City of Albuquerque
P.O. BOX 1293 ALBUQUERQUE, NEW MEXICO 87103

May 13, 1991

Mr. Cleve Matthews
Land Operations Manager
Paseo del Norte Joint Venture
10 Tramway Loop, NE
Albuquerque, New Mexico 87122

RE: TRACT H-28-A DRAINAGE REQUIREMENTS
(C-12/D1 PLATE 4, RECEIVED 2/28/86)

Dear Mr Matthews:

The following is a brief overview of the drainage concept for Tract H-28-A per the Riverview Master Drainage plan. The master plan identified two on-site ponds, one of which is to be located at the east end of this tract with an outlet to the storm drain in Golf Course Road. The second pond is proposed along Taylor Ranch Drive with its discharge into the Mariposa system. This concept includes the acceptance and conveyance of flows from the Mission Ridge Subdivision thru this site.

Please be advised, any revisions to this concept will require updating of the Riverview Master Drainage Plan.

I hope this letter provides you with the information you requested regarding the drainage concept for Tract H-28-A.

Sincerely,

Fred J. Aguirre
Hydrologist

FJA
(WP+2668)

PUBLIC WORKS DEPARTMENT
Walter H. Nickerson, Jr., P.E.
Assistant Director Public Works
ENGINEERING GROUP
Telephone (505) 768-2500
AN EQUAL OPPORTUNITY EMPLOYER

C12/D1

City of Albuquerque
P.O. BOX 1293 ALBUQUERQUE, NEW MEXICO 87103

KEN SCHULTZ
MAYOR

July 5, 1989

RECEIVED
JUL 06 1989
HYDROLOGY SECTION

*****REVISED*****
CERTIFICATE OF COMPLETION AND ACCEPTANCE

Mr. Bob Ryals
Bellamah Community Development
6121 Indian School Road N.E.
Albuquerque, NM 87110

RE: PROJECT NO. 3435, GOLF COURSE ROAD/PASEO DEL NORTE, (MAP NO. C-12 ~~E-10~~)

Dear Mr. Ryals:

This is to certify that the City of Albuquerque accepts Project No. 3435 as being completed according to approved plans and construction specifications. If all required right-of-ways and/or easements have been dedicated, the City of Albuquerque will accept for continuous maintenance all public infrastructure improvements constructed as part of Project No. 3435.

The project is described as follows:

- Installation of water, sewer and storm sewer between Calle Nortena and Paseo Del Norte on Golf Course Road. Constructed crossing structure and channel station across the Piedras Marcadas at Golf Course Road. Paving and curb and gutter between Calle Nortena and Paseo Del Norte on Golf Course Road.
- The contractor's warranty began on April 28, 1989 and will be effective for a period of one (1) year.

Sincerely,

Russell B. Givler, P.E.
Chief Construction Engineer
Construction Mgmt. Division
Engineering Group
Public Works Department

RBG:kt

AN EQUAL OPPORTUNITY EMPLOYER

C12/D1

City of Albuquerque

P.O. BOX 1293 ALBUQUERQUE, NEW MEXICO 87103

KEN SCHULTZ
MAYOR

June 19, 1989

RECEIVED
JUN 21 1989
HYDROLOGY SECTION

CERTIFICATE OF COMPLETION AND ACCEPTANCE

Mr. Doug Reynolds
Bellamah Community Development
P.O. Box 3300
Albuquerque, NM 87190

RE: PROJECT NO. 2850, RIVERVIEW ROADS/PASEO DEL NORTE, (MAP NO. C-11, 12)

Dear Mr. Ryals:

This is to certify that the City of Albuquerque accepts Project No. 2850 as being completed according to approved plans and construction specifications. If all required right-of-ways and/or easements have been dedicated, the City of Albuquerque will accept for continuous maintenance all public infrastructure improvements constructed as part of Project No. 2850. If the required right-of-ways and/or easements have not been dedicated, the City of Albuquerque cannot accept the project for continuous maintenance and said maintenance will be the responsibility of the developer.

The project is described as follows:

- Placed paving and curb and gutter on north side of Paseo Del Norte between Golf Course Road and Eagle Ranch Dr. Placed storm drain at Paseo Del Norte and future collector. Placed sewer and water at Paseo Del Norte and future collector.
- The contractor's warranty begins the date of this letter and will be effective for a period of one (1) year.

Sincerely,

Russell B. Givler

Russell B. Givler, P.E.
Chief Construction Engineer
Construction Mgmt. Division
Engineering Group
Public Works Department

RBG:kt

FILE COPY

City of Albuquerque
P.O. BOX 1293 ALBUQUERQUE, NEW MEXICO 87103

KEN SCHULTZ
MAYOR

November 28, 1988

Michael Yost
Community Sciences Corporation, Inc.
Post Office Box 1328
Corrales, New Mexico 87048

RE: TRAINER DYKES FOR MAIN BRANCH OF PIEDRAS MARCADAS
AND PASEO DEL NORTE (C-12/D1) RECEIVED AUGUST 30, 1988

Dear Mr. Yost:

I have reviewed the proposed trainer dyke scheme of transitioning historic off-site flows within the City's right-of-way and agree that this concept is feasible. However, the major issues with this concept is the compatibility of this scheme with Transportation requirements and recreational requirements; hence, I recommend that you contact the Transportation Division to determine their position on this scheme. Please keep this office informed of your findings.

If this concept is in accord with Transportation requirements, the following information will be required prior to DRC submittal to approve this trainer dyke concept.

We will need detailed drawings of the trainer dykes. Also, the water surface will have to be shown at the trainer dyke area. We will need calculations for the water surface and specifications for the trainer dykes. Easements will be required if upstream properties are impacted by the trainer dykes.

Should you have any questions, please call me at 768-2650.

Cordially,

Carlos A Montoya
Carlos A. Montoya, P.E.
City/County Floodplain Administrator

CAM/bsj
(WP+372)

xc: Adelia Kearney
John Winton
C. Dwayne Sheppard
Dave Harmon

B. H. SWINBURNE, CHAIRMAN
WILLIAM V. HEREFORD, VICE-CHAIRMAN
REX FUNK, SECRETARY TREASURER
R. WARD HUNNICUTT, DIRECTOR
SHEILAH GARCIA, DIRECTOR

RICHARD E. LEONARD
EXECUTIVE ENGINEER

Albuquerque
Metropolitan
Arroyo
Flood
Control
Authority

P. O. BOX 25591 ALBUQUERQUE, N.M. 87125
TELEPHONE (505) 884-2215

RECEIVED
FEB 24 1988
HYDROLOGY SECTION

February 24, 1988

Mike Yost
Community Sciences Corporation
P.O. Box 1328
Corrales, New Mexico 87048

RE: South Branch Piedras Marcadas Arroyo, City Project 3457

Dear Mr. Yost:

AMAFCA approves the energy dissipator design depicted on sheet 7 through 10 of subject plans.

No license from the City will be required, because AMAFCA's Piedras Marcadas Dam exists for the purpose of accepting storm water

You may present this letter to the DRC as our acceptance of the design.

Sincerely,

Larry A. Blair

Larry Blair
Field Engineer

LB/sg

City of Albuquerque
P.O. BOX 1293 ALBUQUERQUE, NEW MEXICO 87103

Mayor
Ken Schultz

October 27, 1987

Doug Reynolds
Bellamah Community Development
Post Office Box 3300
Albuquerque, New Mexico 87190

RE: RIVERVIEW SECTOR PLAN

Dear Doug:

To facilitate our process for your project, the status of Golf Course Road, and the Middle Branch, Piedras Marcadas Arroyo/Paseo Del Norte Road crossing is summarized below.

MIDDLE BRANCH/PASEO DEL NORTE

In our meeting of June 3, 1987, we agreed that:

1. Bellamah would submit a plan showing construction, easements, property lines, etc., for the trainer dykes.
2. The City will review the plans and identify those parcels which must be purchased.
3. Bellamah will provide a legal description and appraisal for the parcel before the City will make an offer to the property owner for the parcel.

Items 1 and 2 have been completed. We have reviewed the conceptual design of the trainer dyke at Paseo Del Norte and the legal description of the off-site property. We concur to the location and size of the latter. The property appraisal is now all that is needed to make an offer to the property owner. Please have an appraisal made and forward it to us for review and for making an offer. It is important that you be aware of the following requirements:

PUBLIC WORKS DEPARTMENT

ENGINEERING GROUP

George E. Selvia, P.E.,
Assistant Director Public Works

Telephone (505) 768-2500

AN EQUAL OPPORTUNITY EMPLOYER

- The City must qualify the appraiser used by Bellamah Community Development. I suggest that BCD submit a list of prospective professional appraisers to us for review and qualification. The City, however, is not obligated to accept the list of appraisers submitted by BCD.
- The City needs to review the instructions to the appraiser and the material provided to him by BCD. The instructions should include, at a minimum, a plat showing the total ownership before the taking, together with the part taken, and the remaining property.
- The City reserves the right of review of the completed appraisals prior to acceptance.

The purpose of these restrictions is to ensure that the appraisal will hold up in court.

GOLF COURSE ROAD

We agreed that:

1. Bellamah would prepare a legal description of the right-of-way needed through church property and through UNM property.
2. George Meador will use that information to initiate discussions with the church and UNM.
3. Bellamah will provide a drawing of the intersection of Golf Course Road and Paradise Boulevard.
4. The City Traffic Department will use the drawing to prepare intersection geometrics and determine what further property may be needed at the intersection.

Item 1 has been completed; item 2 is in progress. We await your submittal of the intersection drawing and remind you that the drainage facilities for Golf Course Road have been approved conceptually. We understand that time is important to you and urge you to have your engineers submit a final design for the system, including the necessary hydraulics and hydrology calculations, before the scheduled DRC review.

If you have any questions, or if I can be of any assistance, please call me at 768-2526.

Cordially,

George Selvia
Assistant Director
Engineering Group

GS/bsj

xc: Fred Aguirre; Hydrology Section/UDD/PWD
Adelia Kearney; Legal Department
Dave Harmon; Transportation-Development Division/PWD
George Meador; Planning Division/PWD
Walt Nickerson; Utility Development Division/PWD
C. Dwayne Sheppard; Planning Division/PWD
Roland Fletcher; Property Management

ILE COPY

City of Albuquerque
P.O. BOX 1293 ALBUQUERQUE, NEW MEXICO 87103

Ken Schultz
Mayor

UTILITY DEVELOPMENT DIVISION
HYDROLOGY SECTION
(505) 768-2650

September 10, 1987

Doug Reynolds
Bellamah Community Development
Post Office Box 3300
Albuquerque, New Mexico 87190

RE: RIVERVIEW OFF-SITE EASEMENT REQUIREMENTS
(C-12/D1)

Dear Mr. Reynolds:

We have reviewed the referenced topography and easement and concur with the trainer dike alignment. The legal descriptions should be made as an exhibit to a City Standard Easement. Copies of the standard easement can be obtained from Della Gallegos (768-2515). The easement should be completed and submitted for review by the City.

If you have any questions, call me at 768-2650.

Cordially,

Carlos A. Montoya, P.E.
City/County Floodplain Administrator

CAM/bsj

Approved plan is dated 8-87

PUBLIC WORKS DEPARTMENT

Walter Nickerson, P.E., City Engineer **ENGINEERING GROUP** Telephone (505) 768-2500

AN EQUAL OPPORTUNITY EMPLOYER

CITY OF ALBUQUERQUE

ALBUQUERQUE, NEW MEXICO

INTER-OFFICE CORRESPONDENCE May 21, 1987 REF. NO. 87H131

TO: George Selvia, Asst. Director, Engineering Group, Public Works Department

Kiehlbauch

FROM: C. Dwayne Sheppard, Manager, Hydrology-Special Projects, Planning Group, Public Works Department

SUBJECT: EASEMENT ON THE PIEDRAS MARCADAS AT PASEO DEL NORTE

Attached is a package of materials referred to the Planning Group for response by Phil Garcia, City Planner. Upon review of the material and the circumstances it appears that the matter more appropriately belongs with the Engineering Group, Development Division.

The following, resulting from our review, may be useful to you in this regard.

It is not clear to us why this request is being made at this time. The City has no apparent responsibility to pursue such easement unless BCD has made an actual ". . .good faith, reasonable effort to cause the Easement, with an area and terms satisfactory to the City, to be granted to the City by the earlier of:

A. June 30, 1988 or;

B. Within thirty (30) days of the City's written notice to BCD that development within the Riverview Sector Plan reasonably requires the off-site drainage improvements to be constructed; or

C. Within thirty (30) days of the City's written notice to BCD that the impending construction of Paseo del Norte in the vicinity of the property requires the dedication of the Easement (the "Deadline")."

Since no description or terms of easement required have been presented to the City for approval by BCD, obviously no offer for such approved easement has been formally tendered to property owners. Additionally, to our knowledge, no written notice requiring BCD to provide the subject easement any earlier than June 30, 1988 has been issued by the City.

To date, we are unaware of any proposed plans for trainer dikes that are specific as to area of easement needed. There exists an AMAFCA easement on the Paradise Valley Properties and it is our understanding that BCD has permission to work on the property east of Paradise Valley at the point where the Piedras Marcadas presently crosses the Riverview Plan Boundary. Have the possibilities of developing appropriate training facilities within these areas been explored? Has the possibility of exchanging existing easement(s) for required easement(s) been explored? Note that BCD's responsibility would appear to be only to obtain any excess easement(s) over those existing required to accomodate the facilities which, subject to City approval, BCD proposes to install.

It would seem necessary to clarify the status of all of the foregoing before appropriate action on the City's part can be recommended.

CDS:mrk

file: William Otto, Asst. Director, Planning Group, PWD
Phil Garcia, City Planner, Planning Department
Adelia Kearney, Asst. City Attorney, Legal Department
Fred Aguirre, Hydrology Section, Engineering Group, PWD

Attachments

FILE COPY

City of Albuquerque
P.O. BOX 1293 ALBUQUERQUE, NEW MEXICO 87103

Ken Schultz
Mayor

UTILITY DEVELOPMENT DIVISION
HYDROLOGY SECTION
(505) 768-2650

February 3, 1997

Kent Whitman, P.E.
Community Sciences Corporation
Post Office Box 1328
Corrales, New Mexico 87048

RE: ROUGH GRADING APPROVAL FOR TEMPORARY IRRIGATION POND, TRACT
H-11, RIVERVIEW INDUSTRIAL PARK (C-12/D1)

Dear Kent:

A Grading Permit to construct the Temporary Irrigation pond as shown on Sheet 12 of 20, is approved. The original mylar, Sheet 12 of 20 has been signed. The contractor is authorized to proceed with the earthwork necessary to construct the pond. Grading outside of the pond vicinity is not authorized at this time. As previously discussed, approval for the mass grading of Riverview Subdivision requires the blanket floodplain easements, covering the affected tracts, being dedicated to AMAFCA.

If you have any questions, call me at 768-2650.

Cordially,

Roger A. Green

Roger A. Green, P.E.
C.E./Hydrology Section

c: Doug Reynolds, BCD
Andre Toules, DRC
Dan Sosa, AMAFCA

RAG/bsj

PUBLIC WORKS DEPARTMENT

Walter Nickerson, P.E., City Engineer **ENGINEERING GROUP** Telephone (505) 768-2500

AN EQUAL OPPORTUNITY EMPLOYER

FILE COPY

City of Albuquerque

P.O. BOX 1293 ALBUQUERQUE, NEW MEXICO 87103

Ken Schultz
Mayor

UTILITY DEVELOPMENT DIVISION
HYDROLOGY SECTION
(505) 768-2650

[illegible]

[illegible] Woodbury, P.E.
Community Sciences Corporation
Post Office Box 1328
Corrales, New Mexico 87048

RE: RIVERVIEW [illegible]

Dear Ken:

The above referenced plan has been approved for grading [illegible].

Please feel free to call me at 768-2650 if you have any questions regarding this project.

Sincerely,

Carlos A. Montoya

Carlos A. Montoya, P.E.
City/County Floodplain Administrator

[illegible]

FINAL REPORT

AGGRADATION/DEGRADATION ANALYSIS
OF
PIEDRAS MARCADAS ARROYO
BERNALILLO COUNTY, NEW MEXICO

RECEIVED
OCT 10 1985
HYDROLOGY SECTION

Submitted To

Community Sciences Corporation
P.O. Box 1328
Corrales, New Mexico 87048

Prepared By

Simons, Li & Associates, Inc.
3555 Stanford Road
P.O. Box 1816
Fort Collins, Colorado 80522

SLA Project Number NM-CSC-02
R790/RDF244

October 1985

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I. INTRODUCTION

1.1 General

Bellamah Community Development plans to develop the Hughes Estate, which includes portions of Eagle Ranch, Taylor Ranch, and Zuris-Mann land ownerships in Bernalillo County, New Mexico. The development is to be a mixture of residential, commerical, and industrial uses. A general vicinity map of the development area is presented on Figure 1.1.

The Piedras Marcadas Arroyo flows through the development site. The watershed and location of the branches of the arroyo being considered in this study area are shown in Figure 1.2. Since the surrounding watershed is composed of highly erodible soils and flooding is caused by high intensity thunderstorms, there is potential for significant erosion and/or deposition of large quantities of sediment. To provide for a well-planned and properly engineered development consistent with the goal of maintaining the arroyo in its natural state to the extent possible, proper consideration must be given to the erosion and sedimentation potential of the various branches of the arroyo.

Simons, Li & Associates, Inc. (SLA) was contracted by Bellamah Community Development to conduct the necessary analysis to evaluate the erosion and sedimentation potential of the arroyo. The primary objective of the study is to determine an appropriate erosion buffer distance along unprotected reaches of the arroyo within which development should not occur. This analysis also provides recommendations on the type and location of protection measures to prevent excessive bank erosion and undesirable lateral migration of channels and excessive aggradation/degradation within the channel in critical areas.

Although proper analysis of the erosion and sedimentation potential of the arroyo requires assessment of the entire Piedras Marcadas Arroyo watershed, the primary focus of this study is to delineate the erosion potential along three branches of the arroyo, the North, Middle, and Main Branches. Figure 1.3 shows the portions of each branch which are to be studied in detail.

1.2 Data Sources

The analysis presented in this report is based on information collected from Community Sciences Corporation (CSC). This information includes hydrology of the arroyo, topographic mapping, aerial photographs, soils data, and information on proposed development conditions.

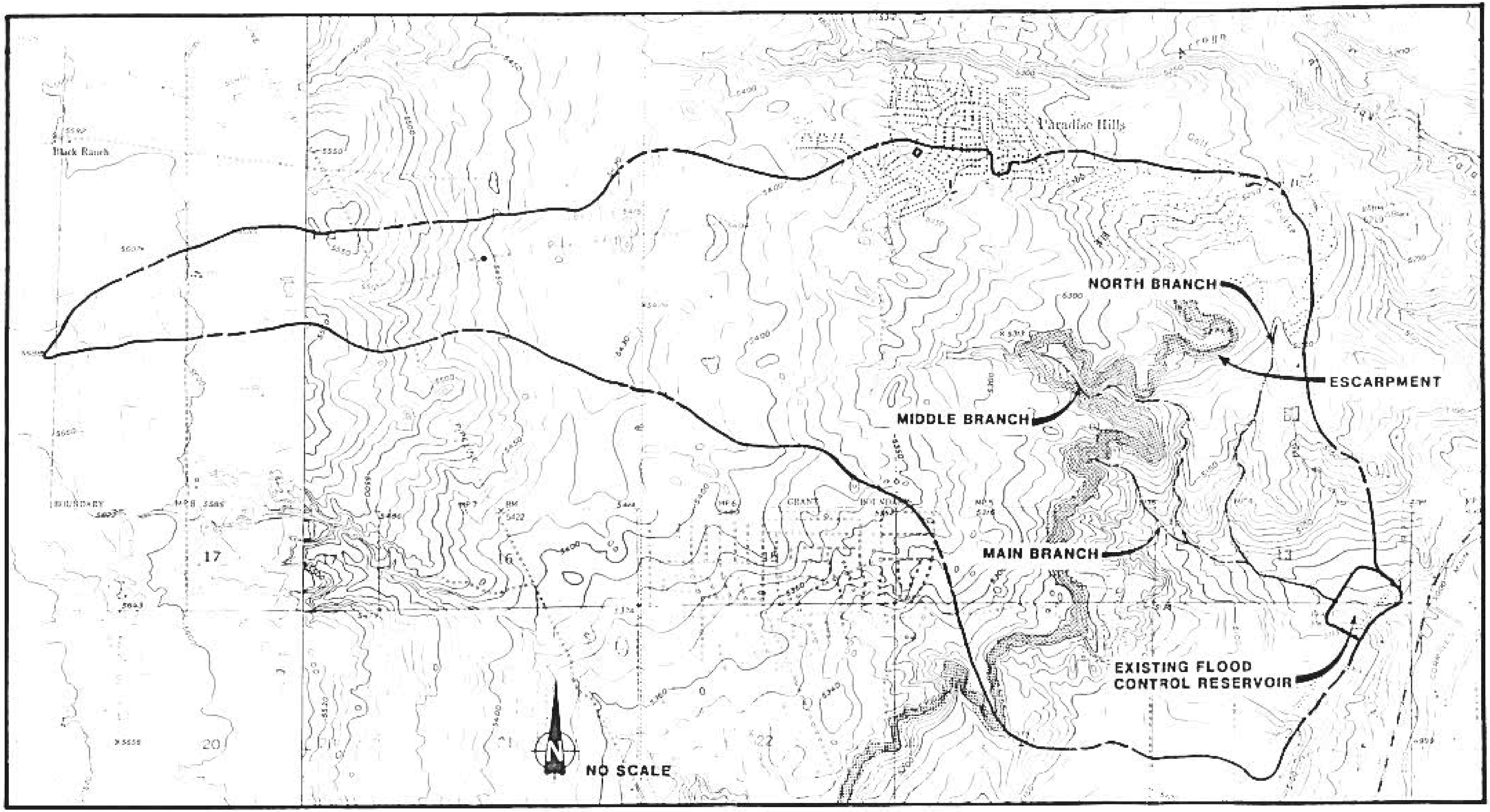

Paradise Hills
Black Ranch
NORTH BRANCH
ESCARPMENT
MIDDLE BRANCH
MAIN BRANCH
EXISTING FLOOD
CONTROL RESERVOIR
N
NO SCALE

Figure 1.2. Piedras Marcadas Arroyo Watershed.

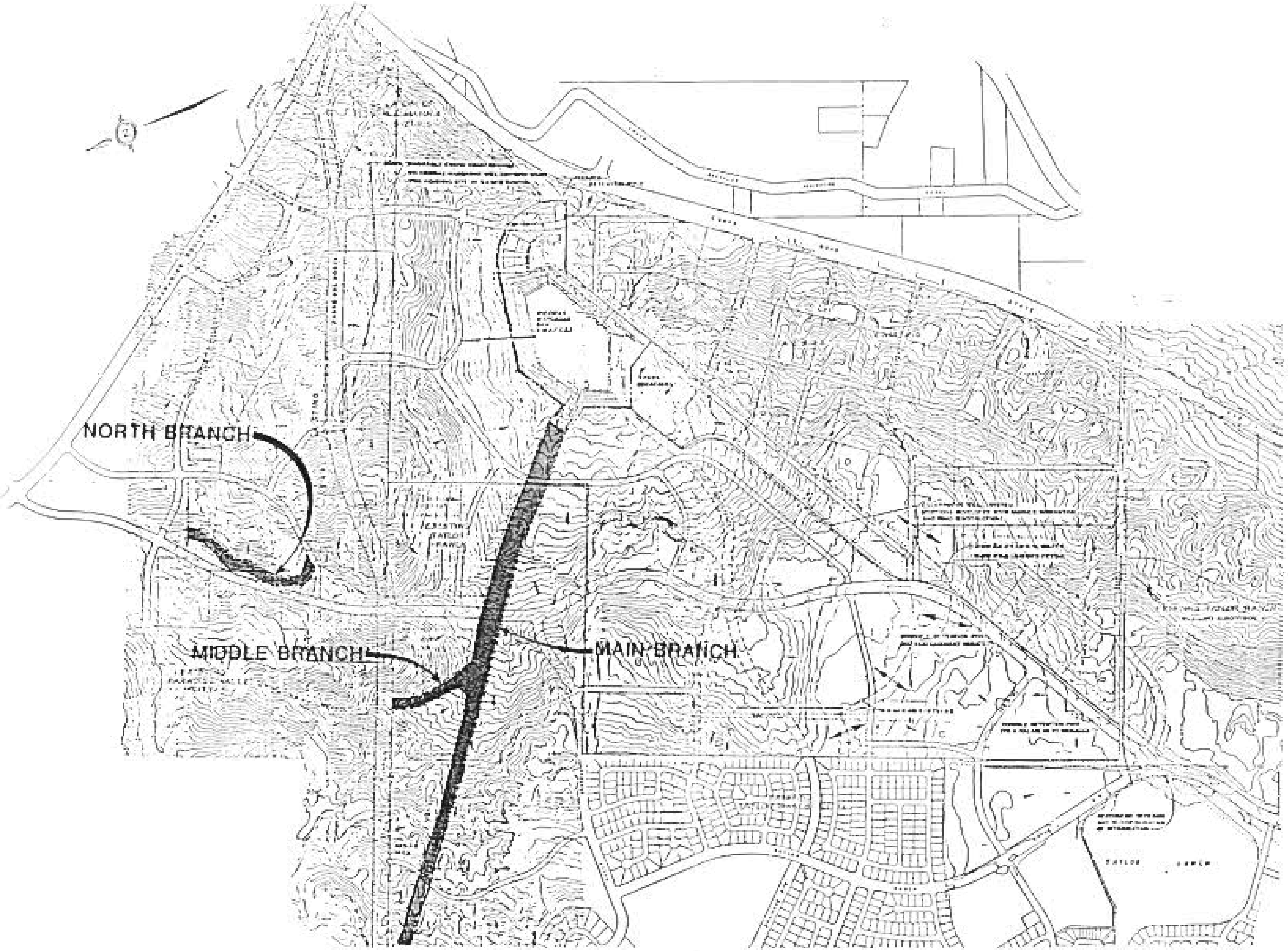

NORTH BRANCH
MIDDLE BRANCH
MAIN BRANCH

Figure 1.3. Study limits.

A site visit was made by members of SLA's project team to collect data and observe the characteristics of the watershed. Observations were made regarding watershed development, stream channels, and locations of existing erosion and sedimentation problems. A summary of observations made during the site visit is presented in Chapter II.

II. QUALITATIVE GEOMORPHIC ANALYSIS

2.1 General

A qualitative analysis of the Piedras Marcadas Arroyo was performed to identify the general sediment-transport characteristics of the arroyo and the identify potential impacts of improvements associated with development of contributing watershed areas.

The qualitative analysis utilized available information to assess the potential response of the system to change. Historical records, aerial photographs, site visit information, and the hydraulic properties of the existing system were analyzed to identify the stability characteristics of the stream, geologic controls, and general tendencies of the system.

As background information, the hydrology, soils, and geology are also discussed in this chapter. Qualitative assessment is made of the effect of each on sediment transport along the arroyo.

2.2 Hydrology

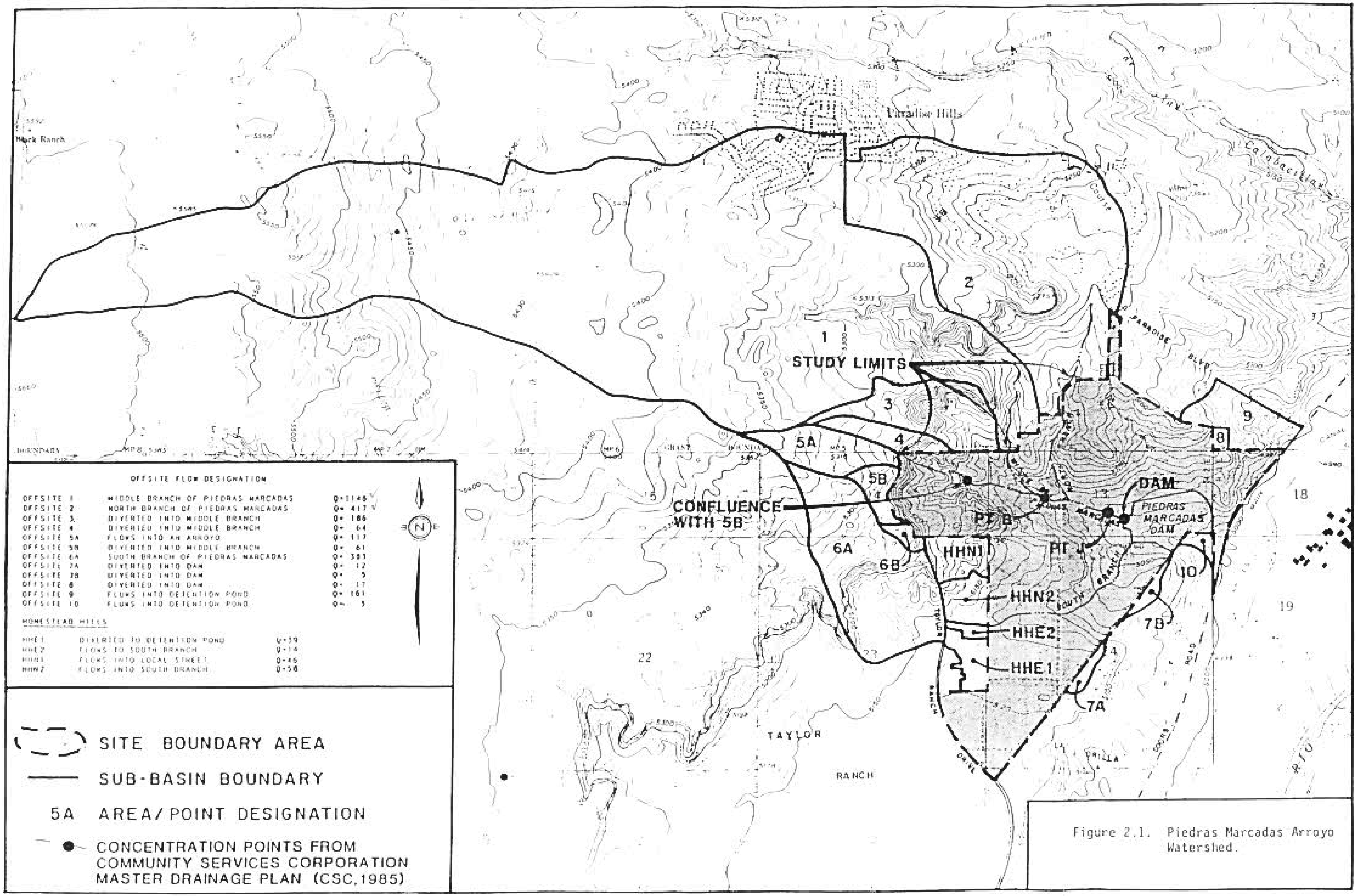
The Piedras Marcadas Arroyo watershed has a drainage area of approximately 4.6 square miles upstream of the flood-control reservoir located above Coors Boulevard. The flood-control reservoir was built as a result of an assessment of the flooding potential of the arroyo for downstream areas (AMAFCA, 1983). The arroyo in its natural state is a tributary to the Rio Grande.

The average annual precipitation of the watershed is 7 to 10 inches. Half of this precipitation falls from July to October, typically as brief, heavy thunderstorms. Flash flooding is common when runoff from these short, but intense thunderstorms is concentrated in local arroyos.

not shown

The Piedras Marcadas Arroyo has 4 major branches: the North, Middle, South, and Main Branches. The approximate drainage areas of each of the branches is listed on Table 2.1. The South Branch drains directly into the Piedras Marcadas Arroyo flood-control reservoir and is not included as a part of this analysis.

No gaging stations are located in the arroyo watershed. A hydrologic model was used by CSC to develop peak flows and hydrographs for future development conditions along the branches. Figure 2.1 shows the locations of branches and points where discharges were determined. Table 2.2 shows the discharge for return periods at various locations along the North, Middle, and


Paradise Hills
Mark Ranch
Calabacillas
PARADISE BLVD
STUDY LIMITS
CONFLUENCE WITH 5B
DAM
PIEDRAS MARCADAS DAM
PT B
PT J
HHN1
HHN2
HHE2
HHE1
SOUTH BRANCH
TAYLOR RANCH
1
2
3
4
5A
5B
6A
6B
7A
7B
8
9
10
13
18
19
22
23
N

OFFSITE FLOW DESIGNATION

OFFSITE 1	MIDDLE BRANCH OF PIEDRAS MARCADAS	Q=1146
OFFSITE 2	NORTH BRANCH OF PIEDRAS MARCADAS	Q= 417
OFFSITE 3	DIVERTED INTO MIDDLE BRANCH	Q= 186
OFFSITE 4	DIVERTED INTO MIDDLE BRANCH	Q= 64
OFFSITE 5A	FLOWS INTO AN ARROYO	Q= 117
OFFSITE 5B	DIVERTED INTO MIDDLE BRANCH	Q= 61
OFFSITE 6A	SOUTH BRANCH OF PIEDRAS MARCADAS	Q= 381
OFFSITE 7A	DIVERTED INTO DAM	Q= 12
OFFSITE 7B	DIVERTED INTO DAM	Q= 5
OFFSITE 8	DIVERTED INTO DAM	Q= 17
OFFSITE 9	FLOWS INTO DETENTION POND	Q= 161
OFFSITE 10	FLOWS INTO DETENTION POND	Q= 5

HOMESTEAD HILLS

HHE1	DIVERTED TO DETENTION POND	Q=39
HHE2	FLOWS TO SOUTH BRANCH	Q=14
HHN1	FLOWS INTO LOCAL STREET	Q=46
HHN2	FLOWS INTO SOUTH BRANCH	Q=58

⬭	SITE BOUNDARY AREA
—	SUB-BASIN BOUNDARY
5A	AREA/POINT DESIGNATION
●	CONCENTRATION POINTS FROM COMMUNITY SERVICES CORPORATION MASTER DRAINAGE PLAN (CSC,1985)

Figure 2.1. Piedras Marcadas Arroyo Watershed.

Table 2.2. Discharges for Developed Conditions Along Study Reaches.

Branch Location	Return Period (years)					
	2	5	10	25	50	100
North	Discharge (cfs)					
at u/s study limit	95	156	213	287	348	417 ✓
at confluence with Main Branch	95	156	216	287	348	422
Middle						
at u/s study limit	230	415	566	780	950	1,146 ✓
at confluence with subareas 3 & 4	230	415	571	780	950	1,154
at confluence with Main Branch	235	420	578	790	960	1,169
Main						
at u/s study limit	35	54	68	87	102	117
at confluence with 5B	38	62	79	105	130	150
D/S confluence with 5B	76	120	156	200	235	276
at Pt. B	76	120	156	200	235	276
D/S of Pt. B	245	460	578	790	970	1,169
at Pt. J	375	625	824	1,080	1,300	1,546
at Dam	400	660	873	1,150	1,400	1,628

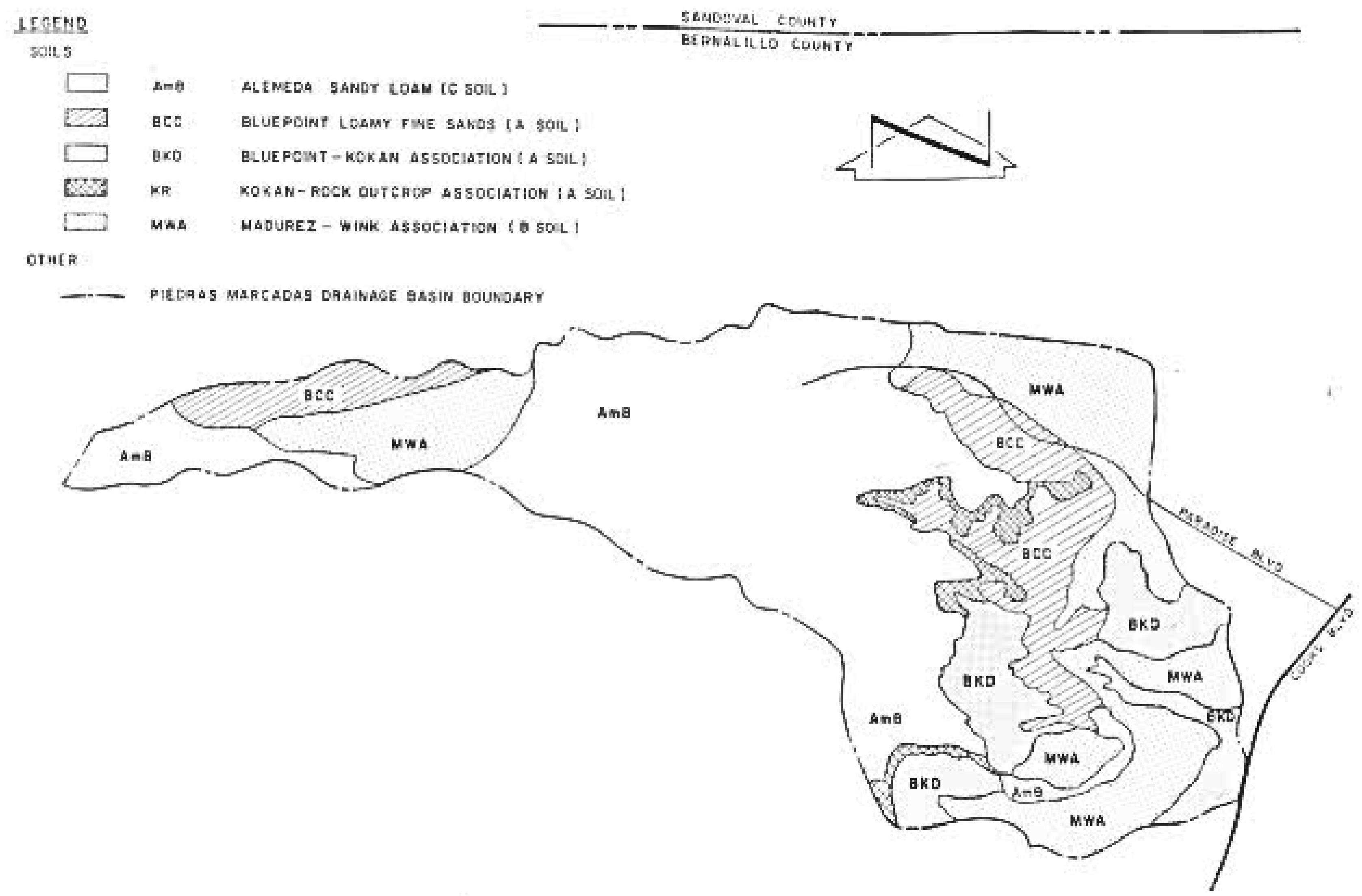

LEGEND
SOILS
AmB ALEMEDA SANDY LOAM (C SOIL)
BCC BLUEPOINT LOAMY FINE SANDS (A SOIL)
BKD BLUEPOINT - KOKAN ASSOCIATION (A SOIL)
KR KOKAN - ROCK OUTCROP ASSOCIATION (A SOIL)
MWA MADUREZ - WINK ASSOCIATION (B SOIL)
OTHER
PIEDRAS MARCADAS DRAINAGE BASIN BOUNDARY
SANDOVAL COUNTY
BERNALILLO COUNTY
N
PARADISE BLVD
COORS BLVD
AmB
BCC
MWA
BKD

Figure 2.2. Soils map of the study area (from Tom Mann & Associates, 1983).

results to the Wischmeier et al. (1971) soil erodibility nomograph. In general, the soils are very sandy and exhibit moderate permeabilities. They have very high potential for wind erosion and low potential for water erosion due to shallow overland flow, although erodibility characteristics are variable.

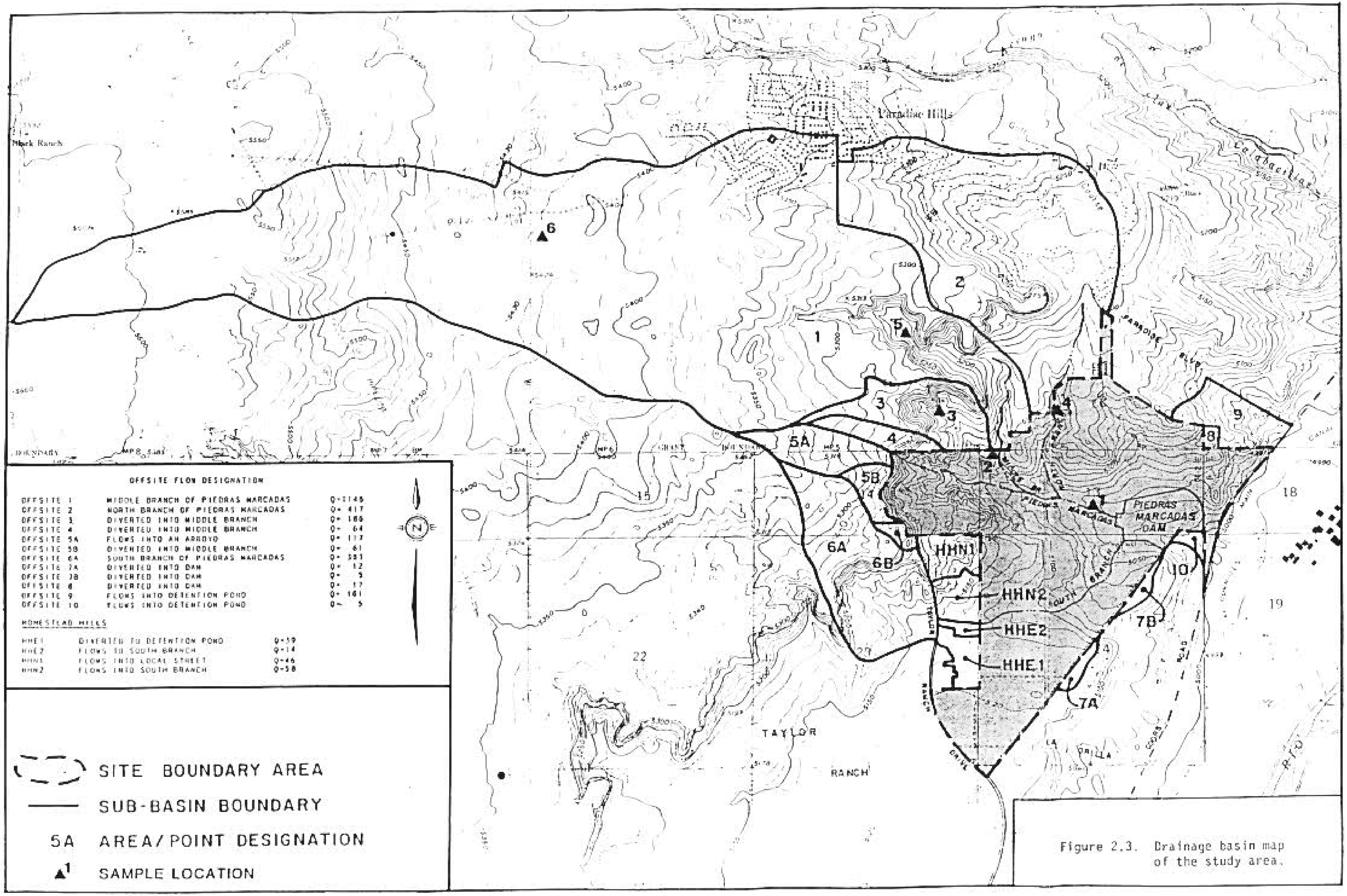
The soil lying west of the escarpment is rather homogeneous and covered by Alemeda Sandy Loam. It is an undulating soil on the basalt flow described in the Section 2.3. Small areas of winnowed loamy sand also occur in this unit. Runoff is moderate, but potential for water erosion due to shallow overland flow is slight due to low slopes, high infiltration, and a discontinuous drainage network. Approximately 20 percent of this mapping unit includes rock outcrop.

Two smaller soil units also occur west of the escarpment: Bluepoint Loamy Fine Sand and Madurez-Wink Association. The Bluepoint unit occurs on nearly level areas where runoff is slow and the potential for water erosion due to shallow overland flow is low. About 10 percent of this mapping unit is comprised of sand deposits. The Madurez-Wink unit lies adjacent to the Bluepoint unit on slightly convex piedmont fans and gently sloping side slopes. Runoff is slow and the potential for water erosion due to shallow overland flow is slight.

The Kokan-Rock Outcrop Association occurs along the narrow escarpment forming the edge of the basaltic mesa break. This unit marks a change in soils, slopes, and drainage conditions of the lower part of the basin. The Kokan soil unit is formed from old alluvial sand and gravel deposits and comprises 75 percent of the mapping unit. It is steeply sloping soil characterized by gravel, sandy loam, low runoff, and medium water erosion potential. The basaltic rock outcrop consists of bedrock and boulders 3 to 4 feet in diameter. Runoff conditions are very rapid.

The remaining area below the escarpment forming the lower watershed is composed mainly of the Madurez-Wink Association, the Bluepoint Loamy Fine Sand, and the Bluepoint-Kokan Association, which are described above. The Bluepoint-Kokan unit occurs on the rolling slope of fans and on steep, gravelly ridges bordering the lower drainage channels. Runoff is low on this mapping unit and the potential for water erosion is moderate to high.

A smaller area of the Alemeda Sandy Loam also occurs in an isolated area overlying basaltic substrate in the southern part of the lower watershed.


Paradise Hills
Black Ranch
Calabacillas
PARADISE BLVD
PIEDRAS MARCADAS DAM
PIEDRAS MARCADAS
SOUTH BRANCH
TAYLOR RANCH
GRANT BOUNDARY
1
2
3
4
5A
5B
6A
6B
7A
7B
8
9
10
H1
HHN1
HHN2
HHE2
HHE1
15
18
19
22
N
SITE BOUNDARY AREA
SUB-BASIN BOUNDARY
5A AREA/POINT DESIGNATION
1 SAMPLE LOCATION

OFFSITE FLOW DESIGNATION

OFFSITE 1	MIDDLE BRANCH OF PIEDRAS MARCADAS	Q=1146
OFFSITE 2	NORTH BRANCH OF PIEDRAS MARCADAS	Q= 417
OFFSITE 3	DIVERTED INTO MIDDLE BRANCH	Q= 186
OFFSITE 4	DIVERTED INTO MIDDLE BRANCH	Q= 64
OFFSITE 5A	FLOWS INTO AN ARROYO	Q= 117
OFFSITE 5B	DIVERTED INTO MIDDLE BRANCH	Q= 61
OFFSITE 6A	SOUTH BRANCH OF PIEDRAS MARCADAS	Q= 381
OFFSITE 7A	DIVERTED INTO DAM	Q= 12
OFFSITE 7B	DIVERTED INTO DAM	Q= 5
OFFSITE 8	DIVERTED INTO DAM	Q= 17
OFFSITE 9	FLOWS INTO DETENTION POND	Q= 161
OFFSITE 10	FLOWS INTO DETENTION POND	Q= 5

HOMESTEAD HILLS

HHE1	DIVERTED TO DETENTION POND	Q=39
HHE2	FLOWS TO SOUTH BRANCH	Q=14
HHN1	FLOWS INTO LOCAL STREET	Q=46
HHN2	FLOWS INTO SOUTH BRANCH	Q=58

Figure 2.3. Drainage basin map of the study area.

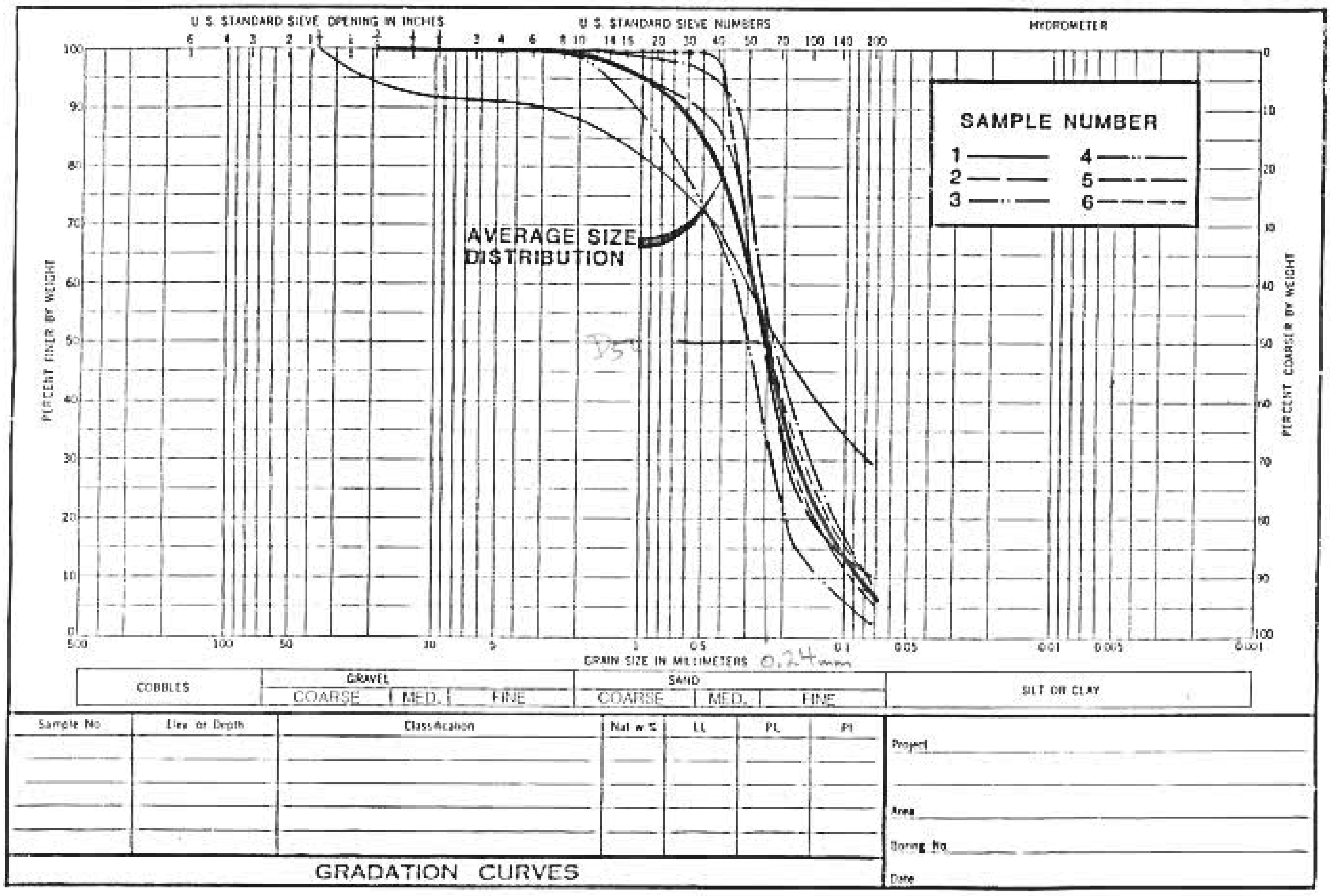


Figure 2.4. Sediment size distribution curves of surficial soil samples (see Figure 3.3 for sample locations).

2.6.3 Channel Characteristics

Most of the channels in the Piedras Marcadas Arroyo are not well defined. The small amount of annual rainfall and high infiltration rates in the watershed prevents development of significant amounts of runoff for small return period, low intensity storms. Channels along the Middle and Main Branches above the confluence with the North Branch were found to be the least well defined. Vegetation is found within the channel and no defined banks were observed. The North Branch channel is significantly different, having defined banks and a bottom width of about 15 feet. Little or no vegetation was found in the active channel of the North Branch. The banks along the North Branch are about 2 to 3 feet in height and fairly steep with bank slopes ranging from 1V:2H to vertical.

The fact that the North Branch channel is more defined than either the Middle or Main Branches can be attributed to the greater volume of runoff and higher runoff peaks caused by the development of approximately 50 percent of its drainage area.

The steepest banks were found along the outside of bends, of which there are several along the North Branch. The steepness of the bank is attributed to the erosion that takes place in these areas. The potential for migration of channels during large floods is quite high considering the erodibility of the soil and the lack of vegetation. Although no significant migration of the North Branch has yet occurred, increasing potential exists as degradation and incisement of the channel continues. It is expected that as the drainage area of the Middle and Main Branches are developed, they will experience larger volumes of runoff and higher runoff peaks. This will in turn cause those drainageways to become more defined, increasing the potential for migration.

Downstream of the confluence with the North Branch, the Main Branch was also more well defined. The effect of the greater volume of runoff being carried by the North Branch has apparently translated itself into this reach as well.

At the point where the Main Branch flows into the flood-control reservoir above Coors Boulevard, the channel gradient steepens significantly. Significant erosion potential exists in this area due to the increased velocities. In an effort to mitigate this problem, several grade controls have been constructed in the entrance channel. It appears that these grade controls may not be tied sufficiently far into the banks to prevent the channel from migrating around the ends.

growing in the channel. In the 1985 photos, the banks of the channel were slightly more defined, particularly at bends in the channel.

2.7.3 Main Branch

Comparison of 1973 and 1985 aerial photographs of the Main Branch show little difference between the channels for reaches upstream of the north branch. For the reach of the Main Branch, downstream of the North Branch, the channel is more defined with less vegetation. The effect of development in the north branch drainage has apparently translated itself downstream into this area. No other significant changes in the Main Branch channel were noted.

2.8 Conclusions

The arroyo watershed is at present mostly undeveloped. The channels draining the undeveloped portions of the watershed are ill defined having no discernible bank lines. Vegetation grows within drainage paths and no evidence of significant erosion or sedimentation problems exist. The channels in the undeveloped portions of the watershed appear to be relatively stable.

The North Branch of the arroyo was found to be considerably different from the Middle and Main Branches, having well-defined banks and an active channel with little or no vegetation. The banks along this branch are 1 to 3 feet high and nearly vertical along the outside of bends. The channel also has more defined bends than either the Main or Middle Branches.

From comparison of the aerial photographs, it is evident that significant changes have occurred along the north branch of the arroyo between 1973 and 1985. The channel banks became more defined, vegetation was removed from the channel bed, and the bends in the channel have migrated up to 10 feet in some locations.

It is apparent that the development which has occurred in the north branch drainage between 1973 and 1985, has caused significant impacts. These changes are attributable to the increased number of occurrences of runoff, larger runoff volumes, and higher runoff peaks associated with the developed portions of the watershed tributary to the North Branch. The higher percentage of impervious areas in the developed areas causes runoff to occur for lower return periods and intensities of rainfall than would have happened under undeveloped conditions. The increased number of occurrences prevents

III. QUANTITATIVE ANALYSIS

3.1 General

A quantitative analysis of the erosion and sedimentation potential along each of the branches of the arroyo was conducted. The purpose of the quantitative analysis was to determine the expected amounts of degradation or aggradation and the maximum limits of potential bank erosion along each of the arroyo branches.

3.2 Hydraulics

Hydraulic analysis for this study was performed using the Corps of Engineers' (COE's) HEC-2 backwater program (COE, 1982). Channel geometry data was taken from available topographic mapping (CSC, 1985), which was developed from May 1985 aerial photography.

Manning's roughness coefficients for the main channel and overbanks were selected based on the characteristics of the channels. Roughness values for the main channel and overbanks were estimated to be 0.030 and 0.035, respectively.

Results of the hydraulic analysis were used to delineate the 100-year flood plain for developed flows using the present topography of the area and develop average hydraulic parameters for the various computational reaches in each branch of the arroyo. The reaches were selected based on similarity of hydraulic, geometric, and soils characteristics and are delineated in Table 3.1. The average hydraulics in each of the reaches from the HEC-2 analysis are presented in Table 3.2. Additionally, Figure 3.1 shows the variation in total top width along the study reach for the 100-year flood. HEC-2 output for the 100-year flood is included in Appendix A.

3.3 Sediment Supply Analysis

3.3.1 General

This section presents quantitative estimates of sediment yields from watershed areas tributary to each of the branches. Sediment yields were determined by use of the Modified Universal Soil Loss Equation (MUSLE). The MUSLE was developed by Williams and Berndt (1972) and provides the watershed sediment yield in the sand-, silt-, and clay-size ranges produced by a single storm.

Table 3.4. Summary of Watershed Parameters for MUSLE Calculations.

existing or proposed

Veget. & Mulch

Tributary* Area	Drainage Area (mi^2)	K	LS	CP
Offsite Areas 1, 3, and 4	3.06	0.39	0.86	0.24
Offsite Area 2	0.85	0.31	0.65	0.24
Offsite Area 5A	0.08	0.40	0.46	0.24
Offsite Area 5B	0.03	0.40	1.26	0.24

* Offsite areas refer to basin delineations used in Community Services Corporation's Master Drainage Plan (CSC, 1985).

Table 3.5. Sediment Yield Estimates From MUSLE For 2-, 50-, 10-, 25-, 50-, and 100-Year Retura Period Floods.

developed Q's

Watershed Return Periods (years)	Peak Discharge Q_p (cfs)	Hydrograph Volume ¥ (ac-ft)	Bed-Material Load-Developed Watershed (tons)
North Branch			
2	95	7.8	56
5	156	12.9	98
10	213	17.6	139
25	287	23.7	193
50	348	28.7	240
100	417	34.4	293
Middle Branch			
2	230	31.0	321
5	415	55.9	621
10	571	77.0	888
25	780	105.1	1259
50	950	128.1	1571
100	1155	155.7	1955
5A			
2	35	1.6	6
5	54	2.5	10
10	68	3.1	13
25	87	4.0	17
50	102	4.7	20
100	117	5.9	24
5B			
2	18	0.7	4
5	28	1.0	6
10	35	1.2	7
25	45	1.6	9
50	53	1.9	11
100	61	2.2	13

/ ~~per~~ what?

How was development taken into account?

[illegible] % imp

3.5 Equilibrium Slope Analysis

Equilibrium channel slope is defined as the slope at which the channel's sediment-transport capacity is equal to the incoming sediment supply. Under this condition, the channel neither aggrades nor degrades. When the present slope of a channel is greater than the equilibrium slope, the channel will degrade in order to reach its equilibrium slope. Conversely, when the present slope of a channel is less than its equilibrium slope, the channel will aggrade. The equilibrium slope method is sometimes referred to as the dynamic equilibrium slope because the gradient of the channel continually changes with upstream sediment supply.

Calculation of the equilibrium slope for a channel is accomplished by applying the continuity principle

$$Q_{s\ IN} = Q_{s\ OUT} \tag{3}$$

where $Q_{s\ IN}$ represents the supply of sediment into a channel reach and $Q_{s\ OUT}$ represents the sediment-transport rate out of a channel reach. Combining the sediment-transport capacity relationship (Equation 1) and the hydraulic conditions in each reach allows calculation of the slope at which the transporting capacity of the reach is equal to the incoming supply.

The equilibrium slope concept is generally used to evaluate the long-term aggradation/degradation response to the channel to flood flows. For this reason, a single, dominant discharge is selected for the analysis. The dominant discharge is that discharge which, if allowed to flow constantly, would have the same channel shaping effect as natural, randomly occurring flows (Design of Small Dams, USBR, 1977). In ephemeral streams, such as Piedras Marcadas Arroyo, the dominant discharge is usually between the 5- and 10-year flood peaks. For this study, the dominant discharge was assumed equal to the 10-year flood peak.

Equilibrium slopes were calculated for the 10-year peak discharge for each reach of the arroyo. The results of these calculations are presented on Table 3.7. The equilibrium slopes shown in the table are significantly flatter than the existing channel slope indicating significant degradation in all of the reaches being considered in this study.

Since there are no apparent natural grade controls within the study reaches, the amount of vertical degradation indicated by the equilibrium slope calculations is excessive. Considering the non-cohesive nature of the bed and bank material, the amount of vertical degradation will be limited by the stable bank height. Additional degradation will take place in the form of channel widening and lateral migration. A continuity analysis was performed to estimate the potential degradation and lateral migration that could take place.

Q_s^{in} = MUSLE ?
Q_s^{out} $Q_s = aQ^b$

3.6 Sediment Continuity Analysis

3.6.1 Sediment Volume Estimation

The volume of sediment transported through each reach of the arroyo during each of the various return period floods was estimated by integrating the flood hydrographs with the sediment rating curves presented in Section 3.4. By comparing the volume of material being supplied to each reach with the transport capacity during a given storm, the volume of material degraded (or sediment deficit) from the reach was estimated. Table 3.8 summarizes the results of these calculations.

?

3.6.2 Channel Degradation

Estimation of the maximum potential vertical degradation in each reach was made based on the sediment deficits identified in the preceeding section. The amount of degradation was determined by dividing the sediment deficit by the reach length and average main channel top width in that reach. The results of the channel degradation calculations are shown in Table 3.8. These calculations are based on the assumption that all of the deficit will be taken from the channel bed.

3.6.3 Lateral Migration

removed only from outside corner

The maximum potential lateral migration in each reach was determined by assuming that the total sediment deficit for each reach will be removed from one channel bank. Since most bank erosion occurs along the outside of bends, the channel length over which the sediment is to be removed was assumed as a typical length of bend as seen on topographic maps of the area. For the reaches of the Main and Middle Branches, the typical bend length was estimated to be 400 feet. For the North Branch and Reaches 1 and 2 of the Main Branch, a smaller length of 200 feet was used. Since the channel in the existing condition has no defined banks, it was necessary to estimate the effective bank height that will be subject to erosion during the migration process.

This was done at each cross section used in the HEC-2 hydraulic analysis based on relative flow depths in the main channel, maximum stable bank heights considering the characteristics of the bank material, site observation of existing banks, and the shape of the cross section in the erosion area. In places where the hillslopes are relatively close to the channel, the lateral migration potential will be limited. For Reaches 1 and 2 of the Main Branch, and 4 of the Main, and Middle Branches, the maximum vertical bank height was estimated to be 5 feet. The maximum vertical bank height for the North Branch was estimated to be 3 feet. The results of the lateral migration calculations for the 100-year flood are summarized and presented on Table 3.9. Channel distances shown in the table are cumulative distances of each respective cross section from the entrance of the dam on the Main Branch and the confluence with the Main Branch on the North and Middle Branches. Exact cross-sectional locations are shown on the 1" x 50' scale maps provided to CSC.

How does curve the bank into channel

3.6.4 Average Annual Erosion Potential

The long-term average annual erosion potential along the study reaches was estimated based on annual sediment yield calculations. The annual sediment yield for each reach was estimated by integrating the flood frequency curve using the following equation:

$$\bar{Y}_s = 0.015\, Y_{s_{100}} + 0.015\, Y_{s_{50}} + 0.04\, Y_{s_{25}} + 0.08\, Y_{s_{10}} + 0.20\, Y_{s_5} + 0.40\, Y_{s_2} \quad (4)$$

where $\bar{Y}_s$ is the average annual sediment yield, Y_{s_i} is the sediment yield for the individual storm events. Maximum potential degradation estimates were then computed using the procedure described in the previous sections. The results of the calculations are summarized in Table 3.10.

The erosion estimates given in Table 3.10 represent the expected average annual erosion rate for the developed condition. As shown in the table, the North and Middle Branches and Reach 3 of the Main Branch have a relatively high erosion potential with lateral migration rate of 20 to 30 feet per year. It should be noted that the rates shown in the table are long-term averages. The actual erosion is most likely to occur in discrete elements depending upon the sequence of flooding that occurs in the future. Little or no migration or

Table 3.10. Average Annual Erosion Estimates.

Reach	Unbulked* Sediment Deficit (CF)	Potential Maximum Channel Degradation (ft)	Potential Channel Migration (ft)
North Branch	25,400	1.1	21
Middle Branch	59,030	2.7	30 y/o (com 300'
Main Branch			
1	1,910	0.1	5
2	900	0.1	2
3	56,600	1.0	28

* Assuming porosity = 0.40.

where are reaches called out
see page 3.2

IV. CONCLUSIONS AND RECOMMENDATIONS

A qualitative and quantitative sediment-transport analysis was performed to evaluate the erosion potential of selected reaches of the Piedras Marcadas Arroyo near Albuquerque, New Mexico. The primary objective of this study was to evaluate the bank erosion and lateral migration potential of the arroyo during flooding to provide the basis for erosion buffer distances and/or other necessary protection measure for the proposed watershed development.

In general, the results of the study indicate that, due primarily to increased runoff and reduced sediment supply associated with the increase in impervious area in the watershed, the entire study reach is degradational during flooding. The degradation and lateral migration potential is significant, but varies depending on the location along the arroyo being considered. The following specific conclusions can be derived from the study:

1. The overall watershed upstream of the Piedras Marcadas Dam has a drainage area of approximately 4.5 square miles.

2. The watershed is naturally divided by a 50- to 100-foot high escarpment with overland slopes ranging from 1 to 3 percent upstream of the escarpment and 2 to 6 percent below the escarpment.

3. In its existing condition, the watershed is less than 20 percent developed with the largest developed area occurring in the upper portion of the North Branch drainage. A small portion of the Middle Branch is also developed.

4. Current development plans will increase the amount of impervious area in the watershed to approximately 40 percent. ~~for~~ Hughes estates only, or entire watershed?

5. The significant increase in impervious area will increase the frequency of occurrence and amount of runoff resulting from precipitation in the watershed. This will also result in a reduction in the supply of sediment from the watershed.

6. Sediment samples collected in the arroyo beds indicate relatively uniform sandy material with little or no cohesion. Median size of the material is approximately 0.25 mm. The nature of the bed material indicates that it is highly susceptible to erosion during flooding.

7. Based on Items 3 through 6 above, a qualitative analysis indicates that the increase in runoff and reduction in sediment supply associated with the proposed development will result in increased erosion potential in the various branches of the arroyo.

8. The above conclusion is supported by historical evidence found in the North Branch study reach. The watershed for this branch is approximately 50 percent developed. Observations during the site visit indicate that the arroyo channel has a well-defined channel with 2- to 3-foot high,

who, when, will do this work

3. As the development progresses, the channel will undoubtedly begin to incise. As this occurs, it may be desirable to install grade controls at critical locations in the channel to limit the amount of vertical degradation that takes place. By limiting the vertical degradation, the tendency for unstable banks and lateral migration will also be reduced.

4. Due to the highly erodible nature of the channel bed material, it is recommended that protection be provided at the outlet of any storm drainages or culverts that enter the arroyo channel. This protection may be composed of either properly sized riprap, reinforced concrete, or soil cement and should be constructed to protect the channel bottom and opposite channel bank from erosion due to flow impingment from the outlet works.

5. The degradation potential (including local scour) within the arroyo channel should be given consideration in designing the foundation of headwalls and outlet works for any culverts or other structures within the main arroyo channel or the storm drain outlets discussed in Item 4 above. If sufficient toedown or erosion protection is not provided, local and general scour could result in failure of the structures.

V. REFERENCES

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HYDROLOGY SECTION

ATTACHMENT B

Background Information on Development of Sediment-Transport Relationships

ATTACHMENT B
Background Information on Development of Sediment-Transport Relationships

I. GENERAL

Transport of the bed-material load in a river channel is divided into two zones. The sediment moving in a layer close to the bed is referred to as the bed load. The sediment carried in the remaining upper region of the flow is referred to as suspended bed load. The total bed-material load is the sum of the bed load and suspended bed load. The turbulent mixing process and the action of gravity on the sediment particles cause a continual transfer between the two zones. Although there is no distinct line between the zones, the definitions are made in order to aid in the mathematical description of the process. The wash load occupies the entire depth of flow, but consists of fine particles that are not present in the bed in appreciable quantities, and will not easily settle out. Wash load is primarily controlled while bed load and suspended bed load are primarily controlled by the transport capacity of the river and availability of material in the channel bed and banks.

Sediments of different sizes will experience different rates of transport. Therefore, the transport capacities for a range of sediment sizes are determined and totaled to produce an acceptable determination of total transport capacity. The total bed-material transport capacity for a channel section is

$$Q_s = T \Sigma P_i (q_{bi} + q_{si}) \qquad (1)$$

In Equation 1, T is the top width of the channel, P_i is the fraction of one sediment size, q_{bi} is the bed-load transport rate per unit for the ith size, and q_{si} is the suspended load transport rate for the ith size.

II. BED-LOAD TRANSPORT CAPACITY

The Meyer-Peter, Muller formula gives good results for bed-load transport over a wide range of sediment sizes. The Meyer-Peter, Muller formula will well suited to model the dynamics of channel armoring processes as well as transport of sand sizes with little armoring potential. The formula is

$$q_{bi} = \frac{12.85}{\sqrt{\rho} \ \gamma_s} (\tau_o - \tau_c)^{1.5} \qquad (2)$$

in which

$$\tau_c = F_* (\gamma_s - \gamma) d_{si} \qquad (3)$$

In Equations 2 and 3, q_{bi} is the bed-load transport rate in volume per unit width for a specific size of sediment, τ_c is the critical tractive force necessary to initiate particle motion, ρ is the density of water, γ_s is the specific weight of sediment, γ is the specific weight of water, d_s is the sediment size, and F_* is the Shield's parameter which ranges between 0.030 and 0.060, inclusive.

The boundary shear stress acting on the grain is

$$\tau_o = \frac{f_o}{8} \rho V^2 \qquad (4)$$

where ρ is the density of flowing water and f_o is the Darcy-Weisbach friction factor, and V is the mean velocity of the flow.

The Darcy-Weisbach friction factor is related to Manning's n by:

$$f_o = n^2 \frac{8g}{1.49^2 R^{1/3}} \qquad (5)$$

where g is the acceleration due to gravity and R is hydraulic radius. Assuming the wide channel approximation is valid, then the hydraulic radius R is equal to depth.

For sediment-transport calculations, Manning's n in Equation 5 represents the skin resistance only, which is typically 0.6 to 0.9 times the total Manning's n for the channel depending upon the preponderance and type of bed forms.

III. SUSPENDED BED-MATERIAL TRANSPORT CAPACITY

The suspended sediment-transport capacity is determined by using a solution developed by Einstein. This method relies upon integration of the sediment concentration profile as a function of depth. The nature of the profile is determined using turbulent transport theory. The sediment profile is assumed to be in equilibrium, and therefore the rate at which sediment is transported upward due to turbulence and the concentration gradient is exactly equal to the rate at which gravity is transporting sediment downward. The resulting concentration profile is given by:

$$\frac{C}{C_a} = [\frac{Y-y}{y}\,\frac{a}{Y-a}]^z \qquad (6)$$

where C is the concentration at a point y, C_a is the concentration at point a generally considered to be the bed layer thickness, Y is the depth and z is given by:

$$z = \frac{w}{\kappa U_*} \qquad (7)$$

where w is the fall velocity for a given size sediment, U_* is the shear velocity, and κ is the von Karman constant (0.4). U_* is defined as $\sqrt{\tau/\rho}$ where τ is the shear stress on the bed and ρ is the density of the fluid. (Note: τ should be the total shear stress on the bed and not the grain-associated shear stress. The shear velocity U_* characterizes both the turbulence and grain resistance, and the fall velocity w characterizes the sediment properties.)

A logarithmic velocity profile is used to describe the velocity distribution in turbulent flows. The equation utilized is

$$\frac{u_\xi}{U_*} = B + 2.5\ \ell n\ (\frac{\xi}{\eta_s}) \qquad (8)$$

in which u_ξ is the point mean velocity at the distance ξ from the bed, B is a constant dependent on roughness, and η_s is the roughness height.

The integral of suspended load above the bed layer is obtained by combining Equations 6 and 7 or

$$q_{si} = \int_a^Y u_\xi C_\xi d\xi = C_a U_* \int_a^Y [B + 2.5\ell\ n\ (\frac{\xi}{\eta_s})]\ (\frac{Y-\xi}{\xi}\,\frac{a}{Y-a})^z\ d\xi \qquad (9)$$

where q_{si} is the suspended bed-material transport for a specific size sediment above the bed layer. In this equation

$$\sigma = \frac{\xi}{Y} \qquad (10)$$

where σ is the dimensionless relative depth and

$$G = \frac{a}{Y}$$

in which G is the relative depth of the bed layer. Integration of Equation 9 yields

$$q_{si} = C_a U_* a \frac{G^{z-1}}{(1-G)^z} \{[B + 2.5 \ln(\frac{Y}{\eta_s})] \int_G^1 (\frac{1-\sigma}{\sigma})^z d\sigma$$

$$+ 2.5 \int_G^1 (\frac{1-s}{\sigma})^z \ln\sigma \, d\sigma\} \qquad (11)$$

The average flow velocity V is defined by the equation

$$V = \frac{\int_0^Y u_\xi \, d\xi}{\int_0^Y d\xi} \qquad (12)$$

Substituting Equation 8 into Equation 12 and integrating yields

$$\frac{Y}{U_*} = B + 2.5 \ln (\frac{Y}{\eta_s}) - 2.5 \qquad (13)$$

The two integrals in Equation 11 can be defined as

$$J_1 = \int_G^1 (\frac{1-\sigma}{\sigma})^z d\sigma \qquad (14)$$

and

$$J_2 = \int_G^1 (\frac{1-\sigma}{\sigma})^z \ln\sigma \, d\sigma \qquad (15)$$

Substituting Equations 13, 14, and 15, reduces Equation 11 to

$$q_{si} = C_a U_* a \frac{G^{z-1}}{1-G^z} [(\frac{V}{U_*} + 2.5) J_1 + 2.5 J_2] \qquad (16)$$

According to Einstein, the concentration at the upper level of the bed layer is related to the total transport in the bed layer by

$$q_{bi} = 11.6 \, C_a U_* a \qquad (17)$$

Substituting into Equation 16 produces

$$q_{si} = \frac{q_{bi}}{11.6} \frac{G^{z-1}}{1-G^{z}} \left[\left(\frac{V}{U_*} + 2.5\right) J_1 + 2.5 J_2\right] \tag{18}$$

Generally, sediment measurements are taken in a zone approximately 0.3 feet above the bed and higher since commonly used measuring devices are incapable of getting closer to the bed. Hence, commonly reported sediment measurements consist of wash load and suspended bed load. This zone of measured sediment transport will be denoted the "measured zone" in the following discussion.

For practical purposes, wash load consists of no particles greater than 0.062 mm. If size analyses of suspended sediment and corresponding concentration measurements have been made, then the concentration of suspended bed material in the measured zone is given by

$$C_{bm} = P * C_m \tag{20}$$

where C_{bm} is the concentration of suspended bed material in the measured zone, P is percent of suspended bed-material load, and C_m is total measured concentration.

No C_{bm} may be calculated theoretically using the following procedure. First, the suspended bed-material concentration at 0.3 feet above the bed is calculated from:

$$C_{0.3} = C_a \left(\frac{Y = 0.3}{0.3} \frac{a}{Y - a}\right)^{z} \tag{21}$$

Substituting this concentration into Equation 16 and changing the limits of integration appropriately, yields the transport rate of suspended bed material for a specific size in the zone extending from 0.3 feet above the bed to the water surface. The resulting relation is

$$q_{0.3i} = C_{0.3}\, U_* 0.3 \frac{G'^{z-1}}{(1-g')^{z}} \left[\left(\frac{V}{U_*} + 2.5\right) J'_1 + 2.5 J'_2\right] \tag{22}$$

where

$$G' = \frac{0.3}{Y} \tag{23}$$

$$J'_1 = \int_{G}^{1} \left(\frac{1-\sigma}{\sigma}\right)^{z} d\sigma \tag{24}$$

and

$$J_2' = \int_{G'}^{1} \left(\frac{1-\sigma}{\sigma}\right)^z \ln\sigma \, d\sigma \qquad (25)$$

Rewriting Equation 22 and using Equation 21, produces the relation

$$q_{0.3i} = C_a U_* 0.3 \left(\frac{Y-0.3}{0.3}\,\frac{a}{y-a}\right)^z \frac{G'^{\,z-1}}{(1-G')^z}\left[\left(\frac{V}{U_*} + 2.5\right) J_1' + 2.5\, J_2'\right] \qquad (26)$$

Introducing Equation 17 modifies the foregoing relation to read

$$q_{0.3i} = \frac{q_{bi}}{11.6}\,\frac{0.3}{a}\left(\frac{Y-0.3}{0.3}\right)^z \frac{G'^{\,z-1}}{(1-G')^1}\left[\left(\frac{V}{U_*}\right) + 2.5\right) J_1' + 2.5\, J_2' \qquad (27)$$

The total concentration of suspended bed material in the measured zone is given by

$$C_{bm}' = \sum_{i=1}^{n} (P_i * q_{0.3i}) / q * S.G. \qquad (28)$$

where C'_{bm} is the theoretically computed bed-material concentration, q is water discharge, and S.G. is the specific gravity of the sediment, n is the total number of sediment sizes.

Comparing C_{bm} and C'_{bm} for a wide range of discharges yields a measure of the accuracy of the theoretical computation procedure.

This procedure can be "calibrated" so that the C'_{bm} values agree closely with the C_{bm} values by adjusting one or more parameters involved in the procedure. These parameters are:

1. Shield's parameter F^*. This is generally assumed equal to 0.047, but may range in value from 0.030 to approximately 0.060.

2. Manning's n for skin resistance only. Typical values of 0.01 to 0.03. This parameter may be estimated from Stickler's relation:

   $$n = \frac{D_{90}^{\;1/6}}{26}$$

   where D_{90} is in meters.

3. Bed layer thickness a. This is an extremely important parameter since it determines the concentration C_a which defines the suspended bed-material concentration profile. The value of a is typically taken as two time the D_{65} or D_{90} of the bed material.

4. As a last resort, the exponent 1.5 and the coefficient 12.85 in Equation 2 may be adjusted.

The next step is to use the "calibrated" transport procedure to generate values for total bed-material transport for a wide range of river discharges. HEC-2 use used to determine the hydraulics for these discharges. A regression analysis was performed on the resulting data to obtain a relation of the form:

$$q_s = a\, V^b Y^c \qquad (29)$$

where q_s is unit bed-material transport, V is velocity, Y is depth, and a, b, and c are coefficients.

The calibrated transport relations are then applied using the average hydraulic and sediment conditions in each of the computational reaches to determine the bed-material rating curves of the form:

$$Q_s = a\, Q^b \qquad (30)$$

for each reach, were Q_s is total bed-material transport within the reach and Q is river discharge. These relationships form the basis of the continuity calculations.