increased flow depth can create high velocities and severe channel erosion during flood flow periods.

The formulation and evaluation of alternative improvement plans to address impairments to stream functions are documented in Sections 6 and 7. Because the level of disturbance to the physical character of Monument Creek is greater downstream of Woodmen Road than upstream, more work would be required in the downstream reach to restore impaired stream functions.

2.4.3 Reservoirs

Table 2-2 identifies the location of water supply reservoirs within the Monument Creek watershed and provides water rights appropriation information. Among the reservoirs listed in Table 2-2, only the largest, Rampart Reservoir, was assumed to provide flood attenuation benefits during hydrologic modeling. This is discussed in Section 3 of Volume I. One of the reservoirs, Monument Lake, is located on the main stem of Monument Creek and is discussed in the following subsection.

Table 2-2
Summary of Monument Creek Reservoirs

Name	Location	Storage Volume (acre-feet)	Appropriation Date	Priority No.
Glen Park Reservoir	North Monument Creek	147.5	November 25, 1904	111A
Lower Reservoir	North Monument Creek	N/S	N/S	N/S
Monument Lake	Monument Creek	310[a]	N/S	N/S
Rampart Reservoir	West Monument Creek	891	June 19, 1913	133A
Nichols Reservoir	West Monument Creek	350	November 19, 1908	48
Northfield Reservoir	West Monument Creek	276	October 16, 1989	21
Stanley Canyon Reservoir	West Monument Creek	117	June 22, 1900	34
Pikeview Reservoir	Off-channel	151.7	March 5, 1894	26
Pikeview No. 2	Off-channel	52.8	February 27, 1894	25

[a]Storage capacity at the crest of the spillway according to State Engineer's office records.

Note: N/S = not shown in reference.

Reference: GEC, 1986.

2.4.3.1 *Monument Lake*

Monument Lake is located on the main stem of Monument Creek immediately west of the town of Monument, Colorado, the owner of the reservoir. The reservoir is used for irrigation, recreation, and municipal purposes. At the spillway crest elevation, the reservoir has a capacity of 310 acre-feet and a surface area of 55 acres. The height of the dam embankment from the spillway crest to the lowest natural ground elevation beneath the embankment centerline is 39 feet. The freeboard, or the distance from the spillway crest to the top of the embankment, is 15 feet. The Monument Reservoir spillway is a 130-foot wide, ogee-type concrete spillway and is designed for a discharge of 11,400 cfs. The dam is listed in Colorado State Engineer's Office (SEO) records as a Class 2 facility. A Class 2 dam is a dam for which significant damage is expected to occur, but no loss of human life is expected in the event of dam failure.

Monument Reservoir is inspected by SEO staff on an annual basis. SEO staff have indicated that, although the dam embankment is basically in good condition, the downstream spillway channel is experiencing significant erosion and a gabion channel wall is failing. Because of the condition of the downstream spillway channel, the water level of the reservoir has been restricted to 3 feet below the spillway crest to minimize spillway overflows. Even with the restriction, the reservoir spills generally every year and continues to erode the banks of the downstream spillway channel.

2.4.4 Diversions

Existing diversions from Monument Creek and its major tributaries are shown in Table 2-3 (GEC, 1986). Table 2-3 identifies diversion locations and appropriation information for the discussions. An important diversion structure is the Pikeview Intake Dam located upstream of Garden of the Gods Road. This diversion directs water to Pikeview Reservoir, which is located south of Garden of the Gods Road and west of Monument Creek. Pikeview Reservoir water is used for nonpotable irrigation on Kissing-Camels Golf Course.

2.4.5 Water Rights

Several senior water rights exist along Monument Creek from North Monument Creek to its confluence with Fountain Creek. Adjudication dates from the most senior water rights date back to 1867. Instream and nonbeneficial use rights are also decreed along this reach of Monument Creek. Other inchoate water rights may also exist in this stream section.

In addition to the surface water diversions shown in Table 2-3, a number of tributary and nontributary groundwater wells are located adjacent to Monument Creek. The City owns wells along Monument Creek. Several private wells are located adjacent to Monument Creek and are tributary to the stream system. Most of the tributary wells are completed

Table 2-3
Summary of Monument Creek Diversions

Name	Location	Amount Appropriated (cfs)	Appropriation Date	Priorit y No.
Palmer Lake Water System	North Monument Creek	0.89 2.19	March 1, 1967 February 1, 1987	1 65A
Monument Ditch	Monument Creek	0.89 2.29 1.37	March 1, 1967 June 28, 1968 December 31, 1975	1 3 12
C. H. Nevims Ditch	Monument Creek	2.29 1.37	June 28, 1968 December 31, 1975	3 12
Anchor Ditch	Monument Creek	0.36	March 1, 1967	1
Star Ditch	Monument Creek	3.64	June 18, 1969	7
Monument Ditch No. 2	Monument Creek	4.80	June 1, 1970	2
Leird and Guire	Monument Creek	4.12	June 1, 1968	6
Arapahoe Ditch	Monument Creek	11.14	June 1, 1968	5
Monitor Ditch	Monument Creek	11.14	June 1, 1968	4
Austin Bluffs Pipeline (Northfield Intake Nos. 1, 2, and 3)	West Monument Creek	0.353 1.000 6.360 4.200 2.493 7.950 2.010 1.660 13.700 5.200	March 20, 1961 December 31, 1961 March 21, 1969 May 1, 1972 December 31, 1972 September 21, 1973 December 13, 1976 December 31, 1976 January 3, 1982 October 16, 1989	2 6 1 2 33 3 4 5 122 77A
Monument Creek Pipeline (Pikeview Intake)	Monument Creek	4.00 1.00 16.43 8.63	April 1, 1962 June 1, 1967 June 1, 1971 March 3, 1994	7 1 9 158

Reference: GEC, 1986.

in the alluvial, unconsolidated deposits along Monument Creek. Some tributary and nontributary wells are drilled into the Denver Basin aquifers that outcrop along the alluvial stream system. Additional well permit filings and augmentation plans with alternate points of diversion may exist in this section of Monument Creek. The tributary wells will affect base flows in Monument Creek, but for the purposes of this study their affect has been assumed to be negligible.

2.4.6 Flood History

The City has endured a long history of flooding along Monument Creek. Early reports are mainly eyewitness accounts documented in newspaper articles. Known flood events are summarized in Table 2-4 (Kiowa, 1992).

Stream flow gauge data were nonexistent before the installation of gages in 1938. Gage data records exist for Monument Creek at Pikeview from 1939 to 1949 and from 1976 to the present. However, no significant flood event occurred during this period of record. Therefore, records of eyewitness accounts provide the only information available to document historic floods.

The known flood of record is documented in the Department of Water Resources *28th Biennial Report of the State Engineer to the Governor of Colorado.* The City Engineer of Colorado Springs made a slope-area determination of the peak discharge of the May 30, 1935, flood and the following report:

> *"Colorado Springs Flood—the flood at Colorado Springs on the Monument Creek, a tributary of the Fountain River, originated 2 miles northwest of Colorado Springs about 10:30 a.m., May 30, 1935, and lasted from 2 to 2-1/2 hours. The creek reached flood stage about 12:30 p.m., crest elevation about 2 p.m., and had receded somewhat by 3:30 p.m. The peak discharge, as determined by F. O. Ray, city engineer of Colorado springs, was 50,000 sec-feet (cubic-feet-per-second). This flood on Monument Creek is the greatest of which there is any record, and created damages to property in Colorado Springs estimated at $750,000 and the loss of three lives."*

2.4.7 Water Quality

2.4.7.1 Stream Classification and Standards

According to the Colorado Water Quality Control Commission's *Classification and Numeric Standards for Arkansas River Basin*, the following stream segments and their classifications and standards correspond to the three identified receiving streams illustrated in Figure 2-5:

Table 2-4
Summary of Known Flood Events
Monument Creek

Storm Date	Precipitation Amount (inches)	Discharge at Fountain Creek Confluence (cfs)	Discharge at Templeton Gap (cfs)	Type of Storm	Destruction	Loss of Life	Depth (feet)	Remarks
June 10, 1984		40,000 (est.)		5 hours long radius of 3 to 4 miles	Crops totally destroyed	13	20 to 30	Rain came down not in drops but in floods
May 21 to 22, 1876	2.62							Chiefly snow—no serious flood
May 20, 1878				Cloudburst near Palmer Lake				
July 25, 1885			6,120	Severe cloudburst over northern part of City				Sharp flood on Monument Creek—highest known up to that time
August 2, 1886		40,000		Intense rainfall in Monument Creek and T-Gap Drainage Area				
May 26 to 28, 1902	3.02 total			Cloudburst				
June 3 to 4, 1921		10,000			No bridge loss			Stream within banks
July 29 to 30, 1932	3.54 total		9,700	Cloudburst				Cloudburst in Black Forest Flooded Papeton
May 30, 1935	4 to 18	50,000		Heavy rains from multiple storm cells of short duration after a period of general precipitation	$750,000 all bridges except one and dozens of homes	3		Caused by intense rainfall in headwaters
June 17, 1965	2 to 14			Major cell over Palmer lake	Monument Dam nearly breached			

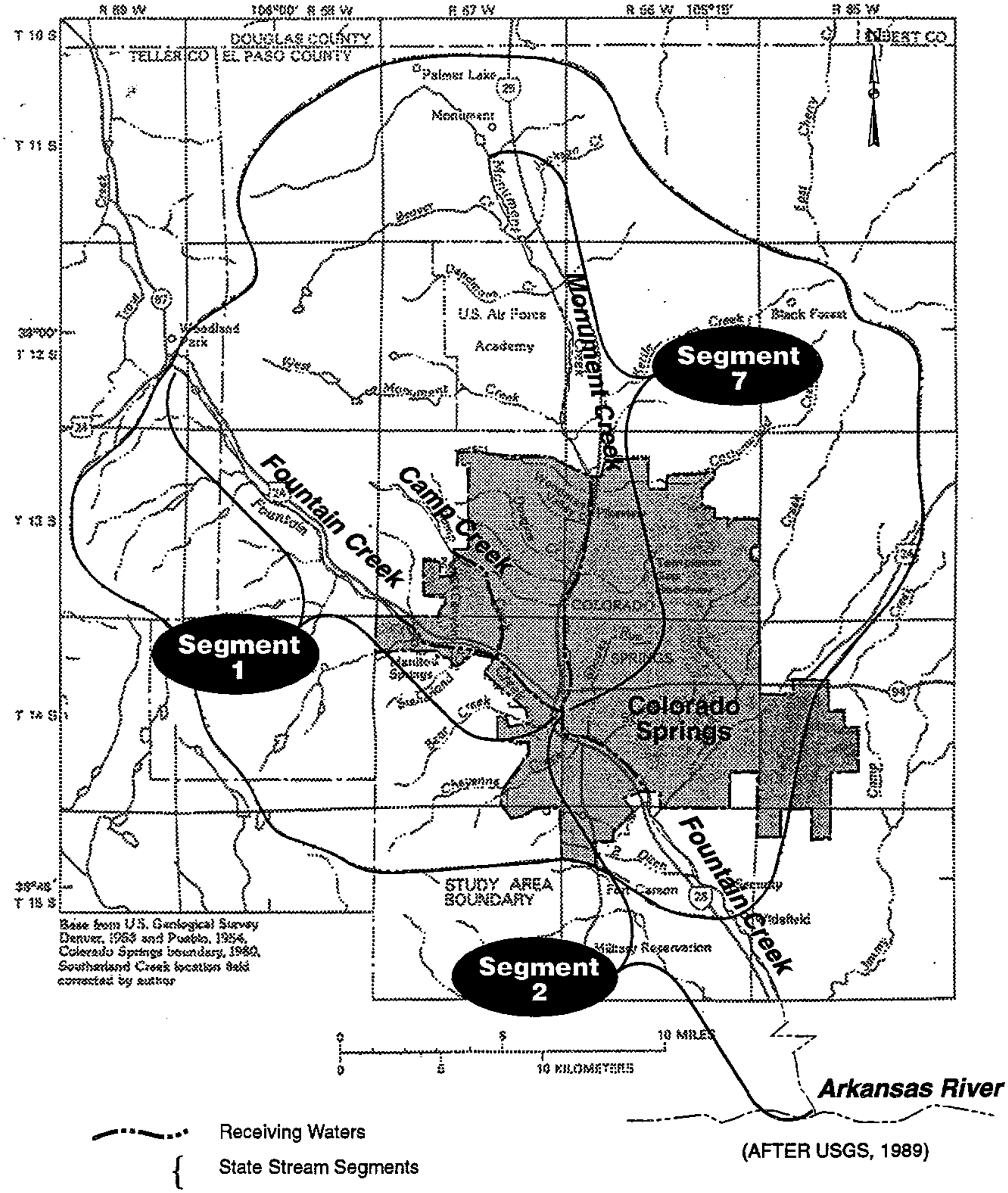


Figure 2-5
STATE STREAM SEGMENTS

- **Stream Segment 1**—Mainstream of Fountain Creek, including all tributaries, lakes, and reservoirs, from the source to a point immediately above the confluence with Monument Creek.

  Designation: None (Insufficient data to properly designate)

  Classifications:
  Aquatic Life Class 1 (Cold)
  Recreation Class 2 (Secondary Contact)
  Water Supply
  Agriculture

  Numeric Standards:
  Physical and Biological (D.O., pH, and Fecal Coliform)
  Inorganic (NH_3, Cl_2, CN, S, B, NO_2, NO_3, Cl, and SO_4)
  Metals (As, Cd, Cr III, Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, and Zn)

- **Stream Segment 2**—Mainstream of Fountain Creek from a point immediately above the confluence with Monument Creek to the confluence with the Arkansas River.

  Designation: Use-Protected (Special protection not warranted)

  Classifications:
  Aquatic Life Class 2 (Warm)
  Recreation Class 2 (Secondary Contact)
  Water Supply
  Agriculture

  Numeric Standards:
  Physical and Biological (D.O., pH, and Fecal Coliforms)
  Inorganic (NH_3, Cl_2, CN, S, B, NO_2, NO_3, Cl, and SO_4)
  Metals (As, Cd, Cr III, Cr IV, Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, and Zn)

- **Stream Segment 7**—Mainstream of Monument Creek from the outlet of Monument Lake to the confluence with Fountain Creek.

  Designation: Use-Protected (Special protection not warranted)

Classification:	Aquatic Life Class 2 (Warm) Recreation Class 2 (Secondary Contact) Water Supply Agriculture
Numeric Standards:	Physical and Biological (D.O., pH, and Fecal Coliforms) Inorganic (NH_3, Cl_2, CN, S, B, NO_2, NO_3, Cl, and SO_4) Metals (As, Cd, Cr III, Cr IV, Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, and Zn)

In addition, these three segments, as well as all surface waters of the state, are subject to the following basic standards:

- Narrative "Free From"
- Radioactive materials
- Organic pollutants
- Site-specific radioactive materials and organic pollutants
- CERCLA provision

2.4.7.2 Overall Stream Status Relative to State Standards

The water quality of the Monument Creek segment is somewhat impaired relative to state standards. The designated uses for Segment 7 are impaired due to nitrates and unionized ammonia. Sedimentation and frequent elevated metals concentrations are also found. Problems arise because of the steep slope and erosive character of the soils in the basin and the impacts from urban runoff.

2.4.7.3 Physical, Chemical, and Biological Water Quality

The physical, chemical, and biological water quality of Monument Creek has been assessed in recent reports. The physical and biological water quality of Monument Creek was assessed in a study conducted by the USGS during the years 1985 to 1988 (USGS, 1989). The purpose of the study was to determine the effects of sediment transport on benthic-invertebrate. Benthic-invertebrate, or larval stage insects, are a main source of food for fish in natural streams. The benthic insects feed by attaching the end of their body to the substrata and extending their filter apparatus into the flow to collect detritus, algae, and zooplankton. Sediment and benthic-invertebrate data were collected along Monument Creek at Pikeview, Colorado, and at the USAFA. The USGS determined that the population of benthic-invertebrate was greatest at sites where there was little or no change in stream bed elevation, large-diameter stream bed material, low sediment transport, and few periods of flooding. It was concluded from the USGS study that the population of benthic-invertebrates was greater at the USAFA site than at the Pikeview site because of larger bed material and less frequent flooding periods.

The chemical quality of surface water in Monument Creek was summarized in another study conducted by the USGS called the *Appraisal of Water Resources of Southwestern El Paso County, Colorado* (USGS, 1976). In the study, the chemical water quality of Monument Creek was monitored below Monument Reservoir and at the confluence with Fountain Creek. The specific conductance and concentration levels of calcium, magnesium, sodium, bicarbonate, sulfate, and chloride were documented for both sites. It was concluded that the water quality deteriorated at the mouth of Monument Creek compared to the upstream Monument Reservoir site.

This study, although containing recommendations for stream improvements that may enhance instream water quality, does not provide detailed investigations pertaining to storm water quality.

2.5 Groundwater

2.5.1 Alluvial Groundwater

Within the Colorado Springs area, the principal alluvial aquifers occur in stream valleys and terraces located along major drainages. Minor, localized aquifers occur within the windblown and colluvial deposits. Groundwater within the alluvial aquifers generally flows towards and follows surface water drainages.

In the immediate vicinity of Monument Creek, the alluvial aquifer: (1) supports baseflow during dry periods of the year, (2) attenuates peak streamflows as bank storage, and (3) provides recharge to the underlying bedrock formations in upland locations.

2.5.2 Bedrock Groundwater

Groundwater occurs within the Precambrian granite, Laramie Fox Hills, Arapahoe, Denver, and Dawson Formations. With minor exception, little to no groundwater occurs in the Pierre Shale Formation. Relative to Monument Creek, bedrock groundwater is important because it discharges to the alluvial aquifer, sustaining baseflow to Monument Creek during dry periods.

2.5.3 Groundwater Quality

The water quality of the alluvial and bedrock aquifers in the vicinity of Monument Creek, which are used for domestic water supply, is generally favorable. An exception to this occurs in the Pierre Shale where water quality is affected because of the solubility of many of the minerals present in the formation. Since the Pierre Shale is present downstream of the study area, it has little or no impact on water quality in Monument Creek within the study area.

2.6 Climate

2.6.1 Average Conditions

The Monument Creek basin is composed of three climatic zones that are distinguished by elevation and vegetation type: (1) a semiarid zone (elevations less than 6500 feet), (2) a foothills and lower montane zone (elevations range from 6500 to 7500 feet), and (3) an upper montane zone (elevations range from 7500 to 9000 feet). The Front Range in the western part of the basin is characterized as a foothills/lower montane zone and a upper montane zone. Vegetation in the Front Range includes pinon pine, juniper pine, ponderosa pine, white fir, and douglas fir. The average annual precipitation in the Front Range is approximately 18 inches. The eastern section of the basin is characterized as a semiarid climatic zone. Vegetation in this zone consists primarily of grasslands, and annual precipitation averages 16.7 inches. Average temperatures in the entire basin range from 30°F in the winter to 75°F in the summer. Relative humidity ranges from 45 percent in the winter to 25 percent in the summer.

2.6.2 Rainfall Patterns

The majority of precipitation in the basin occurs during May through September from convective thunderstorms. These storms generally develop from moisture in the Gulf of Mexico and usually produce short-duration intense rainfalls. The USGS reports that the average occurrence of thunderstorms in the Monument Creek basin is 70 days per year (USGS, 1970). Rain gages maintained in the Monument Creek watershed by the City and El Paso County indicate that the distribution of runoff-producing rainfall has been somewhat uniform over the basin, including the higher western elevations.

2.7 Vegetation

2.7.1 Structure and Composition

The Monument Creek corridor is dominated by a riparian woodland occurring along floodplain areas. Shrub and herbaceous woodlands are included in the riparian system on sandbars, and in the active channel.

The riparian woodlands vary in age, but are generally relatively young. The older stands occur along the creek where a flood of unknown date caused downcutting of the channel to produce the high vegetated banks that are infrequently flooded. Younger stands occur along reaches of Monument Creek where high banks have not formed and along the majority of Fountain Creek. The Fountain Creek floodplain is broad and relatively flat. High water exceeding the capacity of the shallow active channel occurs generally on an annual basis. The younger woodland stands apparently date back to the 1963 flood.

Shrub wetlands are the most common wetland type found in the study area. Shrub wetlands occur on elevated alternate bars and in patches in low-lying woodlands. Sandbar willow, crack willow, peach-leaf willow, and basket willow are the common shrub species. The herbaceous understory of the shrub wetlands is typically undeveloped because of the coarse and well-drained nature of the sand substrate. Herbaceous wetland species including grasses and sedges develop an understory on slightly elevated bars where fine soil materials have been deposited.

Herbaceous wetlands are otherwise minor in extent and distribution and typically occur along the bank in the area of the ordinary high water line. Common species include reed canarygrass, meadow foxtail, carpet bentgrass, smooth brome, and tall fescue. The true emergent species, such as cattail, three square, Baltic rush, spike sedge, hairy sedge, Nebraska sedge, and bulrushes are less frequent except in low lying areas.

Some wetlands zones along Monument Creek are documented in maps prepared by U.S. Fish and Wildlife Service. As part of the current study, vegetation along the creek corridor was inventoried and mapped according to the following categories:

- Nonriparian vegetation
  - Mature woodland
  - Immature woodland
  - Shrubland
  - Grassland
- Riparian vegetation
  - Mature woodland
  - Immature woodland
  - Shrubland
  - Grassland
  - Herbaceous wetland
  - Emergent wetland

The mapped categories are shown on the wildlife and vegetation information drawings (sheets 7 through 10) in Volume II.

2.7.2 Vegetation Dynamics

Cottonwood regeneration in the active channel is chiefly supported by relatively major floods; some incidental regeneration apparently occurs as the result of minor floods. This occurs along the flat and broad floodplain areas of Monument Creek. Riparian woodland presence is typically not associated with sections of the stream that have been channelized (confined between relatively narrow, high banks) since this activity prevents or diminishes overbank flooding. The majority of cottonwood regeneration is found on low alternative bars or in places along the floodplain where the channels carry water to the edges of the floodplain during high water. Cottonwood regeneration on the high banks of the historic floodplain is infrequent to absent. Mature cottonwood trees in all locations are supported by a combination of high groundwater levels and precipitation.

Shrub wetlands dominated by sandbar willow occur as a result of high groundwater levels. Regeneration is limited, however, to spring floods of significant depth and duration. Shrub wetlands typically occupy coarse sand and gravel substrates. The lack of fine material in most sites limits the development of herbaceous hydrophytic vegetation in the understory of the shrub wetlands.

The diversity and areal extent of the riparian system along Monument Creek has been significantly influenced by adjacent landuse. Increased base flows from urbanized areas have accelerated bed and bank erosion leading to some loss of riparian vegetation. Stream channelization measures have also diminished riparian vegetation.

2.8 Terrestrial Wildlife

2.8.1 Mammals

The Colorado Division of Wildlife has generated mapping for the entire El Paso County by using indicator species. The species mapping was based upon the following criteria: (1) indicator species for unique habitat, (2) threatened or endangered species, or (3) big game species of economic importance. Within the mammal category, the mule deer has the largest range which extends the entire length of the corridor. The mule deer is both an indicator species for habitat and economic value. The majority of the mammals within the corridor are smaller (for example, raccoons, squirrels, foxes, skunks, and porcupines). The larger riparian vegetation areas provide greater diversity of habitat coverage, food sources, and species diversification. The Colorado Division of Wildlife generated a terrestrial species list, which is included in Appendix D. Additional information is shown in Sheets 7 through 10 of Volume II.

2.8.2 Birds

Perhaps the most significant use of the corridor by wildlife is that of the resident and migratory bird populations. There are no known nesting sites within the corridor boundary for threatened or endangered species, yet the corridor is used as hunting grounds by the prairie falcon and golden eagle. There is a prairie falcon nesting site in North Cheyenne Canon and several golden eagle nesting sites within the City limits. Two of these sites are located along Garden of the Gods Road near 31st Street near Highway 24.

The Monument Creek/Fountain Creek corridor is considered to be a major migratory route. The corridor is extensively used for breeding grounds, winter usage, and resident bird populations. The Colorado Division of Wildlife listing, included in Appendix C, identifies the season and type of usage (for example, breeding and migration) for individual species of birds.

2.8.3 Reptiles and Amphibians

The corridor provides habitat for turtles, toads, frogs, snakes, racers, and lizards. The riparian vegetation provides excellent habitat for breeding, winter hibernation, and food supply.

2.9 Aquatic Habitat

2.9.1 Macroinvertebrates

The occurrence and composition of the benthic macroinvertebrate population can be a useful tool in assessing the health of a stream reach. Healthy streams are characterized by large numbers of high-diversity macroinvertebrate organism populations. Conversely, less healthy streams are characterized by fewer organisms and less diversity. In addition, it is often the presence or absence of the macroinvertebrate community that determines the abundance and type of fish populations. The larvae of organisms such as stoneflies, true flies, and caddisflies are a significant part of the diet of many fish.

The USGS collected sediment and benthic macroinvertebrate data on Monument and Fountain Creeks during water years 1985 to 1988 (USGS, 1989). The purpose of the study was to determine the effects of sediment transport on the benthic community. Two sites on Monument Creek were sampled—an upstream site near the USAFA and a downstream site at Pikeview. There were 78 different species of macroinvertebrates identified at the USAFA site, comprised mostly of mayflies, true flies, caddisflies, and worms. The mean density of total organisms ranged from 460 to 20,000 organisms/m^2 and the median was 9,500 organisms/m^2. There were only 41 species identified at Monument Creek at Peakview, consisting mostly of worms and true flies. The mean density of total organisms ranged from 42 to 1,200 organisms/m^2 and the median was 370 organisms/m^2.

The vast difference between the abundance and composition of the macroinvertebrate communities of these two sites is believed to be directly related to the flow regime and sediment-transport characteristics of the sites. Stream flows large enough to substantially disturb macroinvertebrate densities occurred more frequently at the downstream site. The stream channel of Monument Creek at the USAFA site was 15 to 25 feet wide with bed material consisting of sand, gravel, and small to large cobbles averaging 60 mm in diameter. The stream channel at Pikeview was 60 to 90 feet wide with sand and gravel averaging 1.83 mm in diameter. Mayflies, stoneflies, and caddisflies, the more habitat-sensitive species, were most abundant and were more frequently collected at the upstream site because they require a stable habitat (for example, cobbles). The worms, which predominated the downstream site, are able to exist in a wide range of habitats.

2.9.2 Fish

As part of the 1989 Use Attainability Analysis of Fountain Creek, the City collected fish from a site on Monument Creek between the confluences of Pine Creek and Cottonwood Creek. Three species of fish were identified from this site in August 1989—longnose dace, creek chub, and longnose sucker. In addition, a white sucker was collected from a pool 100 meters upstream of the sampling site.

The site had been previously sampled in 1981 by the Colorado Department of Wildlife. Comparisons of the 1989 collection with historic records show both similarities and differences over time. For instance, fewer species were found at this site in 1989 when compared to 1981. This was a result of fewer minnow species. Conversely, the two sucker species collected in 1989 were not found during the 1981 sampling. The species list from 1981 is comprised solely of minnows and includes the central stoneroller, the bigmouth shiner, the fathead minnow, the longnose dace, and the creek chub.

Observations and measurements of the stream habitat were also recorded during the 1989 study. It was observed that sands and fine gravel comprised 96 percent of the bottom substrate. A general lack of instream cover was also noted. The combination of fine substrate, lack of instream cover, the high sediment load, and the susceptibility to impacts from flooding events render the habitats of the downstream portions of Monument Creek less desirable for aquatic life.

2.10 Cultural Resources

2.10.1 Historic Sites

The City's early growth included the expansion of the town's commercial center along Tejon Street, Pikes Peak, and Colorado Avenues in all directions. Areas in and around this business district remain, in part, the City's first residential neighborhoods. Cultural and historic resources within the study area are shown on Sheets 11 through 14 in Volume II. Individual residences are not recorded; however, historic district, buildings, sites, and objects have been inventoried in three categories.

The first category includes cultural resources listed on the National Register of Historic Places. Public and institutional buildings were important structures of the city center. These buildings were typically constructed of high quality materials with excellent craftsmanship. Emanuel Presbyterian Church and the Colorado Springs Fine Arts Center are listed on the National Register. In addition to historically significant buildings, unique objects that specifically relate to Colorado Springs' development such as Rio Grande Engine 168 are included on the National Register.

Another category, which makes up the cultural/historic inventory of the Monument Creek Drainage Basin Study, includes cultural resources that are eligible for listings on the

National Register of Historic Places. Historic Districts have been defined because of their historic and architectural significance according to location and architectural style. Districts eligible for inclusion on the National Register include: Colorado College Historic District, Boulder Crescent Place Historic District, and Westview Place Historic District.

Commercial, public, and institutional buildings are individually important and these structures possess many common features relating to use, location, and form. These features contribute to the historic character of Colorado Springs. Buildings eligible for listings on the National Register include: Penrose Public Library (Carnegie Wing), the Muir and Associates building and historic clock, Hearthstone Inn, Van Briggle Memorial Pottery building, Denver and Rio Grande Railroad Depot, and the Trestle Building.

Historic parks represent efforts of early town planning that combine landscaping, structures, and facilities contributing to historical character. Antlers Park and Acacia Park are sites that are eligible for listings on the National Register because they have retained elements that sustain the historic setting. Selected elements in Monument Valley Park are eligible for listing on the National Register and include: The MacLaren, Thomas bath house; the MacLaren Thomas large picnic shelter donated to the City by Julie Penrose; and the Geologic Column.

Historic structures can contribute to the setting, feeling, and association of the early townsite. These individual structures or objects are significant cultural resources of the community. The Cache La Poudre Street bridge is an important historic structure eligible for the National Register.

The third category, which inventories historic districts, buildings, sites, and objects in the Monument Creek Drainage Basin Study, consists of locally significant cultural resources. These properties are not eligible for listings on the National Register of Historic Places although they contribute to the historic setting and local character of the downtown area and adjacent neighborhoods. Locally significant cultural and historic resources in the Monument Creek Drainage Basin Study area include the Monument Valley Park Historic District, the North Cascade Residential Historic District, the South Downtown Residential Historic District, an English/Norman cottage (now a maintenance shed in Monument Valley Park), the Shepards McGraw Hill building, and the Antlers Garage.

Other resources include the MacLaren picnic shelter in Monument Valley Park, the Monument Valley Park Willow Pond, the Van Briggle Pottery Kiln, and Sun Dial, the Giddings Fountain, and the Van Buren Railroad Bridge.

2.10.2 Archaeological Resources

According to the Colorado Historical Society Office of Archaeology and Historic Preservation, an archaeological survey along I-25 from North Academy Boulevard to South Academy Boulevard includes two minor archaeological sites. One site has been vandalized and heavily disturbed. Only four flakes of an originally reported 200 were observed at the time of the survey. The artifacts present at this site are catalogued as flakes, quartzite, and petrified wood. The second archaeological site identified by the survey lists as an artifact a partially complete pot.

2.11 Recreation

2.11.1 Trails

The City's Transportation Plan has identified existing and proposed on-street and off-street bicycle routes. The entire length of the Monument Creek corridor, from the end of the existing spine trail at Fillmore to the USAFA, has been identified in the Multi-Use Trails Plan as a major spine trail. Significant construction of this spine trail has taken place in 1993 and 1994. The Monument Creek spine trail will connect to future feeder trails. The feeder trails include the Woodmen, Rockrimmon, Ute Valley, Templeton Gap, Sinton, Rock Island, Mesa Valley, and Fountain Creek trails. The City's Comprehensive Plan emphasizes the goal of providing a system of conveniently located parks, access points, encouraging bicycle routes, and enhancing the natural setting within the built environment. The existing on-street bike routes provide an initial framework for such a system.

2.11.2 Park Resources

Within the Monument Creek corridor, there is a well established network of neighborhood parks. These parks include:

- Acacia Park
- Antlers Park
- Roswell Park
- Pike Park
- Monument Valley Park
- Pulpit Rock Park

2.12 Urbanization Patterns

2.12.1 Existing Urbanization

The City's population has experienced significant growth since the 1950s. The population growth has been marked by a corresponding increase in the geographic limits of the metropolitan area and the amount of impervious area in the Monument Creek and Fountain Creek watersheds. The conversion of land from agricultural uses to urban development has changed the cover of the ground from rangeland grasses or crops to roadways, buildings, parking lots, and irrigated or nonirrigated landscaped areas. Roofs and pavement are relatively impervious to rain, which has caused surface runoff rates and volumes to increase above predevelopment levels. As a result, the peak rate, volume, and frequency of stormwater in Monument Creek runoff has increased in proportion to the extent of urbanization within the watershed.

In order to quantify design rates and volumes of runoff for the study reach of Monument Creek, the types and geographic limits of existing urbanization in the Monument Creek watershed were determined. The extent of impervious area within each subbasin was established for existing development conditions based on aerial photography of the watershed dated November 1989. Various land uses shown in the aerial photography were categorized according to the information shown in Table 2-5, based on the City/County Drainage Criteria Manual. A watershed map was prepared indicating the location of each land use zone relative to drainage basin boundaries. Areas of the categorized land uses within each subbasin were measured using a planimeter.

Table 2-5
Land Use Categories

Type	Typical Land Use	Range of Imperviousness (%)	Average Imperviousness (%)
1	Agricultural/Forest/Open Space	zero to 4	2
2	Residential (0.1 to 0.4 DU/ac/Park	5 to 14	9
3	Residential (0.4 to 4 DU/ac)	15 to 39	27
4	Residential (4 to 8 DU/ac)/ Multifamily/Neighborhood Business Areas	40 to 69	54
5	Commercial/Industrial	70 to 99	84

Figure 2-6 shows the general distribution of existing imperviousness in the Monument Creek watershed. Table 2-6 identifies the distribution of existing imperviousness according to the major drainage basins. The weighted average imperviousness of the Monument Creek watershed for the existing level of urbanization is 9 percent.

2.12.2 Projected Urbanization

Basin imperviousness for future development conditions was based on information prepared by the City, El Paso County, and Pikes Peak Area Council of Governments for a recent planning study entitled *Socioeconomic Forecasts for Transportation Planning Beyond the Year 2010.* In order to develop the plan, the ultimate holding capacity (in terms of population and residential and business density) was estimated for a number of transportation planning zones. These estimates, developed to ensure that growth would not be over allocated in any planning zone, provide the information necessary to calculate

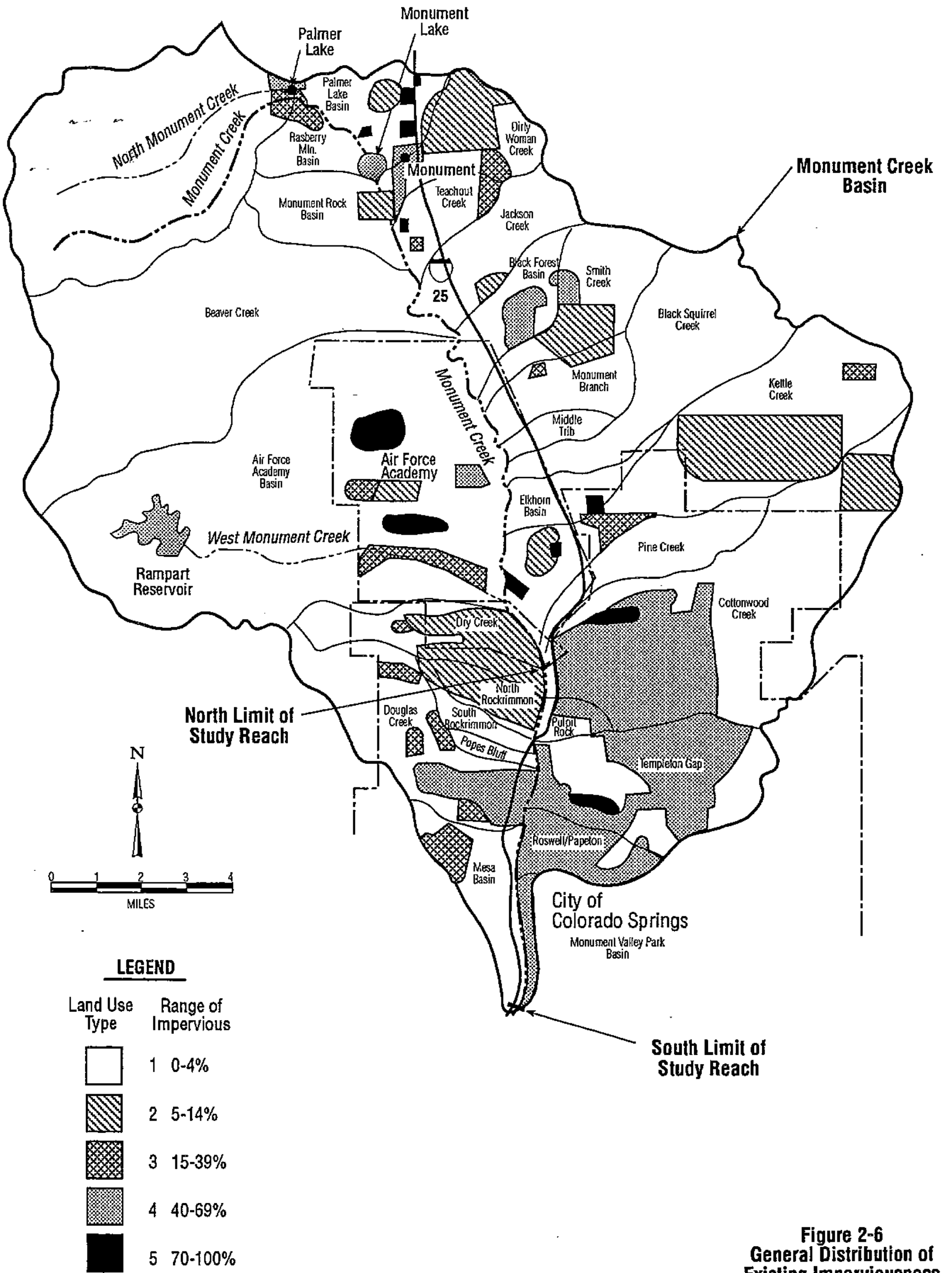


Figure 2-6
General Distribution of Existing Imperviousness

Table 2-6 Distribution of Imperviousness in Monument Creek Watershed		
	Percent Imperviousness	
Major Drainage Basin	**Existing Development Conditions**	**Future Development Conditions**
Upper Monument	3	3
Raspberry Mountain	5	13
Palmer Lake	10	22
Monument Rock	2	12
Dirty Woman Creek	11	15
Teachout Creek	7	15
Beaver Creek	2	4
Jackson Creek	2	11
Black Forest	9	20
Smith Creek	6	18
Monument Branch	2	23
Middle Tributary	2	22
Air Force Academy	5	7
Black Squirrel Creek	2	10
Elkhorn	2	14
Kettle Creek	7	13
Dry Creek	6	17
South Pine Creek	45	67
Cottonwood Creek	14	26
Pulpit Rock	20	38
Pine Creek	2	20
North Rockrimmon	9	28
South Rockrimmon	10	31
Popes Bluff	2	33
Douglas Creek	11	37
Templeton Gap	36	71
Roswell	77	77
Papeton	49	77
Mesa	23	62
Monument Valley	54	77
Entire Monument Creek Basin	9	19

imperviousness percentages for each transportation zone for the ultimate buildout condition.

Several different growth distribution scenarios were analyzed in the plan in order to forecast urban expansion over the next several decades (a shorter time frame than it would have taken to achieve an ultimate buildout condition). The scenarios included a most likely condition, a set of directional scenarios (northern growth, eastern growth, and southern growth) and a buildout condition of existing zoning and approved plans. The continuation of current growth trends and the directional growth scenarios were forecasted to a planning horizon defined as the time frame at which the population in the study area reaches 1 million. This planning horizon, which, according to the plan, is expected to represent the year 2030 or beyond, was assumed to be appropriate for the purpose of estimating quantities of stormwater runoff for future development conditions in the Monument Creek watershed. This assumption is not the same as the future development assumptions used to date in drainage basin planning studies, which have been based on ultimate buildout conditions regardless of how long that may take. Assuming ultimate buildout conditions in tributary drainage basins is reasonable based on their smaller size and the possibility that a directional growth trend could lead to full buildout in the next 30 to 50 years. However, it is unreasonable to assume full buildout in the 250-square-mile Monument Creek watershed within the next 30 to 50 years.

Estimates of imperviousness for the ultimate buildout condition of the transportation zones were adjusted so that they would be representative of the 1 million population planning horizon. The adjustment was comprised of multiplying the area of residential and business development projected for ultimate buildout by the ratio of forecasted population (for the 1 million planning horizon) to the ultimate population. Transportation planning zones were superimposed on a drainage basin map and measured using a planimeter to estimate weighted average imperviousness for each basin for future development conditions.

Table 2-6 and Figure 2-7 show the distribution of projected future impervious area in the watershed according to the major drainage basins. The weighted average imperviousness of the Monument Creek watershed for the projected future level of urbanization is 19 percent.

The imperviousness projections shown in Table 2-6 raise two concerns. First, the basins in the southern portion of the watershed that drain directly to the Monument Creek study reach, where tributary channel erosion is already identified as a problem, are expected to undergo substantial further urbanization. This will accelerate channel erosion. The second concern relates to the basins in the middle portion of the watershed on the east side of Monument Creek that drain into the USAFA. These basins are expected to undergo a transformation from being only slightly urbanized to becoming significantly urbanized. This may lead to additional disturbance of the Monument Creek channel in the upstream portion of the study reach and within USAFA property. The City has been updating a number of these tributary DBPSs and is addressing erosion and sedimentation issues as they relate to Monument Creek.

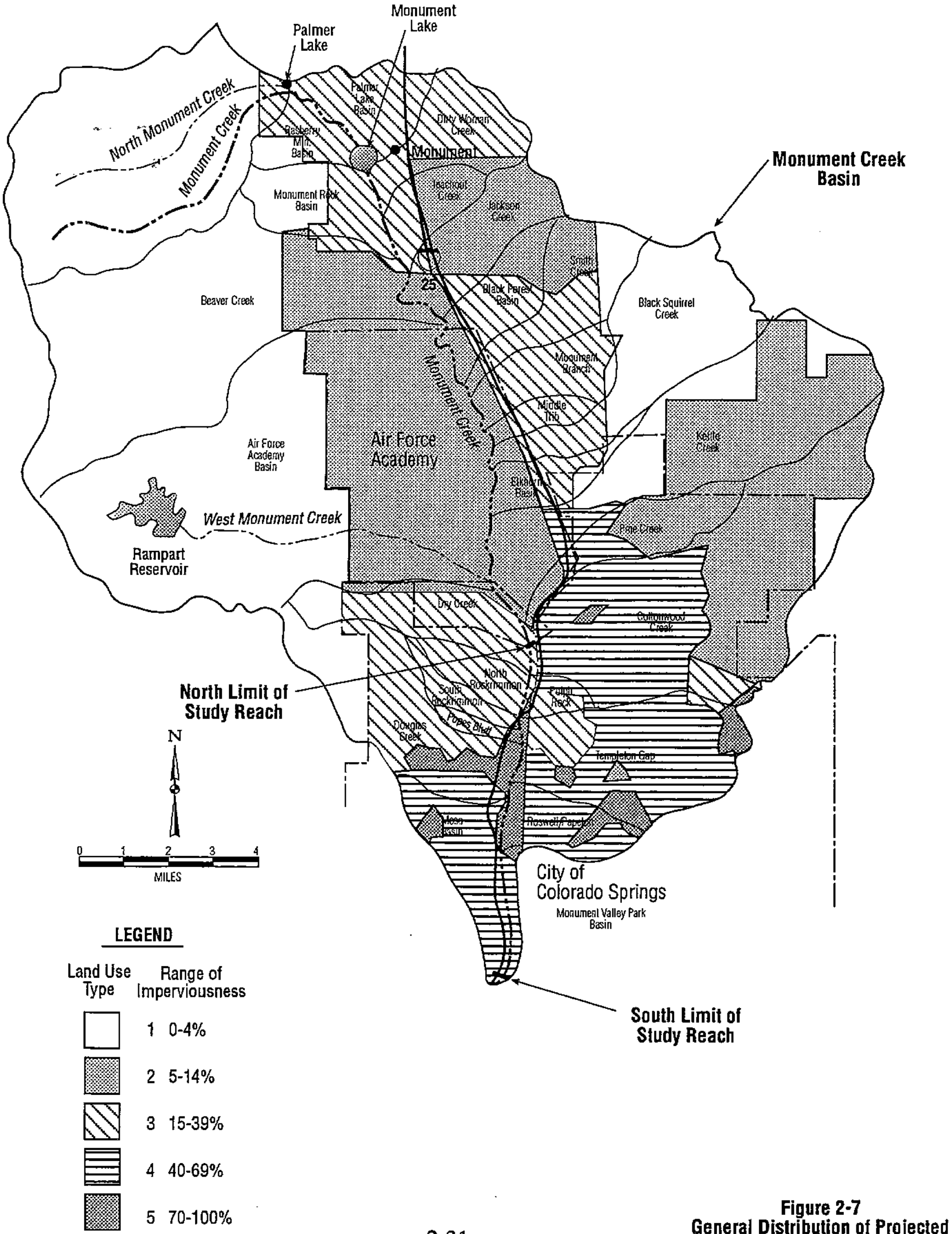


Figure 2-7
General Distribution of Projected Imperviousness

2.13 Utilities

The study reach of Monument Creek serves as an important utility corridor. An existing gravity main located generally within the channel limits conveys wastewater toward the City's Las Vegas Street Wastewater Treatment Plant. This gravity main is 42 inches in diameter at the downstream end of the Monument Creek study reach and 8 inches in diameter at the upstream end. The main pipeline and connecting laterals cross the creek approximately two dozen times within the study reach. Many of these pipeline crossings, which are typically encased in concrete, have been exposed due to channel degradation. Some potential exists that these exposed crossings could rupture during extreme flood events, releasing wastewater into Monument Creek.

Future construction of an additional gravity main is planned in the creek corridor to provide increased wastewater conveyance capacity as the Monument Creek watershed continues to develop. This gravity main is proposed to be somewhat larger than the existing pipeline and extend from the Las Vegas Street treatment plant to a location near Garden of the Gods Road.

In addition, various nonpotable water lines exist in the Monument Creek corridor, including the Pikeview Diversion Dam upstream of Garden of the Gods Road and Pikeview Reservoir. The location of wastewater and nonpotable utilities in the creek corridor was considered during the formulation of stream alternatives, as discussed in Section 6.

3.0 HYDROLOGIC ANALYSIS

3.0 Hydrologic Analysis

3.1 Objectives

A hydrologic analysis was undertaken to establish baseline peak flow rates and runoff volumes appropriate for floodplain planning along mainstream Monument Creek within the study reach. Ten-year and 100-year return period floods were analyzed. The analysis was undertaken both for existing and estimated future development conditions in the Monument Creek watershed. The hydrologic results were used as the basis of the hydraulic analysis, floodplain delineation, stability analysis, and evaluation of alternatives of Monument Creek within the study reach.

As indicated in Section 2.0 and Figure 2-1, there is approximately 420 square miles of drainage area that contributes runoff to the Monument and Fountain Creek DBPS study reaches. Due to the large size of this area and the interrelatedness of the Monument Creek and Fountain Creek watersheds, it was determined that the hydrologic methodology utilized should be consistently developed and applied between the two studies. To guide the development of the hydrologic methodology, a Technical Hydrology Review Committee was established. The committee consisted of representatives from the COE, Soil Conservation Service (SCS), Colorado Water Conservation Board (CWCB), FEMA, National Weather Service, and various City and County departments.

A series of technical meetings were held during the development of the hydrologic models to discuss pertinent hydrologic principles, and consider how they might be applied to the Monument Creek and Fountain Creek watersheds. Discussions pertained to rainfall type, rainfall amounts, areal adjustment of rainfall and its applicability, contribution to flooding from land above 8,000 feet in elevation, storm tracking, average storm cell size, reservoir routing, stream gage analysis and its applicability to this basin, and historical flooding in the basin and in the region.

3.2 Summary of Modelling Approach

3.2.1 Methodology

The methodology and assumptions of the hydrologic analysis are documented in *Baseline Hydrology, Monument Creek DBPS* (Kiowa, 1992) provided in Volume III. The Soil Conservation Service (SCS) dimensionless hydrograph method of the COE's HEC-1 model was used to generate hydrographs for 250 individual subbasins within the Monument Creek watershed. Subbasin hydrographs were routed and combined using the kinematic wave method of HEC-1.

Impervious area within the subbasins was modelled according to the existing and projected future urbanization patterns described in Section 2.12.

3.2.2 Flood Storage

Five existing flood control structures have been included in the hydrologic model. These structures include Rampart Reservoir, the Kettle Creek Detention Pond, also known as the USAFA Detention Pond, Briargate Detention Pond II, and the Chapel Hills Detention Ponds Nos. 1 and 2. The detention ponds were included in the hydrologic model because they are considered flood control structures by the SEO. Rampart Reservoir was included based on discussions with the City's Water Department regarding the operation of the reservoir. Rampart Reservoir is not considered a flood control structure by the SEO; however, the reservoir is operated in a manner that provides flood control benefits. If the operation of Rampart Reservoir is ever modified such that its flood control benefits are significantly diminished, these hydraulic results must be re-evaluated.

3.2.3 Rainfall Analysis

One of the critical hydrologic variables to model was rainfall. After assessing the results of a number of design rainfall approaches, starting with the recommendations of the City/County Drainage Criteria Manual (applying a uniform rainfall over the entire watershed), an approach based on the procedures of Hydrometeorological Report (HMR) Nos. 51 and 52 was adopted. This was because HMR Nos. 51 and 52 provided a representation of a storm cell that could be positioned over the large watersheds of Monument and Fountain Creeks.

Point rainfall depths of 2.96 inches for the 10-year storm and 4.32 inches for the 100-year storm were read from the National Oceanographic and Atmospheric Administration (NOAA) Atlas 2, Volume III for Colorado and used along with basin size to develop depth-area-duration relationships. These relationships were then transformed into elliptically shaped isohyetal values using the COE's HMR No. 52 "Probable Maximum Storm Computation" computer program. While HMR Nos. 51 and 52 were developed for probable maximum flood analyses, the 10-year and 100-year events were represented by inputting, with the concurrence of the Technical Hydrology Review Committee, the appropriate NOAA point values. The result was an elliptically shaped storm cell with maximum rainfall in the center of the cell and gradually diminishing amounts of rainfall at greater distances from the center of the cell. The rainfall cell was positioned to create the maximum total rainfall amount in the Monument Creek watershed. Rainfall depths were read from the elliptical isohyetals and input as uniform rainfall depths over each individual subbasin.

3.2.4 Stream Gage Analysis

In addition to the design storm/runoff modelling approach, a statistical stream gage analysis was conducted for Monument Creek at the Pikeview gage, located near the middle of the study reach. The analysis was based on 25 years of stream flow data. Because the 1935 flood of record can sway the 25 years of actual data, three options for addressing the 1935 flood were considered:

1. Use of recorded peak discharge data from 1939 to 1949 and 1976 to 1989 without the 1935 flood

2. Use of recorded peak discharge data from 1939 to 1949, 1976 to 1989, and inputting the 1935 flood as an annual peak discharge.

3. Use of recorded discharge data from 1939 to 1949, 1976 to 1989, and inputting the 1935 flood as an historical event.

Inputting the 1935 flood as an historic event (Option 3) moderated the effect of the flood on the 25 years of data between low and high extremes. Therefore, Option 3 was selected as the most appropriate approach for estimating extreme event discharges on Monument Creek.

3.3 Hydrologic Analysis Results

The 100-year peak discharges estimated in the hydrologic analysis are summarized in Table 3-1, along with comparison data from the stream gage analysis and FEMA's Flood Insurance Study. Table 3-2 shows total runoff volumes at the upstream and downstream limits of the study reach. These runoff volumes are relatively large, indicating that the use of detention storage on mainstem Monument Creek would likely be unfeasible.

Table 3-1
Summary of Peak Discharges for Monument Creek

	Peak Discharge (cfs) Current Study				Flood Insurance Study[a]
Location	10-Year Future Development Conditions	100-Year Existing Development Conditions	100-Year Future Development Conditions	Stream Gage Analysis	Existing Development Conditions
1. Upstream Study Limits (south of USAFA)	6,960	24,300	26,400	–	27,200
2. Downstream of Pine Creek Confluence	7,060	24,800	27,400	–	30,000
3. Pikeview (north of I-25)	7,310	26,300	29,800	26,000	31,000
4. Upstream of Templeton Gap Floodway	7,560	27,200	31,300	–	32,000
5. Downstream Study Limit (upstream of Fountain Creek Confluence)	7,660	27,900	32,800	–	32,000

[a]From Floodplain Information Report by U.S. Army Corps of Engineers, 1971.

Table 3-2 Summary of Runoff Volumes for Monument Creek (in acre-feet)				
Location	Existing Development Conditions		Future Development Conditions	
	10 year	100 year	10 year	100 year
Upstream Study Limit (south of USAFA)	2,330	6,140	2,480	6,490
Downstream Study Limit (upstream of Fountain Creek Confluence)	3,000	8,520	4,030	10,380

4.0 HYDRAULIC ANALYSIS

4.0 Hydraulic Analysis

4.1 Objectives

A hydraulic analysis was conducted to ascertain the conveyance capacity of the existing channel and hydraulic structures and to assess the hydraulic performance of proposed alternatives along Monument Creek within the study reach. The results were compared with the floodplain profiles shown in the Federal Emergency Management Agency's (FEMA) Flood Insurance Study (FIS). Hydraulic results were also used for the stream stability analysis in Section 5.

4.2 FIS

An FIS investigates the existence and severity of flood hazards in a given geographic area and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. The primary purpose of an FIS is to develop flood risk data, based on existing development conditions, that are used to establish actuarial flood insurance rates. A secondary purpose is to assist communities in their efforts to promote sound floodplain management. Minimum floodplain management requirements for participation in the National Flood Insurance Program (NFIP) are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

In some states or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum federal requirements. In such cases, the more restrictive criteria take precedence. This is the case in the City of Colorado Springs, where floodplain management is based on the future development flow rates identified herein.

In 1980, FEMA began the technical work associated with the publication of an FIS for the City and El Paso County. The FIS became effective in 1986 and was later revised in 1989. Monument Creek, within the City, was included in the FIS. As such, a 100-year floodplain and floodway were delineated for Monument Creek, as well as water surface profiles for 10-, 50-, 100-, and 500-year recurrence intervals. Since the study has been in effect, three crossings have been constructed or replaced. Hydrology used in the FIS for Monument Creek (shown in Table 3-1) was obtained from the 1971 COE *Floodplain Information Report*.

4.3 Methodology

A hydraulic analysis was conducted for the current study using the COE HEC-2/PC Water Surface Profiles program. Cross-section data used in the program was obtained from topographic mapping prepared from aerial photography dated 1988 and 1989. This mapping was compiled using a 2-foot contour interval and a scale of 1 inch to 100 feet. At selected locations, field surveyed cross sections were obtained in order to better define the low-flow channel geometry, the average depth of flow at the time of the survey, and the general stability of the section. This information was used to supplement the topographic mapping. Channel cross sections were input to the model, plotted, and bank stations determined. In general, the cross sections input to the HEC-2 model were located at approximately the same location as in the FIS hydraulic analysis. The numbering system used corresponds to the section numbering used in the FIS except at locations where a new crossing or change in channel geometry warranted additional cross sections.

Photography at selected sections was obtained to assist in the determination of roughness factors. The roughness factors applied in the FIS were also reviewed and incorporated into the analysis, if appropriate. Channel roughness values ranged from 0.03 to 0.045. Overbank roughness values ranged from 0.020 to 0.070. Vegetative roughness was determined using COE guidelines and the *City/County Storm Drainage Criteria Manual*. The 100-year peak discharges used for the hydraulic analysis are shown in the first two columns of Table 3-1.

Roadway and pedestrian bridge crossings were field surveyed. Low-chord and top-of-roadway elevations were field reviewed and input to the HEC-2 model. Pier width, bottom width, and channel side slopes adjacent to bridges were noted. Five new or replaced structures that are not reflected in the FIS were included in the model. These structures include:

- Monument Valley Pedestrian Bridge
- Dilly Low Flow Pedestrian Bridge
- Polk Street Bridge Replacement
- Mark Dabling Boulevard
- Woodmen Road

The Monument Valley Pedestrian, Mark Dabling Boulevard, and the Woodmen Road bridges have been revised in the FIS report through the map revision process.

4.4 Hydraulic Characteristics

A summary of HEC-2 program input and output data for the 100-year flood based on existing and future development conditions is shown in Volume III, Appendix D. The resulting floodplain boundaries were plotted on topographic base mapping shown on Sheets 29 through 36 of Volume II. A flood profile is shown on Sheets 37 through 41 of Volume II. The flood profile is compared to the FIS profile in Figure 4-1.

As shown on the maps in Volume II, the project study reach was divided into seven separate segments, designated M1 (downstream) through M7 (upstream). The reaches

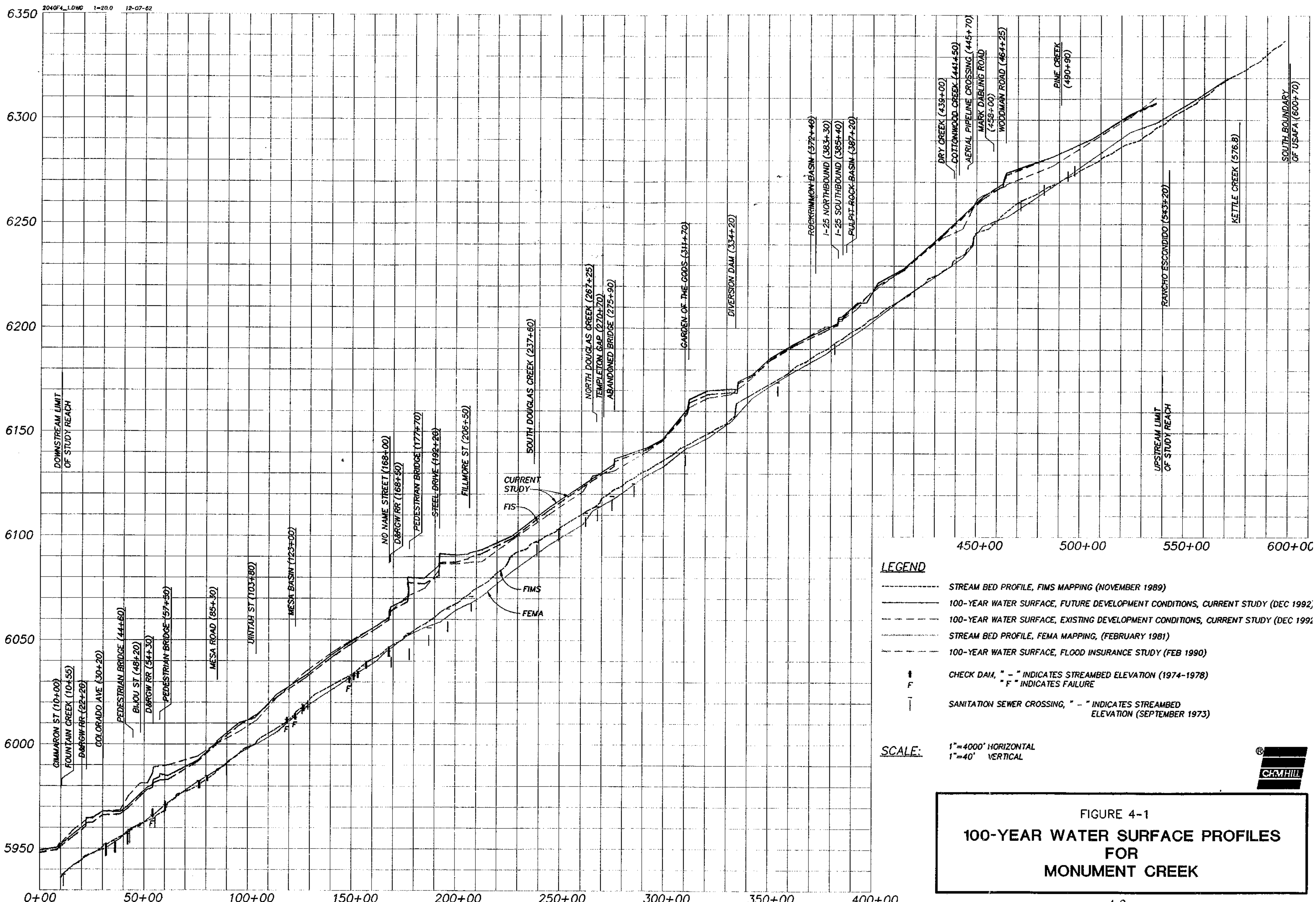


FIGURE 4-1
100-YEAR WATER SURFACE PROFILES FOR MONUMENT CREEK

were identified on the basis of similar stream character. Hydraulic characteristics in each reach are described in the following paragraphs.

4.4.1 Reach M1, Confluence with Fountain Creek to Bijou Street

Hydraulic roughness in this reach is estimated to vary from a Manning's "n" value of 0.04 to 0.07 in the floodplain and 0.02 to 0.03 in the base flow channel. No overbank flooding is estimated to occur in the 100-year event for both existing and developed conditions. Although industrial/commercial developments closely border the creek, no industrial/commercial buildings are located in the floodplain. However, these properties are subject to the risk of flood damage caused by bank erosion and migration. Floodplain widths are estimated to be approximately the same for existing and developed conditions and vary from 170 to 260 feet.

Bridges in this reach include an abandoned Denver and Rio Grande Railroad (DRGRR) bridge, West Colorado Avenue, a pedestrian low water crossing, and Bijou Street. The abandoned DRGRR bridge is estimated to be submerged in the 100-year event for both existing and developed conditions. The West Colorado Avenue and the Bijou Street bridges, however, are estimated to have significant clearance above the 100-year flood profile. Flood velocities range from 8 to 18 feet per second (the higher velocities generally occur at the bridges).

4.4.2 Reach M2, Bijou Street to Van Buren Street

In this reach, hydraulic roughness is estimated as 0.04 to 0.07 in the floodplain and 0.03 in the base flow channel. Overbank flooding is estimated to occur in the 100-year event for both existing and developed conditions at two locations: just upstream of the DRGRR bridge near Bijou Street and just downstream of Uintah Street. As in reach M1, industrial/commercial development closely borders the creek, but no industrial/ commercial buildings are located in the floodplain. However, these properties are subject to the risk of flood damage caused by bank erosion and migration. Floodplain widths are estimated to vary from 150 to 400 feet.

Bridges in this reach include a DRGRR bridge, a long-span pedestrian bridge, Mesa Road, Uintah Street, and Van Buren Street. All of the bridges are estimated to clear the 100-year flood profile for both existing and developed conditions, except the pedestrian bridge. For developed conditions, the pedestrian bridge is estimated to be slightly submerged. Flood velocities range from 8 to 19 feet per second with the higher velocities occurring at narrow channel sections and at bridges.

4.4.3 Reach M3, Van Buren Street to Fillmore Street

In this reach, the roughness is estimated as 0.05 to 0.07 in the floodplain and 0.03 in the base flow channel. As in reaches M1 and M2, industrial/commercial and residential developments closely border the creek floodplain. Significant overbank flooding is estimated to occur in the 100-year event and several industrial/commercial and residential buildings are estimated to be in the floodplain for both existing and developed conditions. Floodplain widths vary from 110 to 500 feet in existing conditions and 110 to 830 feet in developed conditions.

Bridges in this reach include a DRGRR bridge, the Dilly low-water pedestrian bridge, and Polk Street. The DRGRR bridge is estimated to clear the 100-year flood profile for both existing and developed conditions. The Polk Street bridge, however, is estimated to be submerged in the 100-year flood for existing conditions and overtopped in the 100-year flood for developed conditions. The limited channel capacity in the vicinity of Polk Street appears to be the cause of the significant amount of overbank flooding estimated in this reach. Flood velocities are estimated to range from 6 to 20 feet per second. The higher velocities occur at the narrow channel section at the DRGRR bridge and lower velocities occur at areas of overbank flooding.

4.4.4 Reach M4, Fillmore Street to Templeton Gap Confluence

Roughness in this reach is estimated as 0.045 to 0.07 in the floodplain and 0.03 in the base flow channel. No overbank flooding is estimated to occur in the 100-year event for both existing and developed conditions in this reach. Industrial/commercial and residential developments closely border the creek and two City maintenance buildings, located on the left bank just upstream of the Fillmore Street bridge, are estimated to be in the floodplain for both existing and developed conditions. Floodplain widths are estimated to vary from 100 to 400 feet. The Fillmore Street bridge is the only bridge in this reach and is estimated to have significant clearance (approximately 20 feet) above the 100-year flood profiles. Flood velocities are estimated to range from 14 to 18 feet per second.

4.4.5 Reach M5, Templeton Gap Confluence to I-25

Roughness in this reach is estimated as 0.04 to 0.07 in the floodplain and 0.03 in the base flow channel. Overbank flooding is estimated to occur in the 100-year event at an abandoned, partially demolished bridge structure just upstream of the Templeton Gap confluence for both existing and developed conditions. Although industrial/commercial developments closely border the creek, no buildings are located in the floodplain. However, these properties are subject to the risk of flood damage caused by bank erosion and migration. Floodplain widths in this reach are estimated to vary from 120 to 580 feet.

Bridges in this reach include the abandoned bridge structure, Garden of the Gods Road, and I-25. The Garden of the Gods Road and I-25 bridges are estimated to clear the 100-year flood profile for both existing and developed conditions. The abandoned bridge crosses only half of the creek and tends to obstruct flood flows. It is recommended that the remaining portion of the structure be removed to reduce overbank flooding at this location. Flood velocities are estimated to range from 6 to 21 feet per second with the higher velocities occurring at narrow channel sections and at the Garden of the Gods Road bridge. The lower velocities occur just downstream of the I-25 bridge where the floodplain is relatively wide.

4.4.6 Reach M6, I-25 to Woodmen Road

In this reach, roughness is estimated as 0.04 to 0.06 in the floodplain and 0.03 in the base flow channel. No overbank flooding is estimated to occur in the 100-year event for both existing and developed conditions. Land use adjacent to the creek consists of industrial/commercial and residential development. In general, developments are situated farther away from the creek than in the lower reaches and all industrial/commercial and residential buildings are estimated to be outside the floodplain. Floodplain widths in this reach are estimated to vary from 110 to 260 feet.

Bridges in this reach include Mark Dabling Boulevard and Woodmen Road. Also, three aerial pipelines cross the creek just downstream of Mark Dabling Boulevard. The bridges and the aerial pipelines are estimated to clear the 100-year flood profile for both existing and developed conditions. Flood velocities are estimated to range from 7 to 18 feet per second.

4.4.7 Reach M7, Woodmen Road to South Boundary of USAFA

Roughness in this reach is estimated as 0.04 in the floodplain and 0.03 in the base flow channel. Land use consists of open areas and some residential development. In general, buildings are situated farther from the creek than in the downstream reaches. No overbank flooding is estimated to occur in the 100-year event for both existing and developed conditions and all residential buildings are estimated to be outside the floodplain. The average floodplain width is significantly wider than in the downstream reaches, because overbank filling has generally not taken place in this reach, and is estimated to be 160 to 700 feet wide. No bridges are located in this reach. Flood velocities are estimated to range from 10 to 15 feet per second.

4.5 Comparison to FIS

The flood profile information estimated in this study varies slightly from the profile identified in the FIS. Both profiles are shown in Figure 4-1. General reasons for variations in the water surface profile between this study and the FIS include differences in base mapping, channel aggradation and degradation, the presence of new bridge crossings, and slight variations in flow rates and hydraulic roughness.

FEMA regulates the FIS water surface profiles for the Monument Creek floodplain that are used primarily for the purchase of flood insurance. Since this study is a planning document, and does not address final design and construction, the City will not be requesting modifications to FEMA's floodplain maps. FIS maps would be revised, however, as specific projects are constructed that would remove business or residential properties from the floodplain. The water surface profiles and associated hydraulic information delineated in this study were used as the basis for planning stream improvement alternatives.

4.6 Flood Risk Associated with Channel Erosion

It should be noted that neither the FIS nor the floodplain delineation shown in this study explicitly indicates the areal extent of the flood risk associated with channel erosion. The historic pattern of filling the floodplain channel to increase the amount of developable land adjacent to the creek has shrunk the available conveyance area and reduced hydraulically rough vegetation. The result is significantly increased flood velocities and increased potential for lateral migration of the outer channel banks.

The areal extent of bank migration during an extreme flood event is difficult to establish in advance. However, it should be noted that land areas adjacent to Monument Creek are subject to the risk of lateral bank migration, even though they may be currently shown outside of the 100-year floodplain delineated in the FIS or this study.

5.0 STREAM STABILITY ANALYSIS

5.0 Stream Stability Analysis

5.1 Objective

A stream stability analysis was conducted as part of this study to assess the potential for future changes in the physical geometry of Monument Creek within the study reach.

These changes in geometry could consist of a raising or lowering of the channel bottom or lateral movement of the channel banks. The degree of movement, more than the direction, most impacts the physical character of a stream; therefore, the degree of potential movement in the study reach of Monument Creek was assessed. This was accomplished by evaluating historical evidence of past movement, gaining an understanding of the sediment transport processes working in the stream, and by estimating the long-term equilibrium slope of the channel bed. If the equilibrium slope is predicted to increase (from a perspective looking upstream), then aggradation or deposition of sediment as well as raising of the channel bottom will occur. Conversely, if the equilibrium slope is predicted to decrease (from a perspective looking upstream), then degradation or scour of sediment as well as lowering of the channel bottom will occur.

5.2 Principles of Fluvial Systems

5.2.1 Stream Equilibrium

Natural stream channels flowing in alluvial valleys (for example, Monument Creek) continually adjust morphologic characteristics such as cross-sectional shape and area, slope, bed material, and channel pattern to attempt to reach a state of equilibrium. Channel equilibrium is a balance between erosion and deposition of channel bed material. Equilibrium occurs when the sediment supply from the upstream reach ($Q_{sediment\ supply}$), which includes tributaries and watershed drainage, is equal to the sediment transport capacity of the channel ($Q_{sediment\ capacity}$). True static equilibrium is rarely achieved; rather, stream channels continually adjust to changes in control and flow variables. Although a myriad of factors is involved, the primary variables that influence the geomorphic balance are water discharge and sediment discharge. Any change in these two parameters can trigger a period of morphologic transformations in the channel that endure as the sediment supply and the sediment transport capacity seek balance. Lane characterized this geomorphic balance by the following relationship (SLA, 1985):

$$Q\ S \text{ is proportional to } Q_s\ D_{50} \qquad \text{(Eq. 5-1)}$$

where Q is the discharge, S is the channel slope, Q_s is the sediment discharge, and D_{50} is the median diameter of the bed material. A schematic of Lane's principle is shown in Figure 5-1.

In stability analyses, the equilibrium or stability of the channel is commonly represented by two components: (1) lateral stability and (2) vertical stability. Lateral stability relates to the ability of the stream banks to transport water and sediment without undergoing long-term change. Streambank vegetation, in addition to water and sediment discharge, influences lateral stability. Vertical stability refers to the ability of the bed to transport water and sediment without undergoing long-term change. Usually channels adjust both vertically and laterally, with the dominating process controlled by the zone (banks or bed) most susceptible to adjustments.

5.2.2 Sediment Loads

There are three different modes of sediment transport in fluvial systems: (1) rolling or sliding along the bed, (2) saltation (where particles move in suspension above the bed with periodic resting periods on the bed), and (3) suspension (sediment particles supported by turbulent flow). Bed load (Q_b) refers to sediment that is transported by rolling or sliding and saltation. Suspended load ($Q_{s,w}$) refers to sediment transported by suspension. Bed material load includes the bed load and the portion of suspended load that is composed of grain sizes found in the bed (Q_s). Wash load refers to the portion of the suspended load that is composed of grain size particles finer than those found in the bed. Also, wash load can be defined in terms of watershed sediment yield, which is equal to the wash load divided by the total drainage area. The sum of the bed load and the suspended load is defined as the total load ($Q_{b,s,w}$). The total load may also be defined as the sum of the bed material load ($Q_{b,s}$) and the wash load (Q_w).

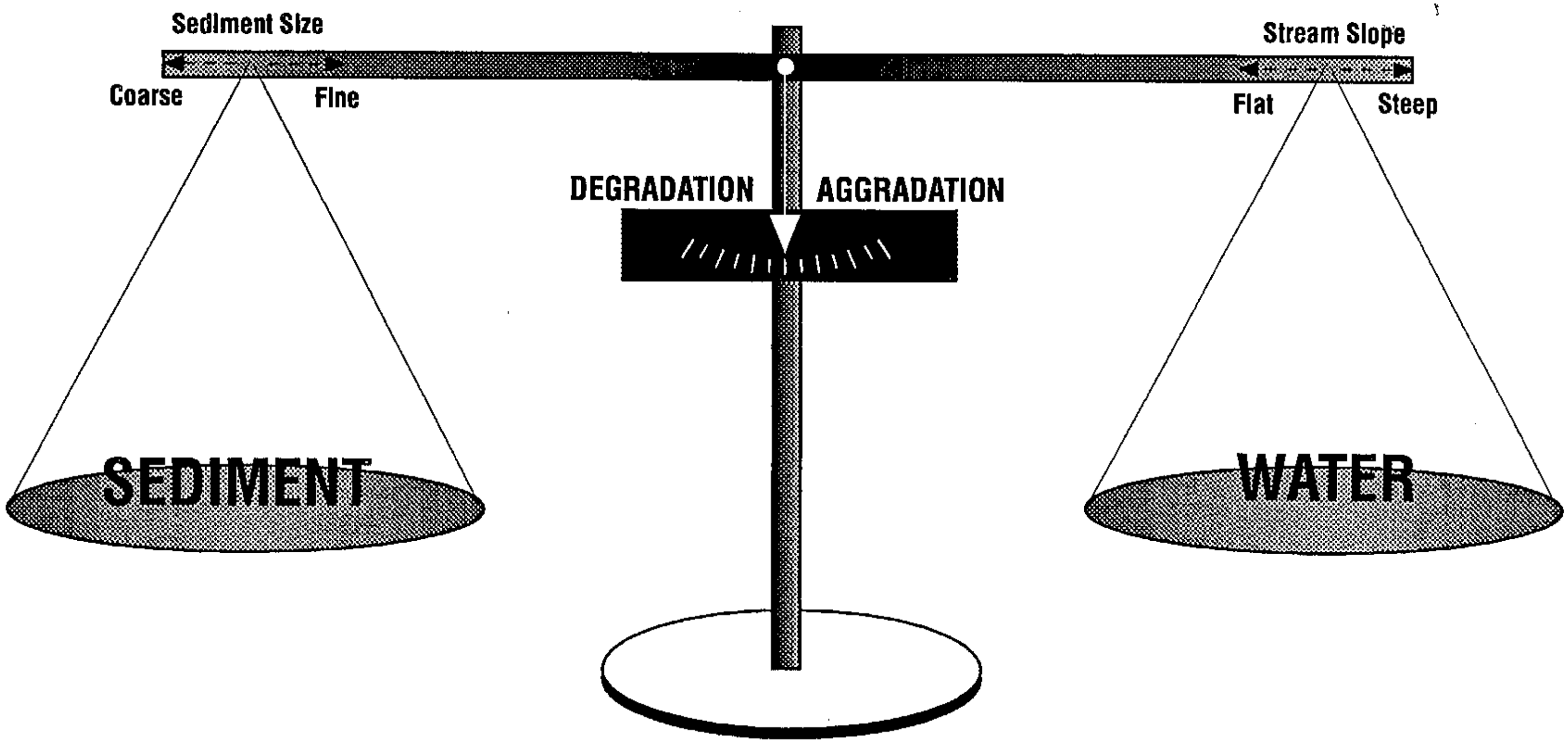
5.2.3 Stream Response

A stream channel responds to an imbalance in sediment supply and sediment transport capacity by adjusting its slope, geometry, and pattern. If the sediment supply rate becomes greater than the sediment transport capacity, the channel may respond as follows:

- Aggrade and increase slope
- Decrease channel depth
- Increase channel width
- Shift towards a braided channel pattern

Conversely, if the sediment supply rate is less than the sediment transport capacity, the channel may:

- Degrade and decrease slope
- Increase in channel depth



(Sediment Load) x (Sediment Size) is proportional to (Stream Slope) x (Stream Discharge)

Figure 5-1
STABLE CHANNEL BALANCE

- Decrease in channel width
- Shifts towards a meandering channel pattern

Channel pattern and stability based on sediment load is illustrated in Figure 5-2.

5.3 Assessment of Stability Based on History

5.3.1 Historic Bed Elevation

A historic analysis of the bed elevation of Monument Creek was conducted to provide insight on the present stability. Bed profile data from previous reports, bridge inspection data, and construction plans were gathered and reviewed.

5.3.1.1 Bed Profiles

Bed profiles mapped in 1981 (FEMA, 1990) and 1971 (COE, 1971) were compared with the latest mapping of the channel in 1989 (FIMS, 1989). This data was plotted in Figure 5-3. Since the stationing in Figure 5-3 was based on the length of Monument Creek along its centerline, some discrepancies between stationing were found between the three map sources. Therefore, the stationing of the 1971 and 1981 mapping was adjusted to match the 1989 FIMS mapping. This adjustment was made by assuming that the bridge crossing were at the same locations and then proportioning intermediate profile points accordingly.

5.3.1.2 Bridge Inspection Data

Bridge inspection data was gathered from the City of Colorado Springs Engineering Division. However, it could not be determined whether the inspection data were measured to the streambed invert, so bed elevation changes could not be reliably identified. In addition, no datum elevation was provided to enable accurate plotting against other data. Because of these limitations, the bridge inspection data was not incorporated into Figure 5-3.

5.3.1.3 Check Dams

Design drawings of check dams constructed within the study reach were obtained from the City of Colorado Springs Engineering Division. The drawings showed the location, invert elevation, and crest elevation of check dams, as well as existing grade elevations. All of this information was plotted in Figure 5-3.

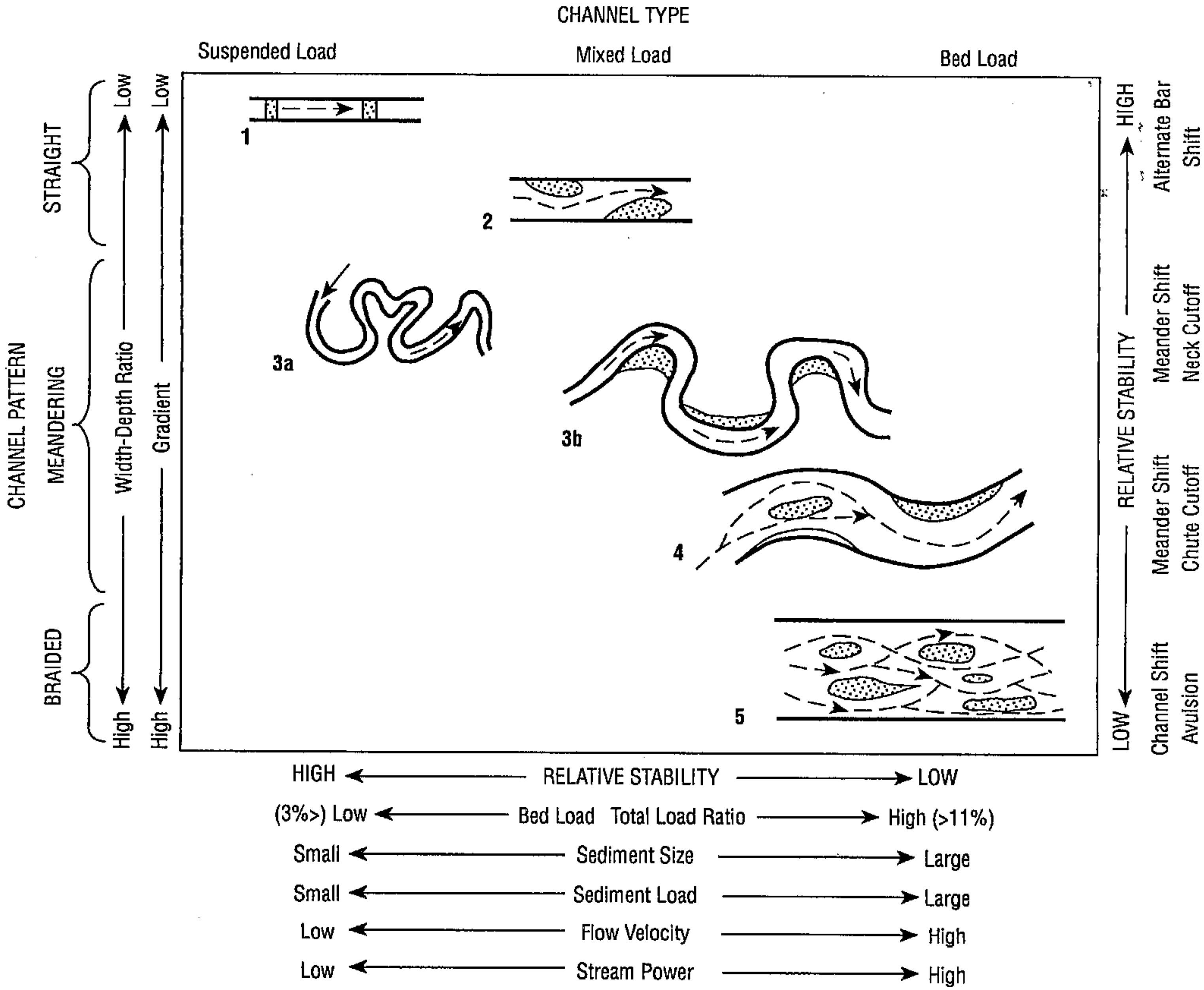


Figure 5-2
CHANNEL PATTERN AND STABILITY

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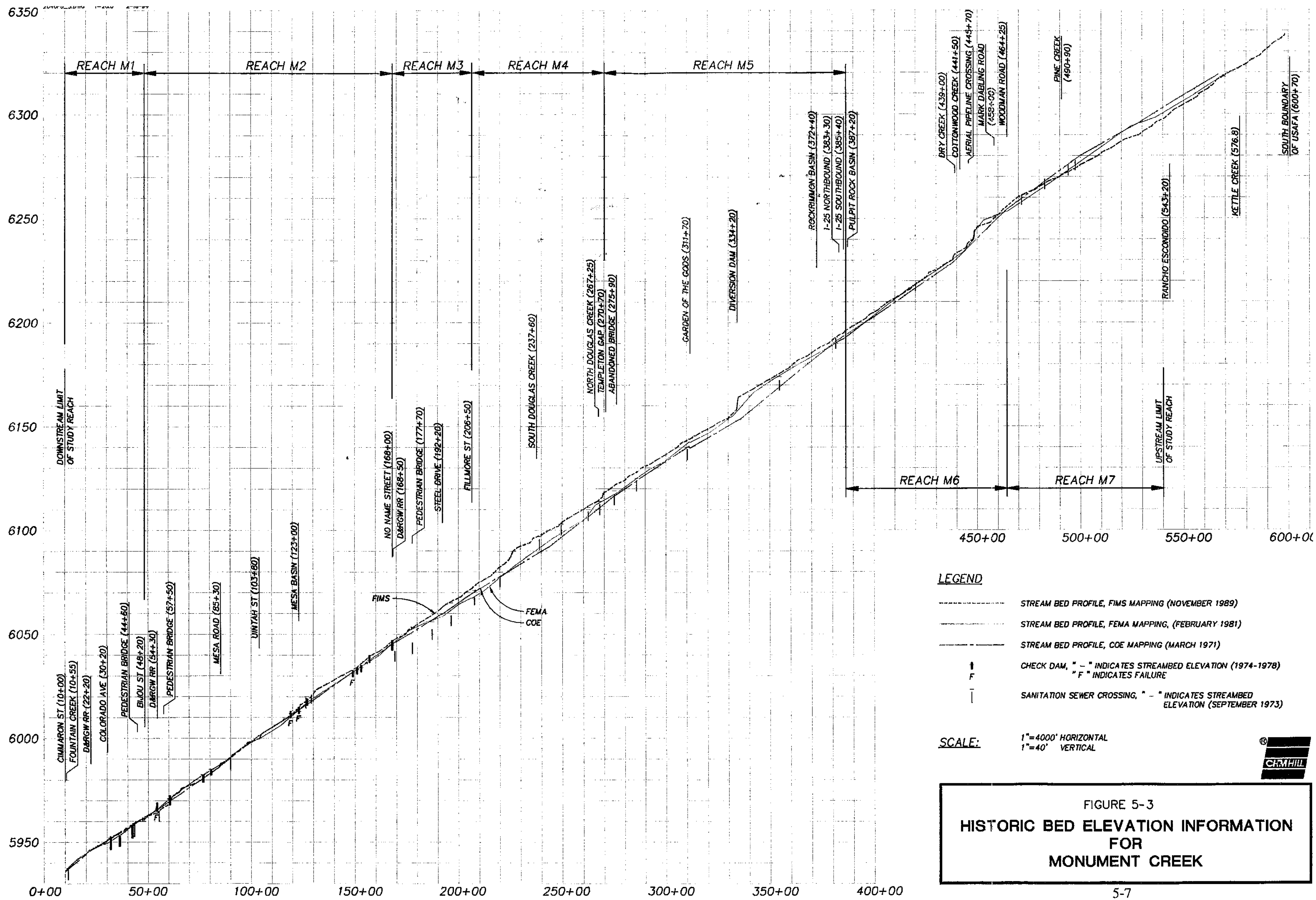

FIGURE 5-3
HISTORIC BED ELEVATION INFORMATION FOR MONUMENT CREEK

5.3.1.4 Sanitary Sewer Crossings

The main Monument Creek collector line of the sanitary sewer system generally follows the Monument Creek streambed. The alignment of the sewer line occasionally crosses the creek channel. Originally, the sewer was constructed to cross beneath the creek bed, but at many points the sewer crossing, which is encased in concrete, has been exposed. To help assess the historic bed elevation of the creek, construction plans from the City's Department of Wastewater and Utilities were obtained and used to plot the station of the sewer, crest elevation of the concrete encasement, and invert elevation of the concrete encasement (see Figure 5-3). Not all of the crossing plans could be located by the Department of Wastewater and Utilities, therefore several exposed crossings were plotted in Figure 5-3 by field approximations.

5.3.2 Historic Channel Planform Information

The lateral stability of the channel over time was assessed by obtaining aerial photographs shot in 1962 by the U.S. Soil Conservation Service and comparing them to 1989 aerial photographs. The scale of the old aerial photographs were adjusted by photocopying to match the scale of the new aerial photographs (1 inch = 400 feet). The channel outline from the old photographs was then transposed onto the new aerial photographs. This comparison showed that, overall, little lateral migration has occurred. Most of the lateral migration that has occurred could be explained by man-made activities on or near the channel. Table 5-1 summarizes the areas of lateral adjustment of Monument Creek from 1962 to the present.

Table 5-1
Historic Channel Planform Information (1962-present)

Location of Area	Description of Lateral Adjustment	Present Structures and Stabilization	Probable Cause of Lateral Adjustment
Downstream of Van Buren Street	Very mild channel bend has been shifted inward 80 feet	Six-foot masonry wall along outer bank.	Channel realigned for development purposes
Upstream of Fillmore Street	Two channel bends have shifted inward 200 feet and 100 feet	Riprap protection along outer bank of one channel bend that has failed.	Channel realigned for development purposes.
Downstream of I-25	Unvegetated channel width has narrowed from 400 feet to 80 feet	Exposed sewer crossing just downstream of I-25, Riprap protection of bridge abutments.	Natural channel narrowing.
Upstream of I-25	Five channel bends have shifted: 90 feet outward, 30 feet inward, 70 feet inward, 70 feet outward, and 350 feet inward.	Riprap protection along the toe of four of the outer banks. A 50-foot high wood retaining wall along the outer bank of fifth outer bank.	Channel realigned by man for development purposes and protection of a roadway embankment.
Upstream of Woodmen Road	Meander bend has shifted outward 90 feet	Grouted riprap protection along banks to protect bridge abutments.	Natural lateral migration.
Upstream of Pine Creek	Meander bend has shifted outward 220 feet	Riprap protection on outer bank.	Natural lateral migration.

5.3.3 Field Reconnaissance

A thorough field reconnaissance of the Monument Creek study reach was conducted. Data documented during the field reconnaissance included:

- Unvegetated channel width
- Hydraulic roughness of the floodplain
- Bank vegetation
- Bank failures
- Bed material size
- Locations of exposed bedrock in the channel bed
- Water quality
- Sediment transport characteristics
- Flow depth
- Flow width
- Channel pattern
- Water temperature
- Location and drop height of exposed sanitation sewer crossings
- Location and drop height of check dams
- Pier scour at bridge crossings
- Relative flow and sediment contribution from tributaries
- Location and condition of bank protection measures (riprap, gabions)

In addition, photographs were taken during the entire field reconnaissance.

Representative 1992 channel characteristics are summarized in Figure 5-4. Channel characteristics shown include flow depth, channel pattern, sinuosity, historic bed movement, and unvegetated channel width.

5.3.4 Summary of Findings Based on Historical Evidence

The historic stability of each of the seven reaches is summarized in the following subsections.

5.3.4.1 Reach M1, Confluence with Fountain Creek to Bijou Street

The channel in this reach resembles the disturbed stream cross section shown previously in Figure 2-4. The base flow channel consists of a wide, shallow, sandy bed and the floodplain channel is narrow and deep as a result of floodplain filling. Grass, shrub, and woodland vegetation cover the floodplain bottom. The base flow channel has a braided form with an average unvegetated width of approximately 70 feet (35 to 100 feet), a depth of approximately 6 inches, and a channel sinuosity of approximately 1.06, as shown in Figure 5-4. During base flow conditions sediment transport is high in this reach and consists primarily of bed loads.

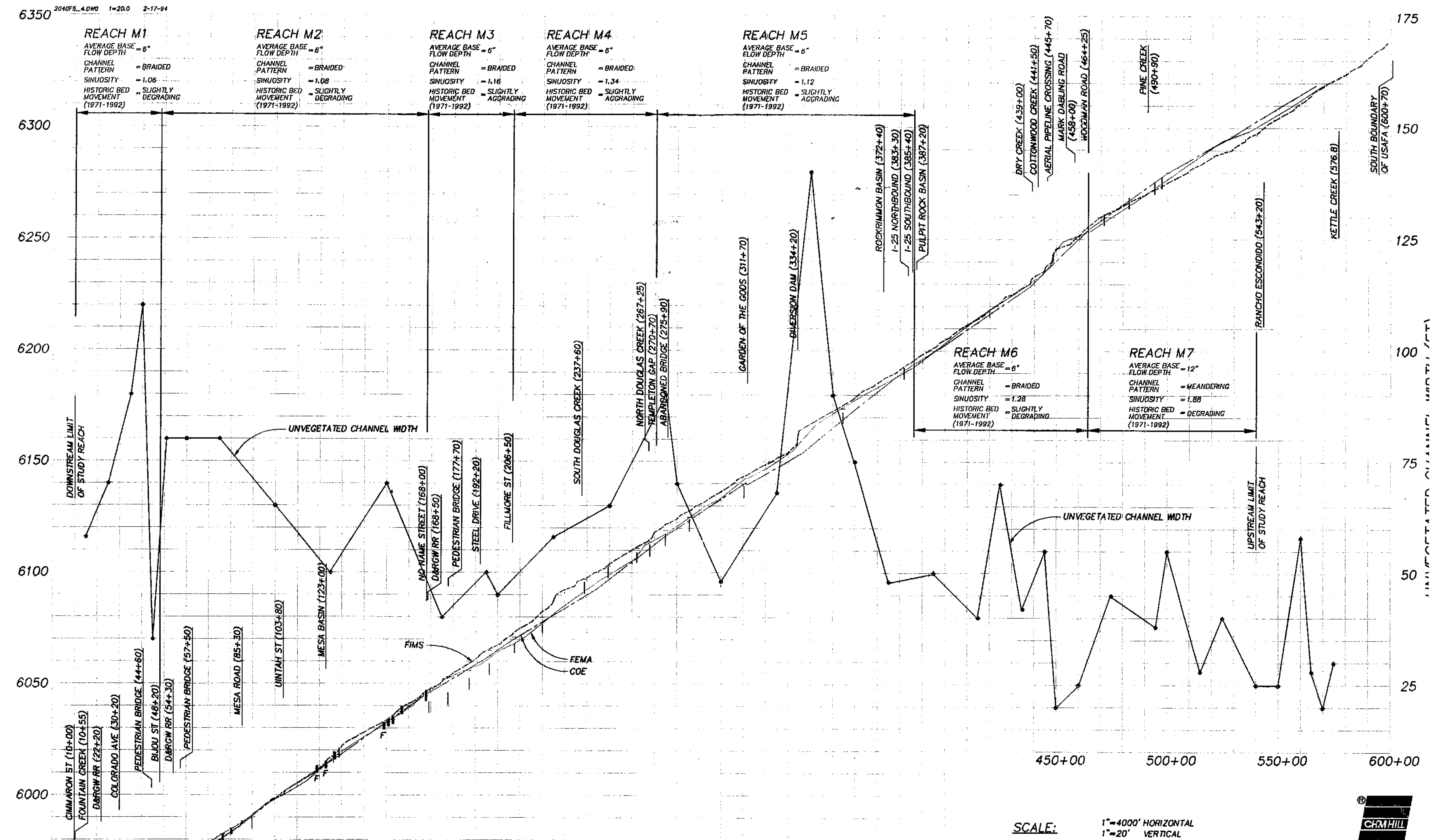

FIGURE 5-4
1992 CHANNEL CHARACTERISTICS OF MONUMENT CREEK

Crossing structures in this reach include two sanitary sewer crossings and three check dams. One of the sanitary sewer crossing is exposed and has drop height of 2.5 feet. All of the check dams were observed to be intact. Pier scour at the West Colorado Avenue bridge was indicated in bridge inspection reports. As shown in Figure 5-3, the bed profiles over the last 20 years indicate little change in bed elevation. From the information collected, it is concluded that degradation occurred in this reach at one time, but that during the last 20 years, vertical adjustments have remained minimal because of check dams, sanitary sewer crossings, and exposed bedrock controls.

The floodplain channel banks are protected by stone flatwork in most of this reach. Other bank protection includes a 6-foot concrete wall that protects the left bank of the base channel immediately downstream of Bijou Street. One 4-foot-high vertical bank is actively eroding and is in need of stabilization.

On the basis of historic planform information dating back to 1962, no significant lateral movement has occurred. This is understandable, because most of the development in this reach was in place by 1962, and any alterations to the channel planform caused by development probably took place prior to 1962.

5.3.4.2 Reach M2, Bijou Street to Van Buren Street

As in reach M1, the channel in this reach resembles the disturbed stream cross section shown previously in Figure 2-4. The base flow channel consists of a wide, shallow sandy bed and the floodplain channel is narrow and deep due to floodplain filling. Grass, shrub, and woodland vegetation cover the floodplain bottom. The base flow channel has a braided form with an average unvegetated width of approximately 75 feet (50 to 95 feet), a depth of approximately 6 inches, and a channel sinuosity of approximately 1.08 as shown in Figure 5-4. During base flow conditions sediment transport is high in this reach and consists primarily of bed loads.

Existing crossing structures in this reach include three sanitary sewer crossings, one water line crossing, and 12 check dams. All three sanitary sewers are exposed and have drops of 3 inches, 12 inches, and 0 inches. The water line crossing is also exposed and has a drop of 2 feet. In addition, four of the 12 check dams have failed. Bank failure and exposed bedrock were commonly found downstream of the failed check dams. The comparison of the bed profiles shown in Figure 5-3 indicates little change in bed elevation over the last 20 years. As with reach M1, it is concluded that degradation has occurred in this reach at one time, but during the last 20 years, vertical adjustments have remained minimal because of check dams, sanitary sewer crossings, and bedrock controls.

The floodplain channel banks are provided with stone flatwork protection in most of this reach. Other bank protection measures include a 20-foot concrete wall just upstream of Bijou Street and a 6-foot masonry wall downstream of Van Buren Street. Despite the existing bank protection, several areas of eroded, vertical base flow channel banks, ranging from 3 to 10 feet in height, exist in this reach and are in need of stabilization.

Historic planform information indicates a mild channel bend has been shifted inward 80 feet downstream of Van Buren Street. The probable cause of this lateral adjustment is man-made channel realignment for development purposes.

5.3.4.3 Reach M3, Van Buren Street to Fillmore Street

The channel in this reach also resembles the disturbed stream cross section shown previously in Figure 2-4. The base flow channel consists of a wide, shallow sandy bed and the floodplain channel is narrow and deep due to floodplain filling. Grass, shrub, and woodland vegetation cover the floodplain bottom. The base flow channel has a braided form with an average unvegetated width of approximately 45 feet (40 to 50 feet), a depth of approximately 6 inches, and a channel sinuosity of approximately 1.16, as shown in Figure 5-4. During base flow conditions sediment transport is high in this reach and consists primarily of bed loads.

Crossing structures in this reach include four sanitary sewer crossings, none of which are exposed. In addition, no exposed bedrock was found in this reach. These signs, plus the comparison of bed profiles shown in Figure 5-3, indicate that the channel has slightly aggraded over the past 20 years. Some local pier scour, however, was observed at the Fillmore Street bridge.

Existing channel bank protection includes a gabion wall on the right bank just upstream of the DRGRR bridge and riprap on the left bank just downstream of Polk Street. The gabion wall just upstream of the railroad bridge is showing signs of instability. Several eroded vertical banks, ranging in height from 15 to 30 feet, exist in this reach and are in need of stabilization.

Historic planform information indicates no significant lateral movement has occurred since 1962. Most of the development in this reach was in place in 1962 and any alterations to the channel planform probably took place prior to 1962.

5.5.4.4 Reach M4, Fillmore Street to Templeton Gap Confluence

As in reaches M1 through M3, the channel in this reach resembles the stream cross section shown in Figure 2-4. The base flow channel consists of a wide, shallow sandy bed and the floodplain channel is narrow and deep due to floodplain filling. Grass, shrub, and woodland vegetation cover the floodplain bottom. The base flow channel has a braided form with an average unvegetated width of approximately 60 feet, a depth of approximately 6 inches, and a channel sinuosity of approximately 1.34, as shown in Figure 5-4. During base flow conditions sediment transport is high in this reach and consists primarily of bed loads.

Crossing structures in this reach include six sanitary sewer crossings, two of which are exposed, with drops of 4 and 12 inches. Note that according to construction plans, the exposed sanitary sewer crossings were built only 6 to 12 inches below the streambed invert. No local pier or abutment scour was observed at any of the bridges in this reach. Also, no exposed bedrock was found. The comparison of bed profiles shown in Figure 5-3 indicates that the channel has aggraded over the past 20 years. From the information collected, it is concluded that this reach has aggraded slightly over the past 20 years.

Several channel bank sections are protected by riprap, one of which is currently being undermined. Several areas of eroded vertical banks, varying in height from 6 to 30 feet, are located in this reach and are in need of bank stabilization.

Historic planform information indicates that two channel bends located just upstream of Fillmore Street have shifted inward 200 and 100 feet. The probable cause of this lateral adjustment is man-made channel realignment for development purposes.

5.3.4.5 Reach M5, Templeton Gap Confluence to I-25

The channel in this reach resembles the stream cross section shown in Figure 2-4. The base flow channel consists of a wide, shallow sandy bed and the floodplain channel is narrow and deep due to floodplain filling. Upstream and downstream of Garden of the Gods Road, significant filling of the left floodplain with trash and debris is evident. Grass, shrub, and woodland vegetation cover the floodplain bottom. The base flow channel has a braided form with an average unvegetated width of approximately 90 feet, a depth of approximately 6 inches, and channel sinuosity of approximately 1.12, as shown in Figure 5-4. A non-potable diversion structure, Pikeview Diversion Dam, is located upstream of Garden of the Gods Road. The base-flow channel upstream of the Pikeview Diversion Dam is very wide (200 feet). The channel bottom in this reach is subject to motion as disturbance or sediments are periodically flushed through the dam. During base flow conditions, sediment transport is high and consists primarily of bed loads.

Crossing structures in this reach include five sanitary sewer crossings and the Pikeview Diversion Dam. One of the sanitary sewer crossings, located just downstream of I-25, was exposed. The Pikeview Diversion Dam drop was estimated in 1991 to be 6 feet and in 1993 to be 8 feet, indicating significant degradation downstream of the dam. The foundation piling for the dam has been exposed as a result of the degradation.

No local pier or abutment scour was observed at any of the bridges in this reach. In addition, no exposed bedrock was found. These signs, plus the comparison of bed profiles shown in Figure 5-3, indicate that the channel has slightly aggraded over the past 20 years, with the exception of the reach downstream of the Pikeview Diversion Dam that is degrading.

Channel bank sections protected by riprap are located just upstream of Garden of the Gods Road, between Garden of the Gods Road and I-25, and just downstream of I-25. Vertical, eroded banks ranging in height from 30 to 35 feet and in need of bank stabilization are located just upstream of the Templeton Gap confluence and just downstream of I-25.

Historic planform information indicates that over the last 20 years the unvegetated channel width has narrowed from 400 feet to 80 in a location immediately downstream of I-25. The narrowing of the unvegetated channel is not due to floodplain filling, but to the establishment of a dense stand of cottonwood trees on the east overbank area.

5.3.4.6 Reach M6, I-25 to Woodmen Road

As in reaches M1 through M5, the channel in this reach resembles the disturbed stream cross section shown previously in Figure 2-4. The base flow channel consists of a wide, shallow sandy bed and the floodplain channel is narrow and deep due to floodplain filling. Grass, shrub, and woodland vegetation cover the floodplain bottom. The base flow channel has a braided form with an average unvegetated width of approximately 60 feet, a depth of approximately 6 inches, and a channel sinuosity of approximately 1.28, as shown in Figure 5-4. During base flow conditions sediment transport is high in this reach and consists primarily of bed loads. Significant sediment load is supplied to this reach by Cottonwood Creek.

One 18-inch-diameter pipeline crossing (no concrete encasement) is located in this reach. The pipeline is exposed, but there is no drop (top of pipe matches the channel invert). No local pier or abutment scour was observed at bridges in this reach. Several areas of exposed bedrock and a 6-foot bedrock drop are evident downstream of Mark Dabling Boulevard. The comparison of bed profiles shown in Figure 5-3 indicates that bed elevation has not changed much over the past 20 years. Degradation has likely occurred in this reach at one time, but during the last 20 years, vertical adjustments have remained minimal because of bedrock controls.

Sections of channel banks in this reach are protected by a variety of measures, such as riprap, a large crib retaining wall, and concrete slope paving. The crib retaining wall protects a long section of the west bank between I-25 and Mark Dabling Boulevard and concrete flatwork protects the floodplain channel banks between Mark Dabling Boulevard and Woodmen Road. No significant bank erosion was observed in this reach.

Historic planform information indicates that five channel bends have shifted over the last 20 years. The planform changes appear to be man-made as a result of grading for adjacent development sites.

5.3.4.7 Reach M7, Woodmen Road to South Boundary of USAFA

The channel in this reach is different in character from the downstream reaches (M1 through M6) because it has generally been left in its natural configuration. The geometry resembles the natural stream cross section shown previously in Figure 2-4. The natural channel is characterized by a relatively deep and narrow meandering base flow channel and a wide, vegetated floodplain channel. The bed material in this reach consists of sand, gravel, and small cobbles and is larger than the bed material in the downstream reaches. The base flow channel has a meandering pool and riffle pattern with a sinuosity of 1.88. The average base flow depth in this reach is approximately 1 foot and the average unvegetated channel width is approximately 40 feet. During base flow conditions, sediment transport in this reach appears to be lower.

Crossing structures include four sanitary sewer crossings. All four of the sanitary sewer crossings are exposed and have vertical drops between 6 inches and 4 feet. Two areas of exposed bedrock were found in this reach. Comparison of bed profiles in Figure 5-3 indicate that bed elevation has significantly decreased over the past 20 years. From the information collected, it appears that this reach has been degrading over the last 20 years.

Two sections of channel in this reach are protected by riprap: the left and right banks just upstream of Woodmen Road and a left bank section downstream of USAFA boundary. Several eroded, vertical bank sections with heights ranging from 20 to 30 feet are located in this reach and are in need of stabilization.

Historic planform information indicates that the channel has shifted laterally at two locations. Just upstream of Woodmen Road, a meander bend has shifted outward approximately 90 feet. Also, a meander bend has shifted outward approximately 220 feet just upstream of the Pine Creek confluence. Both shifts appear to be caused by natural channel migration.

5.4 Estimation of Long-Term Equilibrium Slope

Two analyses were conducted to analyze the long-term equilibrium slope of Monument Creek. The first analysis reviewed the affects of watershed sediment yield on the equilibrium slope. The second analysis assessed the affects of tributary sediment supply on equilibrium slope. Both analyses were conducted assuming that Monument Creek slope is presently in equilibrium.

5.4.1 The Influence of Watershed Sediment Yield on Equilibrium Slope

The objective of this analysis was to develop a relationship for equilibrium slope based on watershed sediment yield ($Q_{s,w}$). The relationship was developed according to the slope stability equation presented below (SLA, 1985).

$$q_{b,s} = \frac{0.0064\ n^{1.77}\ V^{4.32}\ G^{0.45}}{Y_h^{0.30}\ D_{50}^{0.61}} \qquad \text{(Eq. 5-2)}$$

where:

- $q_{b,s}$ = bed material discharge, cubic feet per second/foot (cfs/ft)
- n = Manning's roughness coefficient
- V = velocity, feet per second (ft/s)
- G = gradation coefficient
- Y_h = hydraulic depth, feet
- D_{50} = median bed particle size, mm

Data from a 1989 U.S. Geological Survey study of sediment transport in the Fountain Creek Basin was used to calibrate Equation 5-2 at two cross sections of Monument Creek, section M10 and section M16. Section M10 was located at the U.S. Geological Survey (USGS) flow measurement gage at Pikeview, Colorado, just downstream of the Cottonwood Creek confluence. Section M16 was located on the downstream section of the study reach approximately 4,000 feet upstream of the confluence with Fountain Creek. The USGS report developed regression equations for suspended bed material discharge and total suspended discharge at both sections. Bed load discharge data and bed material size distribution data were also provided. Cross section information for section M10 was determined from information provided in the USGS report. Cross section data for M16 was estimated from the 1989 FIMS mapping. Equation 5-2 was calibrated by utilizing the sediment discharge data provided by the USGS at both sections and an estimated effective water discharge. The Hydraulic roughness variable (Manning's n) was adjusted at each section to fine tune the calibration of Equation 5-2. This resulted in equations of bed material discharge as a function of stream slope.

The next step of the analysis was to develop relationships of watershed sediment yield as a function of bed material discharge. This was done by adjusting the bed material discharge relationships to be representative of finer sediment expected from watershed erosion (deducted bed load and added wash load). Dividing the new relationships of finer sediment discharge by the drainage area upstream of each section resulted in equations for watershed sediment yield, which could be expressed as a function of stream slope.

Figure 5-5 shows the resulting relationship between watershed sediment yield and long-term stream slope. The figure depicts how the long-term equilibrium slope of Monument Creek is estimated to vary based on the quantity of suspended sediment inflowing from the upstream watershed. At present, the slope of Monument Creek within the study reach is approximately 0.7 percent. This corresponds to relatively high sediment yields of 0.6 tons per acre per year (t/ac/yr) for the watershed upstream of Pikeview and 1.2 t/ac/yr for the entire watershed.

If the inflowing sediment quantity remains the same in the future, the channel slope in the study reach is expected to remain about the same as it is currently. If the sediment yield increases as a result of increased uncontrolled construction erosion or tributary stream erosion, the study reach slope is expected to increase as aggradation occurs. If the sediment yield decreases in the future due to improved erosion control measures, the study reach slope will decrease and degradation will occur.

Future trends in watershed sediment yield and recommendations regarding long-term equilibrium slope are discussed in Subsection 5.5.

5.4.2 The Influence of Tributary Channel Stabilization on Equilibrium Slope

To provide a check on the analysis of equilibrium slope based on sediment yield, a second analysis was conducted. The objective of this second analysis was to relate long-term equilibrium slope to the stabilized slope of the tributary channels that supply sediment to Monument Creek. As discussed in Subsection 5.2.1, a stream reach is in equilibrium when the sediment supply from upstream sources is equal to the sediment transport capacity of the reach. Equation 5-2, which is based on bed material discharge, was used to model the sediment transport capacity of Monument Creek.

5.4.2.1 Monument Creek Cross Sections

Two representative cross sections were used to analyze the sediment transport capacity of Monument Creek. The M10 site discussed in Subsection 5.4.1 was used to represent the upper and middle reaches of Monument Creek. The channel width, side slopes, and channel slope was estimated from the FIMS mapping (FIMS, 1991) to be 50 feet, 1V:4H, and 0.007, respectively. The bed material size distribution was assumed to be equal to the values documented in the USGS report for site M10. The lower reach was represented by a cross section with a width of 90 feet, side slopes of 1V:4H, and channel slope equal to 0.0069. The bed material size distribution was assumed to be equal to the values documented for site M16 in the USGS report (USGS, 1989). Both of the representative cross sections were assumed to have Manning n values equal to 0.030.

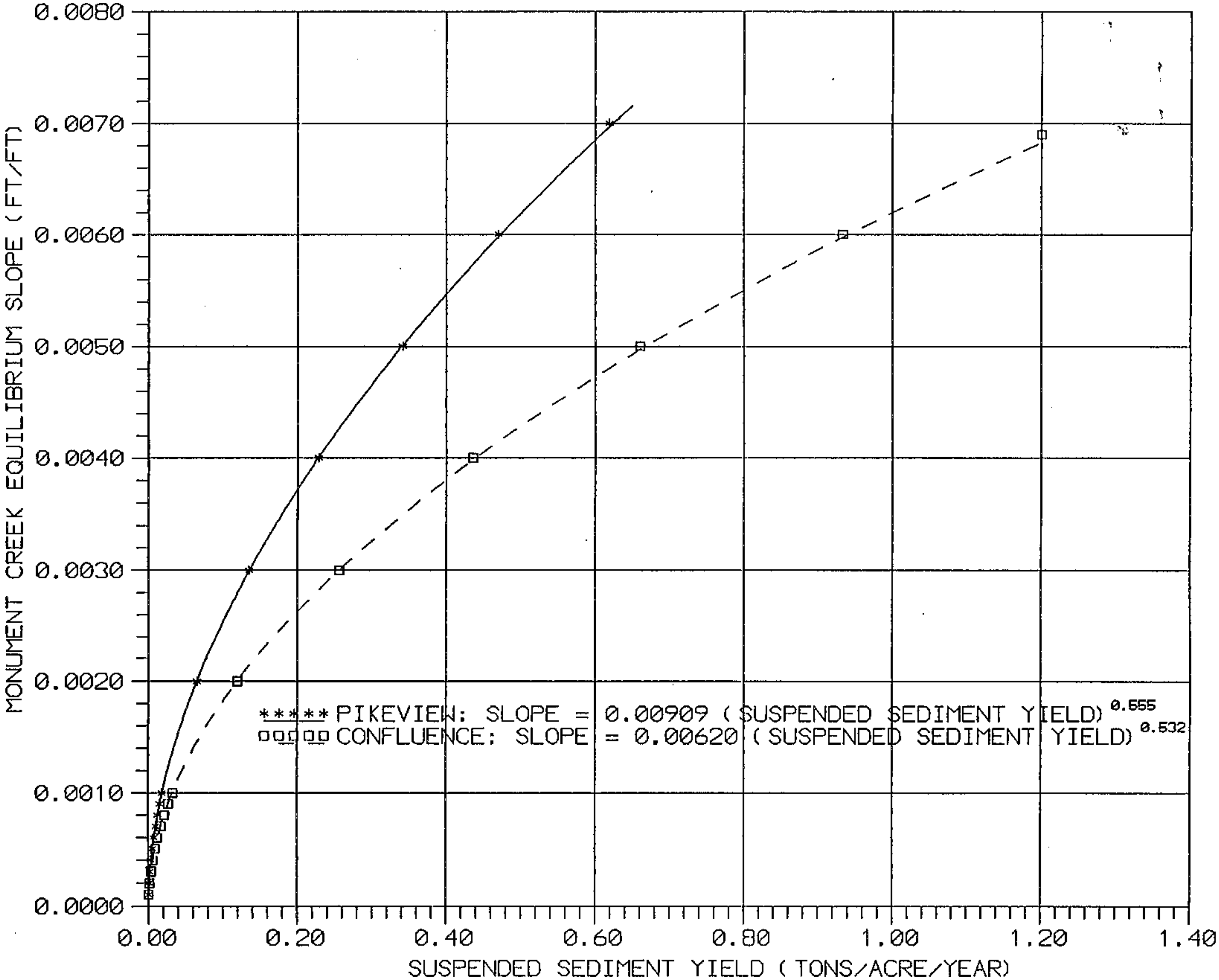

Figure 5-5
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SUSPENDED SEDIMENT YIELD

5.4.2.2 Tributary Cross Sections

Analyzing the sediment supplied to Monument Creek from every one of the 28 major basin tributaries was not feasible due to the lack of cross-sectional data. Cottonwood Creek was assumed to represent the tributary channels because it supplies a significant amount of sediment to Monument Creek and has available cross section data (USGS, 1989 and URS, 1991). The representative cross section of Cottonwood Creek was located near the confluence. The width, channel side slopes, and channel slope were estimated as 40 feet, 1V:4H, and 0.0178. The Manning's n was assumed to 0.030 and the bed material distribution was assumed to be equivalent to the values documented by the USGS for site M10.

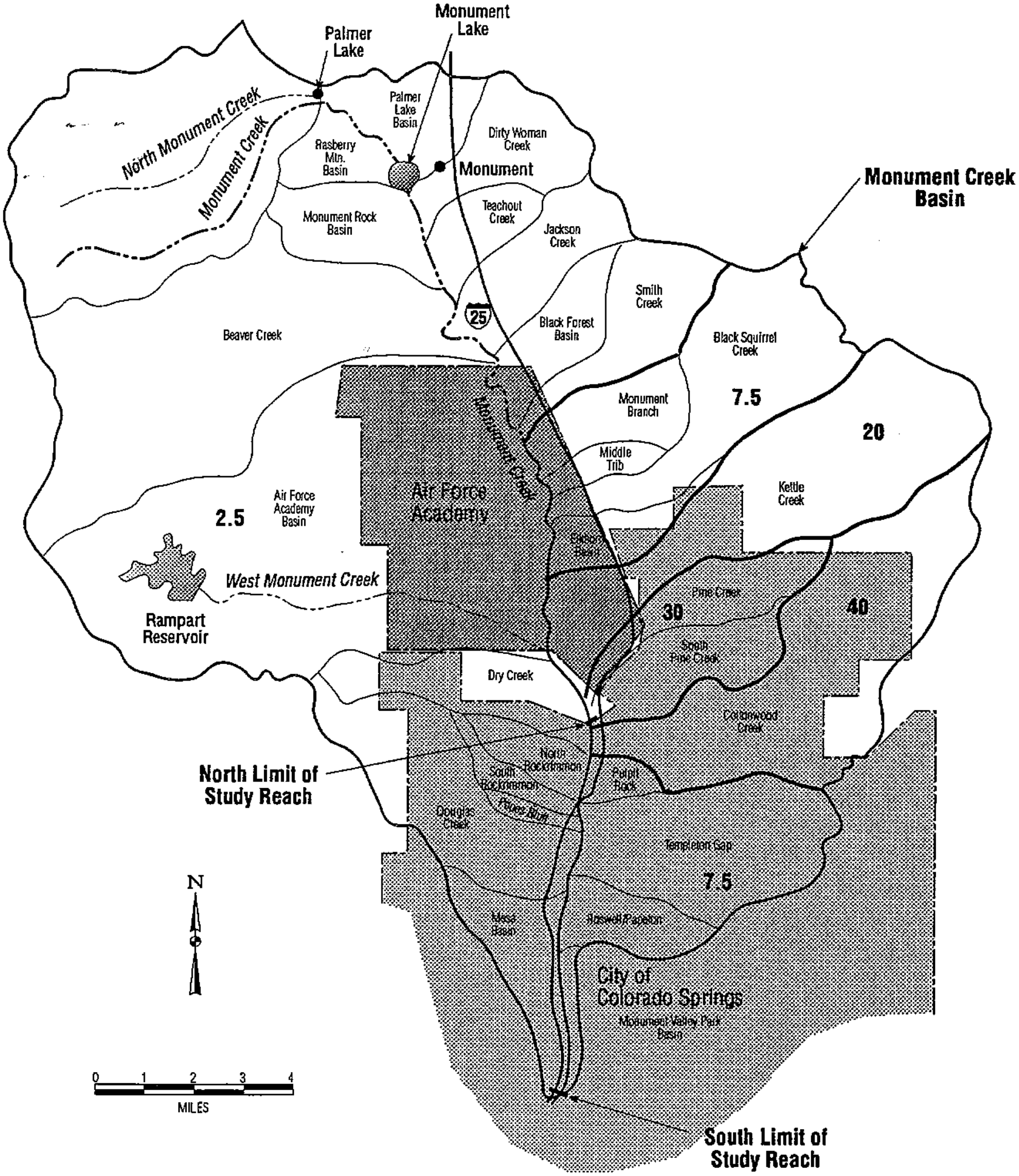
5.4.2.3 Estimating Tributary Sediment Supply

Estimation of the total sediment supply from the tributaries was based on the sediment supply from Cottonwood Creek. This required an estimation of the ratio of total tributary sediment supply to Cottonwood Creek sediment supply (i.e., a tributary discharge factor). To estimate the tributary discharge factor, suspended sediment data collected by the USGS was assessed. This data was collected during a storm on May 21, 1985 (USGS, 1988). Figure 5-6 depicts suspended sediment yields determined by the USGS from the collected data. For areas where the suspended sediment yield was not determined, the suspended sediment yield was estimated. Figure 5-7 shows the assumed suspended sediment yields for seven Monument Creek basin areas. The area of each of the seven sections was determined and then multiplied by the suspended sediment yield values. This resulted in suspended sediment loads for each of the seven areas. The sediment load for each of the seven areas was divided by the sediment load from Cottonwood Creek. The tributary discharge factor was determined by summing the sediment load ratios. The tributary discharge factor was determined to be 2.74 for the upstream cross section and 2.97 for the downstream cross section.

5.4.2.4 Sediment Discharge Capacity of Monument Creek.

The next step in the analysis was to determine the sediment discharge capacity of Monument Creek at both the upstream and downstream cross sections. Instead of using total sediment discharge, bed material discharge was used because it is more representative of adjustments in the slope of the channel bed. The bed material discharge was calculated according to Equation 5-2. The discharge that was used in this equation was the dominant discharge or bankfull discharge because it controls the long-term channel morphology. It was estimated that the bankfull discharge was 750 cfs at the Pikeview gauge and 500 cfs upstream of the confluence with Fountain Creek.

Utilizing the estimated bankfull discharge flows and the cross-sectional and bed material characteristics described in Subsection 4.2.1, the bed material discharge was estimated for the upstream and downstream cross section. At the upstream cross section, the bed



Values shown are approximately suspended sediment yields in tons per square mile estimated from data collected by USGS during rainfall-runoff period of May 21, 1985.

Figure 5-6
MAY 21, 1985
SUSPENDED SEDIMENT YIELDS

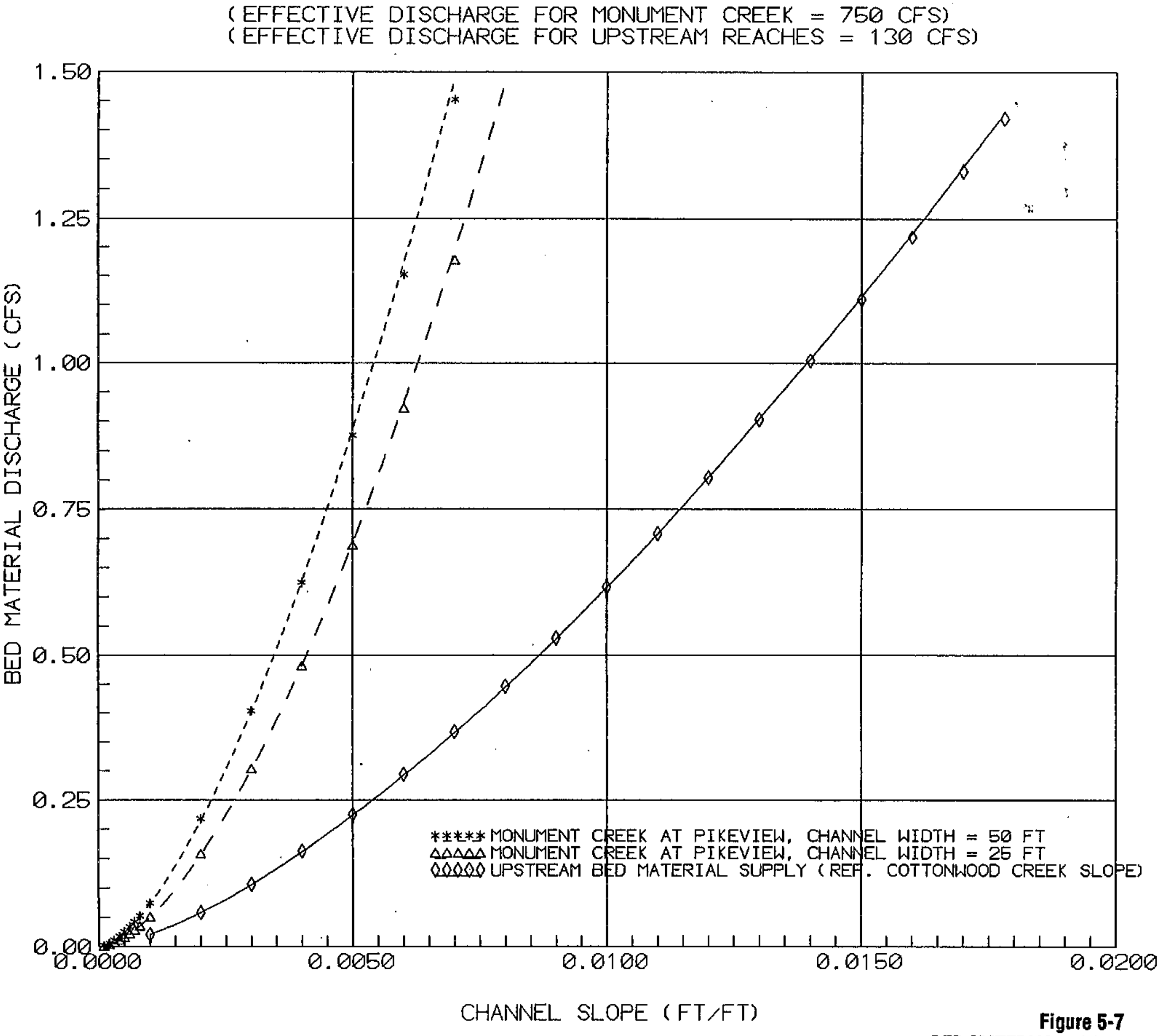


Figure 5-7
BED MATERIAL DISCHARGE VERSUS CHANNEL SLOPE AT PIKEVIEW

material discharge was estimated as 1.45 cfs, while the bed material discharge at the downstream cross section was estimated as 3.96 cfs.

This entire procedure was repeated for a narrower channel cross section to check the sensitivity of the results to variations in channel width. The widths of upstream and downstream cross sections used for this analysis were 25 feet and 35 feet, respectively. The analysis resulted in bed material discharges of 1.18 cfs and 3.37 cfs.

The bed material discharge for each of the four relationships (two widths for each of the two sites) was estimated for slopes ranging from 0.006 to 0.0001. These relationships were plotted in Figures 5-7 and 5-8.

5.4.2.5 Sediment Supply from the Tributaries

The bed material discharge from all tributaries upstream of the two sites on Monument Creek was determined by estimating the bed material discharge from Cottonwood Creek and then multiplying this by the tributary discharge factor. The bed material discharge for Cottonwood Creek was determined from Equation 5-2 utilizing the cross-sectional characteristics described in Subsection 4.2.1. Because Cottonwood Creek represented all the tributaries, the dominant discharge could not be determined from conventional methods (i.e., bankfull discharge). Since the Monument Creek was assumed to be in equilibrium, the total bed material supplied by the tributaries was set equal the bed material transport capacity of Monument Creek. Based on this assumption, the representative dominant discharge was estimated by trial and error until the bed material supplied to the upstream and downstream cross sections equaled the bed material capacity of 1.45 cfs and 3.96 cfs, respectively for the "wide" channel cross sections. This procedure resulted in representative dominant discharges of 130 cfs for tributaries supplying the upstream cross section and a representative dominant discharge of 255 cfs for tributaries supplying the downstream cross section.

The total bed material supplied to both cross sections was calculated for Cottonwood Creek slopes ranging from 0.017 to 0.001. These results were then plotted along with the bed material transport capacity results in Figures 5-9 and 5-10.

5.4.2.6. Equilibrium Slope of Monument Creek Based on Tributary Channel Slope

Figures 5-9 and 5-10 display a total of six relationships. Using a software package called "Grapher" (Golden Software, 1991), best fit lines were determined.

Equilibrium conditions were modeled by equating the bed material supply and bed material transport capacity for each cross section (two sites with two cross-section widths). This resulted in relationships of equilibrium slope of Monument Creek based on tributary channel slope (represented by Cottonwood Creek). The results are shown in Figures 5-9 and 5-10. These figures depict how the long-term equilibrium slope of Monument Creek

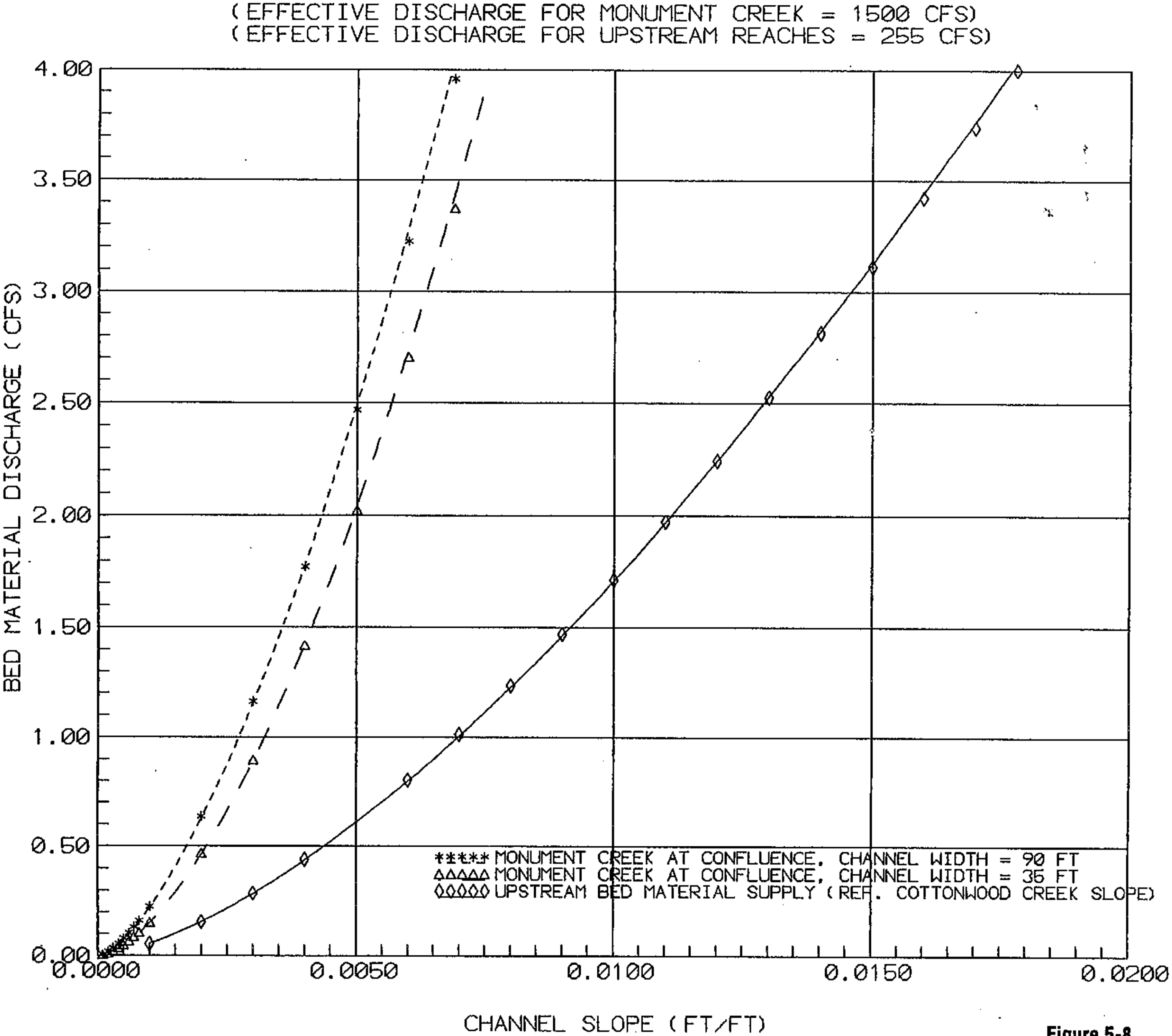


Figure 5-8
BED MATERIAL DISCHARGE VERSUS CHANNEL SLOPE AT CONFLUENCE

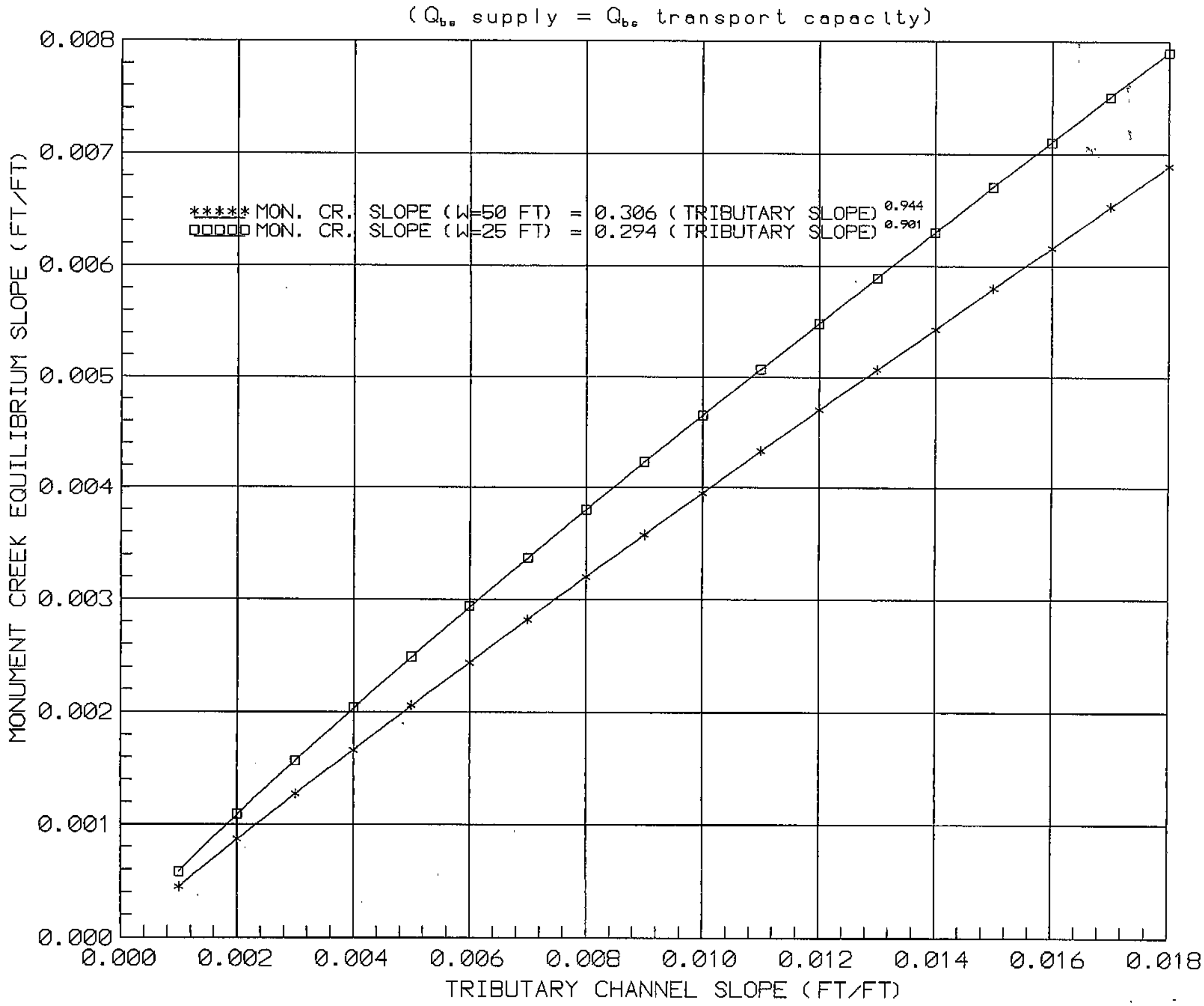


Figure 5-9
EQUILIBRIUM SLOPE VERSUS TRIBUTARY CHANNEL SLOPE AT PIKEVIEW

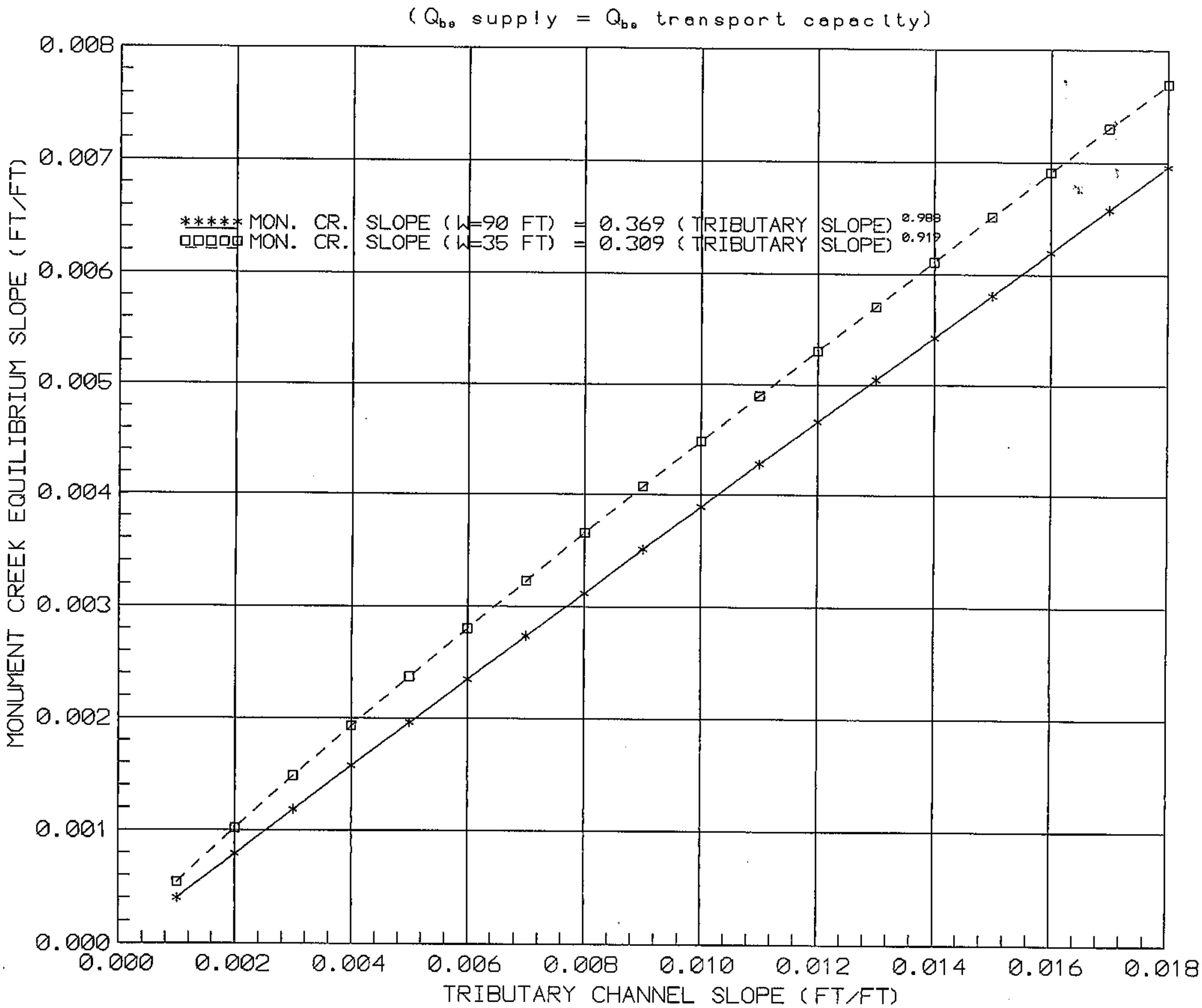


Figure 5-10
EQUILIBRIUM SLOPE VERSUS
TRIBUTARY CHANNEL SLOPE AT CONFLUENCE

is estimated to vary with the stabilized slope of tributary channels supplying sediment to the study reach.

5.5 Conclusions

As discussed in Subsection 5.2.1, Monument Creek is in a state of dynamic equilibrium when the sediment supplied from upstream watershed areas and tributary channels is equal to the sediment transport capacity of the creek. Currently, the sediment supply is high. In fact, predevelopment rates of sediment yield from the upstream watershed of Monument Creek have historically been high (observations of 1963 aerial photography show evidence of significant stream and watershed erosion). Urbanization has likely caused sediment yield to increase above natural rates. First, uncontrolled erosion from construction sites has been documented to be as much as 20 to 200 times greater than that from watershed areas in a predevelopment condition. Second, the increased volume and frequency of runoff from impervious urban areas has caused degradation in streams carrying urban runoff, eroding substantial quantities of sediment from the streams' bed and banks. Substantial bed and bank erosion is evident in tributary streams to Monument Creek, such as Cottonwood Creek. This erosion has been the cause of damage to utilities, undermining of bridge foundations, and loss of property adjacent to the stream and a large sediment supply to Monument Creek.

Because the sediment supply has been high, the current sediment transport capacity of Monument Creek is great, evidenced by a steep stream slope (0.7 percent) and a braided stream pattern in the majority of the study reach. However, it seems likely that the sediment supply to Monument Creek will decrease steadily in the future. If future development continues in the upstream watershed, sediment yield will ultimately be reduced by stabilization of the ground surface with pavement, roofs, and landscaped areas. Increased attention to controlling erosion from construction and other land disturbing activities would also decrease the sediment supply. Recent National Pollutant Discharge Elimination System (NPDES) storm water regulations encourage the adoption of management programs to control erosion. Individual tributary drainage basin planning studies typically call for the construction of drop or check structures to control stream erosion. As these plans are implemented, the quantity of sediment supplied by tributary streams will be reduced. Tributary channels will achieve a flatter slope as erosion continues to remove bed material. Construction of drop structures on the tributary channels in accordance with individual DBPSs will also flatten slopes and decrease sediment supply erosion and degradation.

Monument Creeks slope will decrease when a long-term decrease in sediment supply occurs. Figures 5-5, 5-6, and 5-7 were prepared to provide insight into the equilibrium slope that could develop in Monument Creek as a result of future decreases in watershed sediment yield and tributary channel slope. Based on monitoring results from fully stabilized urban basins, it is possible that future watershed sediment yield could be as low as 0.1 t/ac/yr. The long-term equilibrium slope corresponding to this yield in Figure 5-5 is approximately 0.2 percent. It is expected that the future stable slope of drainage channels typical of the Monument Creek tributary basins may be in the range of 0.4 to 0.5 percent. These slopes also correspond to a long-term equilibrium slope of approximately 0.2 percent in the study reach, according to Figures 5-6 and 5-7.

It is recommended that an ultimate equilibrium slope of 0.2 percent be used to plan for stream improvements in the study reach of Monument Creek. Because the actual equilibrium slope is directly related to the amount of sediment supplied to the study reach, monitoring the quantity of sediment inflow would reduce uncertainty in the estimate of equilibrium slope. Monitoring would also provide insight into the rate of change of the equilibrium slope, information useful for selecting an implementation schedule for stream improvements. If, in the future, monitoring shows that the equilibrium slope stabilizes at a steeper slope, fewer grade control structures would be required than identified herein.