ROCKRIMMON NORTH
DRAINAGE BASIN PLANNING STUDY

COLORADO SPRINGS, COLORADO
May 1992

Prepared for:

CITY OF COLORADO SPRINGS

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May want to switch these around. Need to present recommendation in conjunction with fee determination.

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I. INTRODUCTION

Authorization

In _____ of 19__, the City commissioned engineering services for three Drainage Basin Planning Studies; Rockrimmon North, Bear Creek and Cottonwood Creek. The City awarded the Rockrimmon Study to KLH Engineering, Inc. The study was approved by the Colorado Springs/El Paso County Drainage Board ~~and~~ the Colorado Springs City Council. The study was completed in _____, 1992. Subconsultants of KLH participating in the study included:

- NSA, Inc. - Landuse and environmental analysis
- GCI, Inc. - Geotechnical Analysis

Study Location

The Rockrimmon North Drainage Basin lies in the northwestern portion of Colorado Springs, as shown in the Appendix. It occupies portions of Section 11, 12, 13, and 14 of Township 13 South, Range 67 West, and portions of Sections 7 and 18 of Township 13 South, Range 66 West of the 6th P.M. The basin drains in a southeasterly direction to the outfall points along Monument Creek near the Rockrimmon Boulevard interchange at Interstate Highway 25.

The total basin comprises 1271 acres (2 square miles), all of which is within the existing Colorado Springs City Limits.

The basin is bounded on the south and west by the Rockrimmon South Basin, at the west tip by the Douglas Creek Basin, on the northeast by the Dry Creek Basin and on the east by Monument Creek.

Study Objective and Scope

The Drainage Basin Planning Study (DBPS) provides a basis and direction for future planning and design of drainage facilities. The study provides a plan that incorporates the input and review of many diverse agencies and interest groups including:

- Local public citizens and public interest groups
- Local Homeowner's Associations
- City Engineering ~~Department~~ Division
- City Parks ~~Department~~ and Recreation Dept.
- City Planning Department
- City/County Drainage Board
- Colorado State Engineer's Office
- U.S. Fish & Wildlife Service
- U.S. Army Corps of Engineers
- Colorado Division of Wildlife

The study will conform with the drainage criteria adopted by the City of Colorado Springs in 1987. The existing and proposed drainage systems within the basin were analyzed and where deficiencies exist, alternatives and a recommended plan was developed.

Drainage Basin Planning Studies have two primary objectives:

1) To develop a Drainage Plan that provides a safe and economical drainage system for the major and minor drainageways through the basin, while still accounting for the public regulations and the interests of private citizens with respect to the environmental and social concerns.

2) To develop a fee structure that accounts for the anticipated expenses associated with the public improvements required within this basin.

The scope of work was broken down into four basic phases:

Phase I	- Gathered relevant information - Acquired mapping - Inventoried existing drainage facilities
Phase II	- Developed hydrologic model - Conducted hydraulic analysis
Phase III	- Developed alternatives - Conducted public & agency reviews - Selected preferred alternative
Phase IV	- Generated an economic analysis - Finalized study through approval process

II. "EXECUTIVE SUMMARY"

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III. BACKGROUND INFORMATION

Previous Drainage Studies

Basin studies of the Rockrimmon North Drainage Basin include the following:

1) "Hydrologic Engineering Study of the Rockrimmon North and Rockrimmon South Drainage Basins" by Karcich & Weber, Inc., dated March, 1967.

2) "Hydrologic Engineering Study of the Rockrimmon North Drainage Basin" by United Western Engineers, dated March, 1973.

3) "Flood Insurance Study - City of Colorado Springs" prepared by Federal Emergency Management Agency (FEMA), dated December, 1986.

The first study, done in 1967, for the City of Colorado Springs used procedures as outlined by the Soil Conservation Service (SCS) and modified by the Bureau of Reclamation. A 50-year frequency with a 1-hour duration was determined to be the controlling storm. A 2' inch rainfall intensity was used along with a watershed/soil condition of II. The basin area was determined to be 1.68 miles with the estimated land use being very similar to what exists now, except for a golf course located in the center of the basin. The study indicated that it accounted for proposed and existing detention and retention in the hydrologic calculations. This detention, along with the smaller basin area, the greater impervious area of a golf course, and the low duration intensity and frequency, all combine to provide a low peak runoff from the basin. The 1973 study, like the 1967 study, was developed prior to any development within the basin, except for a few structures along the railroad corridor. The proposed Landuse Plan used for full development hydrologic calculations is very similar to the actual development that has occurred in the basin. The basin boundaries used in this 1973 study are based on the historic natural boundaries since no significant development had occurred by that time. These 1973 boundaries are different from this 1992 study due to development in the basin. Minor changes to the internal and perimeter boundaries occur throughout the basin. The basin area has decreased from 1401 acres to 1271 primarily due to development.

The criteria and methods used for the 1973 study is considerably different that what is used for this study. An excerpt from the 1973 study describes the criteria used: "The major greenbelts are designed to accommodate the 100-year storm runoff, having rainfall intensity of 3.42 inches per hour for a duration of one hour. The interior collection systems and minor greenbelts are designed to accommodate the 50-year storm runoff, having a rainfall intensity of 2.0 inches per hour for a duration of one hour." The USDA-SCS Synthetic Hydrograph Method was used with manual calculations.

The Probable Maximum Flood (PMF) was also calculated for the proposed detention pond. The PMF rainfall depths were: 22.8 in. for 6-hour duration, 25.3 in. for 12-hour and 26.8 in. for 24-hour. The peak flow for the PMF in the 1973 study, at CO 1040, was determined to be 12806 cfs. This 1992 study determined the PMF of the 24-hour storm (34 inches of rainfall) controlled over the 1-hour (14 inches) with a flow of 36859 cfs at CO 1040.

The FEMA study, completed in 1986, used the City of Colorado Springs criteria in use at that time. The primary document used was the SCS report entitled, "Procedures for Determining Peak Floods in Colorado." HEC-2 was used to determine water surface profiles. Cross-sections for the HEC-2 runs were derived from mapping that was flown between 1981 and 1982. Significant degradation has occurred at various locations throughout the basin since 1982 which would alter the results from the FEMA HEC-2 runs.

Comparisons in the peak flows at the confluence with Monument Creek provided the following results:

Study	Date	Frequency (Years)	Duration (Hours)	Peak Flow (cfs)
KW	1967	50	1	621
UWE	1973	100	1	1562
FEMA	1986	100	-	2480
KLH	1992	100	24	3244

Adjacent studied basins include: Dry Creek to the north, Douglas Creek to the west and Rockrimmon South to the south of this study area.

Project Mapping

Aerial mapping prepared by Analytical Surveys, Inc. for the City of Colorado Springs Utilities Division is used as the primary base maps. These maps were flown during April, 1988 and are referred to as FIMS Maps (Facilities Information Management Systems) by the City Utilities Divisions. These maps contained 2 foot contour detail on 1"=100' and 1"=200' scales. All the basin delineations were derived on these maps as well as most of the hydrologic information. Detailed hydraulic information like dimensions and elevations of culverts and concrete channels were acquired by field surveys.

General basin and regional information was derived from the United States Geological Service (USGS) 7.5 minute series "Pikeview" Quadrangle Map, dated 1986, Scale: 1"=2000'.

More detailed information for selected areas within the Rockrimmon Basin was available from numerous Master Drainage Studies and Final Drainage Plans.

Agency Jurisdictions

The Rockrimmon Drainage Basin is entirely located within the City of Colorado Springs. The City of Colorado Springs is the recipient of this study and is the regulatory agency with the responsibility of implementing and enforcing the drainage policies within this basin. Departments within the city involved in the development of this study include: Engineering Division, Flood Plain Administration, Parks Department, Planning Department and the various Utility Departments. Other agencies involved include: Corps of Engineers (COE), Environmental Protection Agency (EPA), Division of Wildlife (DOW), Federal Emergency Management Association (FEMA), U.S. Fish & Wildlife (USF&W), the State & Federal Soil Conservation Services (SCS) and Geologic Societies (USGS, SGS) and the Pikes Peak Area Council of Governments (PPACG).

A detailed list of participants in this study is available in Appendix _____.

IV. BASIN CHARACTERISTICS

Climate

The Colorado Springs and Rockrimmon Basins are classified as a semiarid region. Winters are generally cold and dry and summers are relatively warm and dry. Total precipitation amounts range from 12 to 20 inches per year. It is estimated that about 36% of this moisture occurs in summer thunderstorms. Much of this water is lost due to rapid runoff. The moisture which does infiltrate the soil is also lost quickly due to the soil's low water handling capacity and intense solar radiation.

Topography

The basin lies in the foothills at the base of the Rocky Mountains. The basin consists of dissected mesas and foothill ridges separated by southeasterly draining valleys. The north and western portions of the basin are dominated by mesa caps on high ridges of exposed weathered bedrock known as the Arapahoe Formation. Slopes on the mesa tops are around 10%, while the steep face of the ridges range from 30% to 60%. This area is covered with a good growth of scrub oak, ponderosa, pinon pine and wild grasses.

The mid and lower portions of the basin are located in the south and eastern portions of the basin comprising about 2/3 of the basin area. Rolling hills of weathered and deposited materials dominate this area. Slopes range from 5% to 20%. Rangeland grasses and shrubs comprise most of this area with pockets of scrub oak, ponderosa and pinon pine.

The three primary drainageways are easily identified by the relatively deep and narrow corridors which have been recently cut through the lower portions of the basin. This headcutting process is still active as evidenced by the recent headcutting occurring in portions of the drainageways. As of early 1992, a particular reach has experienced 6 feet of degradation since the mapping was flown in April of 1988.

Soils and Geology

As mentioned above, the basin lies in the foothills at the base of the Rampart Range of the Southern Rocky Mountain physiographic province. To the west of the basin are mountains of hard, Precambrian granite. At the foot of the mountains to the west is the Rampart Range Fault which separates the granite and older sedimentary deposits from the younger sedimentary rocks to the east. The area of the Rockrimmon North Basin is underlain by sedimentary rocks which dip at low angles toward the northeast. The landform which dominates the basin consists of weathered mesas and foothill ridges separated by shallow rolling valleys.

Bedrock underlying the Rockrimmon North Basin area consists of the Arapahoe Formation and the underlying Laramie Formation. Overlying these bedrock units are various surficial deposits which were deposited in more recent geologic times. These various geologic units are described in more detail in the following sections. A map showing these various geologic units is on file at the Colorado Springs Engineering Division in a soils report for the basin prepared by Geotechnical Consultants, Inc. A translation of these units into hydrologic soil groups is shown on the Soils Map, Figure ____.

Bedrock Units:

Laramie Formation - The Laramie Formation is the oldest bedrock unit which is exposed on the site. Exposures of the upper part of the Laramie Formation can be found in the extreme southeasterly part of the basin in the stream channel bottom and in some exposures on the

banks. Exposures indicate that the Laramie Formation consists of fine grained sandstones and siltstone which are typically light tan to white in color, interbedded with gray claystones. The sandstones and siltstones are typically very dense, however, not highly cemented.

Arapahoe Formation - The Arapahoe Formation overlies the Laramie Formation in this region and is the only other geologic formation exposes within the basin area. The Arapahoe Formation is the lowest formation in the Dawson Group and consists of two distinct units.

> Arapahoe Formation, Lower Andesitic Unit: The Lower Andesitic Unit directly overlies the Laramie Formation. This Lower Andesitic Unit consists of interbedded claystones, carbonaceous shales, sandstones, and siltstone. These materials were derived from the weathering of volcanic rocks (andesites and basalts) and are characterized by dark browns, greens, and blue-grey colors. These rocks are known in the region for containing highly expansive clay minerals. Because of the relatively low resistance to erosion, the Andesitic Member forms low ridges and more gentle topographic features.
>
> Arapahoe Formation, Upper Arkosic Unit: The Upper Arkosic Unit of the Arapahoe Formation underlies the westerly part of the basin. This bedrock unit consists of coarse grained, arkosic sandstones and conglomerates with some interbedded claystones. Although typically not highly cemented, the arkosic unit does contain local layers and lenses of iron cemented sandstones. The sandstones are typically very dense and moderately to highly resistant to erosion. The Upper Arkosic Unit of the Arapahoe Formation forms the steeper ridges in the westerly portion of the site and also forms some of the more prominently topographic features in Colorado Springs, such as Pulpit Rock and Austin Bluffs.
>
> The sandstones and conglomerates of the arkosic member were formed from the weathering of the Pikes Peak Granite to the west of the area. They, therefore, tend to be arkosic (contain a significant amount of feldspar in addition to the quartz grains).

Surficial Deposits:

During relatively recent geologic times, the region has been subject to various erosional and depositional episodes including some secondary glacial effects. This has resulted in an eroded bedrock surface on which the younger, surficial deposits have been deposited. Even the surficial deposits have been subject to younger erosional processes which have tended to dissect and erode the older deposits in the region.

> Verdos Alluvium: The Verdos Alluvium is the oldest surficial deposit found on the site. It was deposited by streams on a pediment surface during glacial times and exists mostly as mesa caps on the high ridges that extend from the west to east across the western portion of the site. A few isolated erosional remnants of the Verdos can also be found across the region. Typically, the Verdos Alluvium is a red to brown, poorly sorted, moderately compacted, stratified, sandy gravel, containing lenses of silt and clay. Large boulders are common near the mountains and typically the deposit becomes finer grained to the east. The Verdos consists almost entirely of material derived from weathering of the Pikes Peak granite. The verdos is generally fairly resistant to erosion and is considered a source of sand and gravel in the region.

Slocum Alluvium: The Slocum Alluvium is found as a valley fill deposit in the easterly portion of the region. The Slocum Alluvium, like the Verdos, was deposited in the Pleistocene Epoch by high energy streams fed by glacial meltwater. The Slocum differs from the Verdos in that it is finer grained and typically contains less silt and clay layers and lenses. Some small sand pits which extracted the Slocum sands were known to exist in the extreme easterly portion of the basin.

Louviers Alluvium and Broadway Alluvium: The Louviers Alluvium and Broadway Alluvium consist of alluvial deposits associated with the Monument Creek when it flowed at higher levels. These deposits exist in the extreme easterly portion of the site as elevated terrace deposits. These typically consist of stratified sand, silt, clay with sandy materials dominating.

Colluvium: Colluvium is soil which has been deposited by the combined actions of wind, sheetwash and gravity. Thicker deposits of colluvium exist within the basin at various points. Colluvial deposits tend to be highly variable because they consist of locally derived materials which have not been transported very far.

Alluvium and Colluvium: Mixed soils consisting of alluvium, or stream deposited material, and colluvium exist within the valleys within the basin area. These materials consist of a poorly stratified mixture of sand, silt, and clay, derived from the various older surficial and bedrock units existing in the area. In the upper part of the basin, these materials consist of silty sands to clayey sands, containing scattered gravel and cobbles. In the easterly and lower part of the basin, the materials become much more clayey because of the andesitic Arapahoe source material influence. In the steeper valleys, the colluvial "wedges" formed by weathering from the slopes, merge with the alluvium and colluvium in the extreme valley bottoms.

Alluvial Fan Deposit: One alluvial fan deposit has been identified in the extreme southwesterly portion of the basin. This fanshaped deposit may in fact be an earthflow or erosion "blowout" created in the geologic past. The unit from which it was derived is the arkosic unit and/or Verdos Alluvial deposits which once existed in the area. Alluvial fan deposits are typically deposited at the mouths of small drainageways where the gradient changes and the suspended load is deposited.

Man-made Fill: Because the majority of the basin has been developed (approximately 86%), man-made fill exists throughout the basin region. Throughout much of the area, natural soils have been disturbed, areas regraded, and structures built. Only those areas of obvious or significant man-made fill have been mapped on the Geologic Map. These man-made fills consist of both engineered and non-engineered fills existing within the basin area.

Geologic Factors Affecting Drainage:

Several geologic factors affection the overall drainage conditions in the Rockrimmon Basin. These include the location and type of bedrock, topographic conditions, location and type of surficial soil deposits, and man-made development and disturbances within the basin.

The upper portion of the basin is characterized by steep slopes and shallow bedrock conditions. This results in relatively high runoff from this region. In the central and lower portions of the basin, the area is underlain by mostly claystone bedrock. This results in relatively high runoff characteristics due to the shallow nature of the bedrock and the clayey nature of the colluvium and soils derived from the bedrock. The combination of these factors results in relatively high overall runoff coefficients in this basin.

In the upper portion of the basin, the younger surficial deposits are generally sandy because of the sandy source rock and surficial deposits which exist in this region. As one continues downstream, the surficial deposits source material include significant amounts of claystone bedrock. The younger, surficial deposits, therefore, get more clayey and silty downstream. The relatively clean, sandy deposits which exist in the lower portion of the basin represent ancient alluvial deposits associated with glacial outwash episodes, and associated with Monument Creek terraces.

Man-made disturbances, such as drainage structures, diversion piping, dams, and general development in the basin has also resulted in alteration of natural drainage patterns. Review of aerial photographs indicate that in many areas considerable downcutting of the drainageways has occurred in the recent past.

Erosion and Sedimentation:

This study is based primarily on evaluation of recent and past aerial photography and on visual examination of the stream bed and banks. The soil and rock materials exposed in the stream bed were examined in-place to provide an estimate of their erosiveness.

The topography of the Rockrimmon North Drainage Basin is a mesa and ravine topography which is similar in many respects to other drainage basins along the foothills of the Front Range. The streams have been incised into relatively erosive soils, resulting in steep banks and relatively steep flowlines. In the course of development, the topography of portions of the basin has been altered by significant cuts and fills. The development of the area has altered the drainage patterns to a degree, particularly by the creation of point discharges of storm drains. In the course of development, attempts have been made at various locations to control channel erosion, primarily by construction of concrete channel linings and by placement of stone riprap on the outside of channel bends. Most of the concrete linings appear to be performing satisfactorily. Most of the riprap channel protection appears to be failing, primarily by undermining of the toe of the riprap.

Normally the streams within this basin carry very little base flow and the discharge occurs primarily in response to rain storms. The brief, intense rainstorms, typical of the Colorado Springs area, result in high discharge, short duration flows.

The soil and rock materials within the channel are all erodible to a greater or lesser degree. The most erodible materials will be soils composed of silt and fine sand with no binder or cementation. These materials will tend to erode when subjected to flowing water with a velocity on the order of 2 feet per second. The better materials in the basin are the soft sandstone materials such as the Laramie Sandstone exposures in the lower portion of the main channel. These materials should be capable of withstanding water velocities on the order of 8 feet per second. Typical permissible velocities for the various soil and geologic units are shown on Table ____.

Stream erosion can be said to occur when the velocity of water against the bed or bank exceeds the maximum velocity which the bed or bank is capable of withstanding. In this basin, relatively high velocities are common, due to the steepness of the streambed. Erosive velocities can also occur in relatively flat reaches of the stream if the discharge is unusually high.

Erosion "hot spots" also occur at localized areas of oversteepened bed gradient, usually resulting in a "head cut" which migrates upstream. Erosion hot spots are also common at isolated point discharges from off-channel, if the flow is not properly conveyed to the channel and energy properly dissipated. Erosion is also common at the downstream end of lined portions of the channel, as the energy is dissipated from the relatively high velocity waters resulting from the smooth channel lining surface.

Several erosion mitigation methods have been used within this basin with greater or lesser degrees of success. Concrete channel linings have been used, and generally have been successful. However, problems are occurring with failures at the downstream ends of the channel sections. This can be resolved in most cases by better energy dissipation prior to discharging onto unlined channels.

Riprap linings have also been used at various locations in the basin; however, the riprap linings have not fared as well as the concrete. Typically, the riprap has been placed on the outside of bends to reduce bank erosion. In most instances, the riprap has been undermined and the erosion is proceeding. Obviously, a more substantial treatment of the riprap is necessary to minimize the occurrence of this undermining. Riprap has also been used to convey point discharges down the banks from storm drain discharges into the channel. In almost all cases that we observed, these riprap "rundowns" have failed.

Grade stabilization structures, or "drops", have been successfully used within this basin, but their use as been infrequent. At several locations throughout the basin, drops would be appropriate to mitigate against head cutting and accelerated bed erosion. At other locations, drops would be useful in reducing flow velocities and thereby minimizing bank erosion.

V. HYDROLOGIC ANALYSIS

Methods and Criteria:

The methods and procedures outlined in the City of Colorado Springs/El Paso County Drainage Criteria Manual (DCM) were used in the development of this study.

Major System Hydrology:

The SCS Method was utilized to determine runoff quantities generated within the Rockrimmon North Drainage Basin as required in the DCM for basins greater than 100 acres. The 10 and 100-year frequency storms with a 24-hour duration were calculated. The results were compared and it was determined that in all cases the 24-hour ~~storm~~ duration ~~governed.~~ Therefore, all further discussion is based on the 24-hour storm. Separate drainage basins and their respective drainage patterns were determined from topographic maps provided by the City of Colorado Springs. City of Colorado Springs zoning maps and the Land Use maps were utilized by Nass/Skinner Associates in the preparation of the Land Use Map ~~used in~~ this study. These maps, along with the soils maps, were utilized to determine representative runoff coefficients for each basin based on proposed land uses. From this information, runoff quantities for each basin were determined for the ultimate development conditions.

for 2 hour and 24 hour?

storm provided higher peak discharges.

? Whose? Where from?

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Existing and proposed?

The majority of the Rockrimmon Drainage Basin is already fully developed; therefore, the difference between existing runoff quantities and fully developed runoff quantities for the entire Rockrimmon Basin is minor. In fact, only Basins 1010, 1020, 1030, 1040, 1050, 1060, 1080 and 1090 have areas which can be developed further. This is primarily along the corridor of the main south channel. In several of these basins, only a small portion of the total area remains which can be further developed.

Runoff quantities generated during the 100-year frequency storms and the drainage patterns within each of the basins were evaluated to determine the effects of the runoff on the major channels and structures involving those channels. A HEC-1 analysis as described in the DCM was utilized to determine the amount of flow at various design points. The HEC-1 flood hydrograph model was developed by the U.S. Army Corps of Engineers to simulate the surface storm runoff response of a watershed by representing the basin as an interconnected system of hydrologic and hydraulic components.

The Probable Maximum Flood (PMF) was determined from procedures outlined in the Hydrometeorological Report No. 55A prepared by NOAA, COE and the Bureau of Reclamation, dated June, 1988. The two methods provided are based on the "local storm" and the "general storm" procedures. The local storm procedure provides Probable Maximum Precipitation (PMP) depths for shorter storms with durations of 1/4, 1/2, 3/4, 1, 2, 3, 4, 5 and 6 hours. The corresponding depths are 6.8, 8.8, 9.6, 10.3, 11.9, 12.8, 13.3, 13.9 and 14.2 inches of rainfall. The general storm procedure provides durations and depths for larger storms; 1, 6, 24 and 72 hours and 14, 26, 34 and 40 inches respectively. No area reduction factor is applied since the basin is less than 10 square miles. The 24 and 2 hour durations were compared and the 24 hour controlled with a flow of 42,900 cfs at the discharge point at Monument Creek.

Minor System Hydrology:

The Rational Method was used to determine the runoff quantities generated in the minor basins (less than 100 acres) of the Rockrimmon North Basin. These flows were used to determine the hydraulic adequacy of the existing streets, inlets and pipes. The 10 and 100

year storms were determined for the existing and proposed systems. See the technical addendum titled "The Minor System Drainage Study of the Rockrimmon North Basin". This study provides a detailed hydrologic and hydraulic analysis of the existing and proposed minor systems, with a generalized cost estimate for proposed facilities. This is a separate study from the DBPS and the minor system costs are not included in the economic analysis for the major system improvements as discussed in the DBPS.

A summary of flows at various design points is included in the Appendix. Cost estimates for the selected alternatives are also tabulated in the Appendix. Copies of the HEC-1 and HEC-2 runs are available for inspection.

Existing Irrigation Facilities:

Rockrimmon North Basin does not contain any major irrigation facilities. Although there are abundant minor irrigation systems, these are primarily for watering lawns of private residential and small commercial sites and some public park and ROW areas. There are not believed to be any well water supplies for irrigation, therefore, ground water conditions should not be affected.

Existing Surface Water Impoundments:

The basin only contains one existing detention facility. This small pond is south of Allegheny Dr. and east of War Eagle Lane and is able to store 6.5 acre feet of water. This pond is not large enough to be categorized as a State Jurisdictional Dam. This pond is situated within park land.

Other minor impounding areas exist, but their effect on the overall hydrology would not be noticeable.

The section "Hydrologic Alternatives", below, discusses proposed detention facilities.

Rainfall:

The rainfall intensities for the Rockrimmon North Basin were derived from the Colorado Springs and El Paso County Drainage Criteria Manual (DCM). These rainfall amounts in the DCM are reproduced from the National Oceanic and Atmospheric Administration (NOAA) Atlas 2, Volume III. The precipitation depths are read directly from isopluvial maps and are 4.4 inches for the 100-year, 24 hour and 3.0 inches for the 10-year, 24 hour storms. Since the area of the basin is less than 10 square miles, no area reduction factor is applied to the rainfall depths. As mentioned above, the 24 hour PMP depth is 34 inches.

The rainfall distribution is based on the Type IIA storm with an Antecedent Moisture Condition of 2 (AMC2) as recommended in the DCM.

Soils:

A major factor in determining the runoff discharges is the determination of the infiltration capacity of the various soils indigenous to the drainage basin. Geotechnical Consultants, Inc. determined geological information by photogeologic analysis, research and review of published references in the area and a review of private studies which have been conducted in the region. Upon completion of geologic mapping, the geologic units were compared to soil units mapped by the Soils Conservation Service for purposes of estimating the hydrologic soils groups within the basin. This comparison provided a more detailed delineation of the hydrologic soil groups within the basin.

The Soil Conservation Service has divided the different soils naturally found into four soils groups. Group A composes of very pervious sandy soils and Group D composed of very impervious soils. Soil Group B and Soil Group C fall between the two extremes. The City/County Design Criteria Manual combines soils types A & B and C & D, leaving only two basic soils types. Soil types A & B are to be used for ultimate runoff calculation, only when soils of that classification are in an area which is not projected to be developed. The subbasins were traced on the soils maps, and the acreage of each soil group was determined for each subbasin. The more pervious soils were in the east end of the basin, along the north tributary channel and interspersed throughout the north end, with the less pervious materials found in the south and central portions of the basin. Isolated pockets of nonhomogeneous materials can be found through the basin. See the Soils Map, Figure ____ for detailed locations of the soil groups in the Rockrimmon North Drainage Basin.

Hydrologic Alternatives:

Based upon the development patterns within the basin and associated runoff, it became apparent many of the channels and structures were not capable of transporting the expected flows. In some locations, it was ~~decided~~ that no property damage or threat to life existed where floodwaters were not contained within the channel. In other locations, improvements to the channel or structures ~~was~~ required for greater transport capability. In the lower reaches of the basin, the projected high water elevations were unacceptable, (i.e., did constitute a threat to life and property) and the cost of increasing the capacity of the structures in that area was economically unfeasible. Upstream detention was determined to be the most practical solution in this area.

The detention modeling on the basin was done such that the peak flows would not exceed the capacity, at acceptable high water elevations, of the structures in the lower part of this basin. This modeling was accomplished by choosing sites along the major channels which would be readily adaptable to detention due to their existing physical characteristics.

Three detention pond scenarios were reviewed. The first scenario involved one pond just below the main confluence of the north and south tributaries. The second scenario included two ponds, one on each branch of the main tributaries just above the main confluence. The third scenario involves adding one pond ~~to the two in the second scenario~~. This additional pond would be located about 1500' below the main confluence.

Each pond was maximized to the extent that the water surface was ~~near~~ the lowest elevation of the adjacent private property. The detention ponds reviewed are earthen berm embankments with side slopes less than 3h:1v. Primary drainage outlets will consist of low flow concrete pipe culvert(s) with a trash rack entrance structure and an energy dissipator/rip-rap pad at the outlet. An overflow spillway ~~will need to be analyzed and designed according~~ to state regulations. The State Engineer's "Rules and Regulations for Dam Safety and Dam Construction" provide classifications and regulations for all "Jurisdictional Dams." A jurisdictional dam has a capacity greater than 100 acre-feet or has a surface area in excess of 20 acres or exceeds 10 feet in height (measured vertically from the lowest point on existing ground to the spillway elevation). All the ponds analyzed in the 3 scenarios are State Jurisdictional Dams, with a size category of "small" and a probable classification rating of I or II. "I" indicates loss of human life is expected and II indicates no loss of human life is expected, but significant damage is expected. A final detailed hydrologic and hydraulic analysis of the ponds will be required ~~prior to acceptance by the state. Also~~, the jurisdictional classifications and requirements ~~will need to be determined.~~

See Table ? ____ for a summary of results from the three detention pond alternatives.

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the same points as in the second scenario and along the main channel just downstream of the confluence of the north and south tributaries,

prior to construction of these facilities

was included for each of the ponds in the model. Detailed analysis and design of the ponds and spillways ~~will need to be~~ was not a part of this study. It will need to be done at a later date in accordance with

VI. HYDRAULIC ANALYSIS

Methods and Criteria:

The Methods and Procedures outlined in the City of Colorado Springs/El Paso County Drainage Criteria Manual (DCM) were used in the development of this study.

Upon completion of the HEC-1 analysis for the North Rockrimmon Basin, a HEC-2 analysis also developed by the Corps of Engineers, was performed to determine high water elevations and other flow characteristics within the major drainageways. From that information, the expected maximum floodplain was plotted and an assessment of potential property damage was made. By the use of hydraulic analyses as outlined in the DCM, the adequacy/inadequacy of all structures (culverts, bridges, etc.) was determined. Also, several alternatives, if available, were analyzed which would contain and transport the design flows. Cost estimates were determined for each alternative to assist in the selection of the preferred alternative.

The Probable Maximum Flood (PMF) was determined from procedures outlined in the Hydrometeorological Report No. 55A prepared by NOAA, COE and the Bureau of Reclamation, dated June, 1988. The two methods provided are based on the "local storm" and the "general storm" procedures. The local storm procedure provides Probable Maximum Precipitation (PMP) depths for shorter storms with durations of 1/4, 1/2, 3/4, 1, 2, 3, 4, 5 and 6 hours. The corresponding depths are 6.8, 8.8, 9.6, 10.3, 11.9, 12.8, 13.3, 13.9 and 14.2 inches of rainfall. The general storm procedure provides durations and depths for larger storms; 1, 6, 24 and 72 hours and 14, 26, 34 and 40 inches respectively. No area reduction factor is applied since the basin is less than 10 square miles. The 24 and 2 hour durations were compared and the 24 hour controlled with a flow of 42,900 cfs at the discharge point at Monument Creek.

Existing Channel Descriptions:

KLH Drawing Nos. depict the major drainage basins analyzed by the SCS Method. All basins were analyzed assuming 100% development with the land uses depicted on the Land Use Plan prepared by Nass/Skinner Associates. A summary of the drainage patterns within each of these basins utilizing a 100-year frequency and a 24-hour storm duration is provided below.

Basin 1000

All of Basin 1000 sheet flows to curb cuts and inlets and flows are transmitted directly to Monument Creek without entering the main channel. Therefore, the analysis of Basin 1000 involved only the runoff generated by the HEC-1 analysis from the remainder of the basin and the hydraulic capability of the existing structures in the main channel to convey this discharge.

The design flow for this section of channel is 3244 cfs. The existing culvert with the available elevation for head is adequate to convey 1200 cfs. Three alternatives will satisfy the requirements for the remaining flow. They are the addition of 1) 2 RCB's at 10' x 9', 2) 3-8' diameter RCP's, or the construction of a regional detention pond to reduce the flows.

Basin 1010

This entire basin sheet flows on private property to various discharge points into Monument Creek. The main channel does not flow through this basin. No hydrologic or hydraulic analysis was performed on this basin.

South Channel:

Basin 1020

The incoming flow into the top of this basin is 2905 cfs. After combining with local flows, the final channelized discharge leaving this basin and the entire Rockrimmon Drainage Basin is 3244 cfs. There are three culverts and two sections of channel to be evaluated in this basin.

First is the existing 10' x 10' RCB under I-25. With the head available before the backwater overflows onto Rockrimmon Blvd., this structure is capable of carrying 1700 cfs. To transport the remaining 1544 cfs, two 9' RCP's will need to be installed by tunnelling.

The section of open channel 20' wide with vertical concrete walls above this culvert is adequate to carry the design flow as is.

Next is the existing culvert under Mark Dabling Blvd. and the D&RGW Railroad. This concrete box culvert is 10'w x 12'h at the entrance and 10'w x 10 1/2'h at the outlet. The capacity of this culvert is limited to 1400 cfs, due to the elevation at which the backwater flows onto Rockrimmon Boulevard where it is diverted around the culvert. In order to bring this section of culvert to the required capacity, two 10' diameter tunnels will have to be installed.

Above this culvert is a natural channel with a 14' bottom width and 2.5:1 sideslope. This section is adequate to convey the required flows and only minor erosion is occurring. However, if the required improvements are made on the downstream facilities and velocities are increased in this reach, more serious erosion may occur and a concrete lining may be required.

The last structure in this reach is the 14'w x 5'-6"h RCB under the Rockrimmon Boulevard and Delmonico Drive intersection. The design flow at this point is 2905 cfs and this structure has a capacity of 518 cfs with the current head limitations. This intersection will be several feet under water during a 100-year storm event. This culvert will have to be removed and replaced with three 10' x 9' RCB's or four 9' diameter RCP's. The entrance elevation must be lowered from 24.9 to 18.3 and the outlet elevation from 21.6 to 15.0.

Basin 1030

The incoming flow into this basin is 2642 cfs increasing to 2905 cfs at the outlet. The lower 325 feet of the main channel in this basin is concrete lined. If the improvements downstream are implemented, thus dropping the backwater flow elevation, the existing lined channel section will be sufficient to carry the design flow of 2905 cfs, but is not large enough to provide the freeboard required by the Colorado Springs/El Paso County Drainage Criteria Manual (DCM). The channel wall would have to be extended to meet this criteria.

The remainder of the main channel in this basin is natural. Much of it is large enough to contain the design flow but at a number of locations the channel banks will be exceeded. However, there is adequate area and depth in the vegetated buffer area to contain this flow without danger to any surrounding property. There are some small areas of minor erosion in this reach.

Basin 1040

The incoming flow for this reach is 2413 cfs below the confluence with the north channel, increasing to 2642 cfs through the basin. The main channel is natural and most of this short reach is not capable of containing the design flow. However, all locations in which overflow occurs are contained within the vegetated buffer located on park/open space land and no private property should be endangered. There is some more serious erosion in this reach.

A major tributary discharges into the main channel at the lower end of this reach. There are several areas of major erosion within this tributary basin.

Basin 1050

The incoming flow into this reach is 1069 cfs which increases to 1180 cfs above the confluence with the north channel. The main channel throughout this reach is natural and very deep with steep sides which completely contains the design flow. The soils in this reach are highly erodible and several areas of serious erosion are occurring. There are three discharge points for local drainage in this reach, all of which have seriously eroded and failed.

Basin 1060

The design flow at the end of this reach is 1069 cfs and is 773 cfs at the top of the reach. The lower 1/3 of the reach is natural and is deep with steep banks and completely contains the design flow. There are numerous areas of serious erosion in this portion of the reach. There are also two points of discharge for local drainage, both of which have seriously eroded and failed.

The upper 2/3 of this reach is concrete lined. This portion of the reach is not adequate, within the confines of the concrete lining, for the 100-year design flow of 772 cfs. However, the surrounding vegetated buffer is more than adequate to contain this flow. There seems to be no erosion occurring in this area except some minor channelization at the lower end and upper end. (See deficiencies drawings.)

North Channel:

Basin 3010

Design flows for this basin are 1234 cfs through the lower portion and 1195 cfs through the upper portion of this reach. The lower part is from the confluence with the main south channel up to the top of the breach in the dam of an old lake bed. This section is very steep with a narrow bottom width and steep sides. It has been previously riprapped and the west side is very stable while the east side has failed and is eroding badly. This area is sufficient to contain the design flow within the channel banks.

The next portion of the reach is the bed for an old lake that was breached and drained for liability reasons. The slope of this section is less than 2% with well established vegetation and wetlands. There is no apparent erosion in this area and the vegetated buffer is sufficient to contain the design flow without endangering any adjacent private property.

Above the lake bed is the crossing under Saddle Mountain Road which ends in an effective energy dissipator. The crossing under Saddle Mountain Road is made via an 11' x 7'-6" Arch CMP which is capable of conveying 975 cfs within the head restraints present at this location. This is inadequate to convey the design flow of 1234 cfs. It will be necessary to add an 8'-2" x 5'-9" Arch CMP above the existing pipe to adequately convey this design flow.

The portion of this reach above Saddle Mountain Road is natural channel with very well established vegetation and wetlands. There is no apparent erosion and the existing vegetated buffer is sufficient to contain the design flow.

Basin 3020

This reach has design flows ranging from 1195 cfs at the lower end to 836 cfs at the upper end. Basin 3030 discharges into this reach at about the lower 1/3 of the reach.

Except for the crossing of Rockrimmon Blvd. at the north end of this reach, the channel is natural. The channel itself is inadequate through almost all of this reach to contain the design flow, but the adjacent vegetated buffer is large enough to accept this flow. There are, however, numerous places in this reach where major bank erosion/channel bed downcutting is active. There are also several places in this reach where private property is threatened at this time and other places where private property will soon be threatened.

At the upper end of this reach is the crossing of Rockrimmon Blvd. The existing conveyance structure is an 8' x 4' RCB which is inadequate to carry the design flow. Due to space constraints, and in order to provide for a trail crossing under Rockrimmon Blvd., it is recommended that the existing box culvert be removed and replaced with either two 7'w x 8'h RCB's or two 8' diameter RCP's.

Basin 3040

The design flow is 836 cfs for the lower half of this reach and 714 cfs for the upper half. All of this channel is natural. In the lower half of this reach, there is no apparent active erosion except at one place and property damage is occurring there. The channel is insufficient to contain the design flow and the vegetated buffer is not large enough to contain the overflow on the southwest side. While there is no erosion or property damage at this time, except as noted above, the design flow high water mark does encroach onto private property on the southwest side. No structures are endangered at this location.

The upper half of this reach has very serious and active erosion and downcutting in a highly erosive soil. In the lower half, the design flow is contained within the channel banks and no private property is threatened at this time.

Basin 3050

The incoming flow for this reach is 601 cfs and increases to 714 cfs through the reach. The lower 3/4 of this reach is natural and has serious and active bank erosion occurring. The channel banks for most of this portion of the reach is sufficient to contain the design flow. In the lower 300 feet of this reach, the design flow exceeds the capacity of the channel flows into the vegetated buffer area. The design flow high water mark appears to encroach slightly onto private property on the north side, but no damage is expected to result other than some debris deposit. There is one tributary from Foothills Elementary School (north) that is badly eroded. There is also a foot bridge in this reach which is a constriction but does pass the design flow. It must be pointed out that the north abutments of this bridge are experiencing erosion and are exposed.

The upper 1/4 of this reach is concrete lined and experiencing no erosion along the channel. The channel is near capacity with the entire design flow and currently no erosion is occurring. There is, however, very serious head cutting at the discharge point of the concrete channel to the extent that the end of the channel lining is failing. This is an active condition requiring immediate attention.

Basin 3070

The design flow for the lower portion of this reach is 459 cfs and at the top is 328 cfs. The lower 350 feet of the reach is concrete lined and is able to contain the design flow. The vegetated buffer on the south side is adequate to convey any overflow and no erosion is apparent in this area. However, on the north side, overflow may encroach onto private property. Additionally, a discharge point for local drainage is released north of the channel without benefit of a conveyance structure, flowing by overland sheet flow to the channel. This is causing some channelization along the north side of the concrete channel.

The next portion of this basin is a detention facility. This facility appears to be adequately designed and constructed for the design flow. There is no apparent erosion or evidences of failure around the dike, the outlet structure of the channel within and immediately above the detention facility. On the north side of this facility, the design flow will encroach onto two lots but should not reach the structures. No damage is expected, except debris deposits.

The channel above the detention facility and below War Eagle Lane is inadequate to convey the design flow but the adjacent vegetated buffer appears of adequate size to contain it without encroachment onto private property.

At present, there are two 36" CMP's under War Eagle Drive. An additional seven or eight 36" CMP's must be installed to convey the design flow without overtopping War Eagle Lane. There is insufficient head available at this location to install fewer larger conduits unless the channel above and below this crossing is deepened.

The 200 feet above War Eagle Lane to a discharge point for local drainage, is small and well defined with little indication of erosion. The channel is too small to carry the design flow but the adjacent vegetated buffer is sufficient to convey this flow without endangering adjacent property.

The remainder of this reach, from the local discharge point up to the discharge for a small detention facility, is larger and a more defined channel. There is only minor signs of erosion in this section. The channel and surrounding slopes are steep enough that the design flow remains within their confines. Even so, the lot for one house apparently comes well down into the channel. The high water mark will encroach somewhat on this part of the property, which is presently in a natural state, but should pose no threat to the property or the structure.

Basin 3080

The lowest portion of this basin is a small detention facility. It accepts flows from approximately 140 acres and appears to be functioning adequately. There is no evidence of erosion or failure of any part of this facility. A small swale proceeds west to Northface Lane along the approximate back lot lines of the adjacent houses. This water way is entirely on private property and is showing no signs of erosion. The flows to the detention facility are 328 cfs. The flows at the top of this reach are 245 cfs.

Analysis of Existing Structures:

As discussed above, the minor drainage systems were analyzed in detail in the technical addendum "Minor System Drainage Study for the Rockrimmon North Basin". This section will touch on the major drainage structures at the outfall area of the basin. Sheet 16 of the existing set of maps displays culverts No. 1 (10'w x 12'h under railroad), 2 (10'w x 10.5'h under Mark Dabling Blvd.), 4 (10' x 10' under I-25), 6 (10'w x 9'h under parking lot east of I-25) and the culvert under Rockrimmon Blvd. and Delmonico Drive. All these culverts are concrete box culverts. (5.5'h x 14'w)

Using the City's standard culvert design method (Fig. 9-40) an analysis was conducted on the culverts with the full 100 year design flow of 3244 cfs. Starting at the downstream end and working upstream, the anticipated water surface was calculated. It is estimated that whatever flow reaches culvert #6, the overtopping depth should not exceed 2'. Using this as the ~~tail~~ TAIL water elevation for culvert #4, the flow conditions were calculated for #4. The water surface elevation at the entrance of this culvert was estimated to be at 6232 feet based on entrance condition and overtopping along a highway ramp swale. This water surface will back up flow to the intersection of Rockrimmon Blvd. & Delmonico Dr. This flow condition is not acceptable due to flow depths of 11 feet at Mark Dabling Blvd. and Rockrimmon Blvd., 16 feet at the low point on Rockrimmon Blvd., and 4 feet or more at the intersection of Rockrimmon and Delmonico. The alternative analysis looks at mitigating this situation with the installation of detention ponds and/or adding culverts at this outfall area.

Basin Inventory:

An inventory of all the drainage related facilities was compiled into a format provided by the city. The information was derived by field surveys and inspection of construction drawings. The format used by the city utilizes a computer spreadsheet with standardized symbols and descriptions. This spreadsheet will be used for all the basins in the city and will be a part of all drainage basin planning studies started after 1988. The 16

maps of proposed facilities show the numbering system used in the inventory to represent the existing facilities. The three numbers in the hexagon are the last three digits of the Basin Inventory Number (BIN). The subbasin numbers (3070, 1020, etc.) are the first four digits of the BIN. The basin inventory list is on file with the City Engineering Department.

TABLE 1

FLOW SUMMARY ~~OF~~ DESIGN POINTS @ MAJOR

Listed below is a summary of flows at the major Design Points along the North and South Tributaries.

Design Point #	HEC-1 POINT #	Design Flow (cfs) (10-YR.)	(100-YR.)	Sheet No.	Channel	LOCATION
DP1	CO1020	1685	3244	16	S	Discharge to Monument Creek
DP2		1685	3244	16	S	Channel @ Railroad
DP3	CO1030	1476	2905	16	S	Rockrimmon Blvd. @ Delmonico Dr.
DP4	CO1040	1328	2642	13	S	At Confluence 2550' above DP3
DP5	CO1050+	1192	2413	13	S	Confluence of North & South Tributaries
DP6	CO1060	598	1069	10	S	Near Anaconda Dr.
DP7	CO1070	436	773	9	S	At Rockrimmon Blvd.
DP8	CO3020	470	1109	10	N	200' E. of the Gunnison Cul de Sac
DP9	CO3040	319	836	7	N	Rockrimmon Blvd.
DP10	CO3050	264	714	6	N	Near Blackhawk Dr. @ Cul de Sac
DP11	CO3060	227	601	6	N	Confluence at W. side of Foothills Elem.
DP12	CO3084	153	328	5	N	Outlet to Detention Facility 300' N. E. of Cul de Sac on Northface Lane

TABLE 2

DETENTION POND ALTERNATIVES - SUMMARY TABLE

100-Year Information

POND AT DESIGN POINT	ITEM	POND SCENARIO NO POND	1	2	3
DP5.1 (South Channel above Confluence)	Flow-in (cfs)	1180	1180	1180	1180
	Flowout (cfs)		1180	517	517
	Storage (AC FT)			23	23
	Water Depth (FT)			19.8	19.8
	Spillway Height (FT)			20	20
DP5.2 (North Channel above Confluence)	Flow-in (cfs)	1234	1234	1234	1234
	Flowout (cfs)		1234	197	197
	Storage (AC FT)			47	47
	Water Depth (FT)			19.6	19.6
	Spillway Height (FT)			25	25
DP5 (Below Confluence of North and South Tributaries)	Flow-in (cfs)	2413	2413	700	939
	Flowout (cfs)		166	700	772
	Storage (AC FT)		105		6
	Water Depth (FT)		31.6		13.9
	Spillway Height (FT)		33		15
Resulting Flow at:					
DP3 (Rockrimmon and Delmonico)		2905	792	1206	1033
DP1 (Monument Creek)		3244	1202	1609	1403