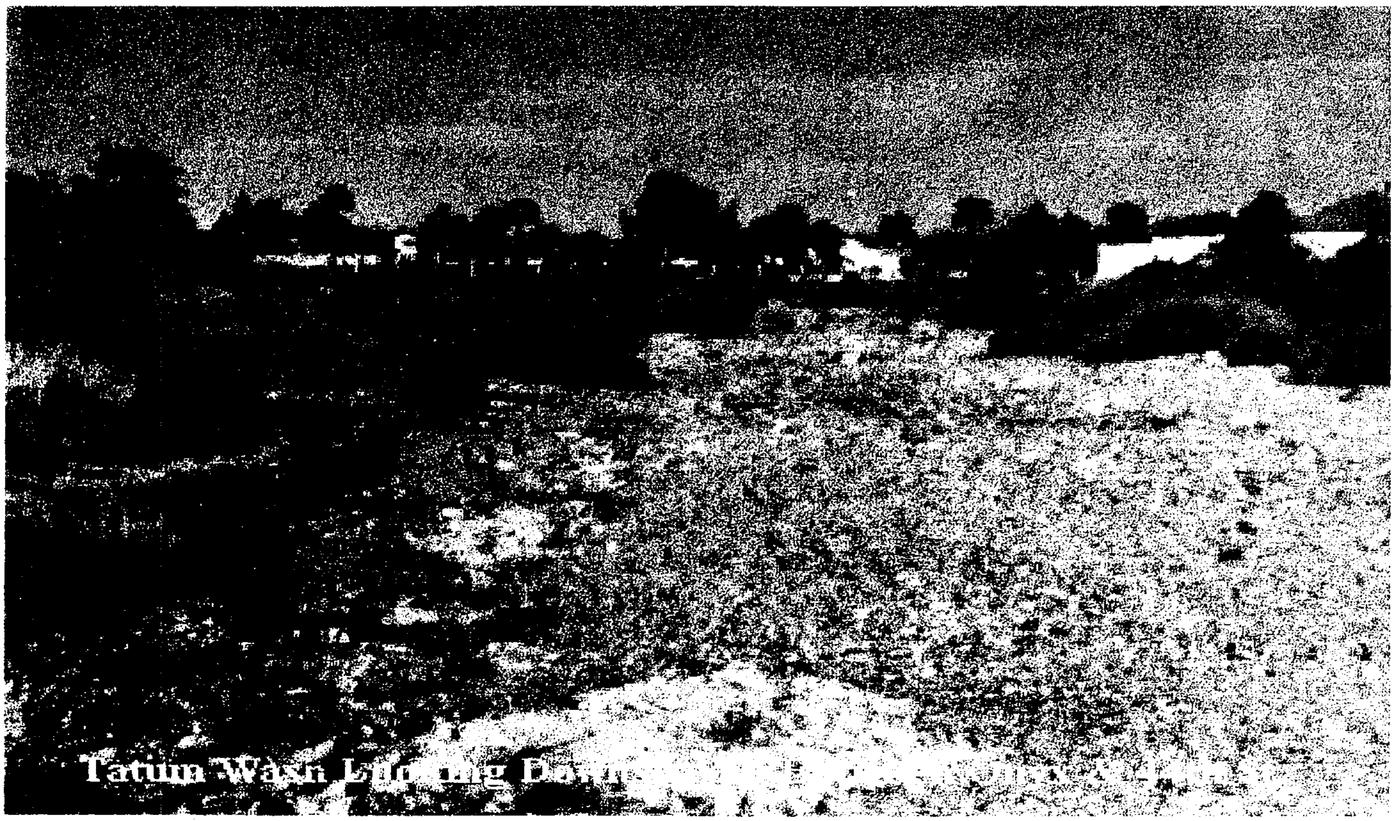
Tatum Wash Sedimentation Study

Final Report

January 28, 1997



Flood Control District of Maricopa County
Planning Division
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Executive Summary

The Tatum Wash study area is located within the City of Phoenix, and extends from the Phoenix Mountain Preserve boundary to Shea Boulevard. The Flood Control District of Maricopa County has proposed a two-phased drainage improvement project to alleviate local flooding problems, particularly in the neighborhoods along the historical flow path of Tatum Wash downstream of Shea Boulevard. The proposed drainage improvements include (Phase 1) a sediment trap basin and storm drain connection at Shea Boulevard, and (Phase 2) a detention basin located immediately upstream of the Phoenix Mountain Preserve boundary.

This sedimentation study evaluated the impacts of the proposed drainage improvements on channel stability, and estimated sediment yield and storage requirements at the proposed basins. The geomorphic evaluation of the Tatum Wash indicated that the existing channel is at or near a stable, equilibrium conditions. Construction of the sediment trap basin at Shea Boulevard will have no significant impacts on the Tatum Wash study reach. Construction of the Phoenix Mountain Preserve detention basin will tend to increase local scour in the study reach over the long term. Conceptual design of grade control structures and monitoring of channel changes were proposed to mitigate the affects of increase local scour following implementation of Phase 2 of the project.

Average annual sediment deposition at the sediment trap was estimated at 2 acre feet per year, with the 100-year sediment volume estimated at about 15 acre feet. Following construction of the detention basin in the Phoenix Mountain Preserve, the sediment deposition volume at the Shea Boulevard sediment trap basin will be reduced to about 11 acre feet, with average annual sediment volume essentially unchanged at about 2 acre feet per year. The average annual sedimentation rate in the Phoenix Mountain Preserve detention basin was estimated at 3 acre feet per year, with the 100-year rate at about 17 acre feet.

Conceptual design modifications for the proposed drainage improvements based on the sedimentation study included constructing a debris and sediment screen to prevent clogging and/or burial of the sediment trap outlet, protecting the basin inlets from erosion, and conducting regular inspection and maintenance of the basins and channel.

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Section 1:
Introduction

The Tatum Wash study area is located within the City of Phoenix, and extends from the Phoenix Mountain Preserve boundary to Shea Boulevard (Figure 1-1). The residential area surrounding the Tatum Wash study area is subject to periodic flooding. The Flood Control District of Maricopa County (FCDMC, 1996) described the flooding problem as follows:

> "The City of Phoenix has received several complaints from residents, mostly located north of Shea Boulevard and west of Tatum Boulevard, who have been experiencing frequent flooding problems. The extent of the problem encompasses floodwater inundating neighborhood roadways, floodwater entering yards and destroying landscaping, and floodwater entering homes. These flooding problems have occurred during relatively minor flood events, events that are considerably smaller than both the 100- and 50-year flood events. During the Flood Control District's FY 94/95 project prioritization process, the City of Phoenix submitted this area as a potential District project due to the severity of the flooding problem. The District's project prioritization process recommended that this project go forward through the pre-design study stage. On June 19 1996, the District's Board of Directors approved the Tatum Wash Drainage Improvement Project feasibility study as a project that would be performed primarily by District Staff."

The Tatum Wash Sedimentation Study was performed by JE Fuller/ Hydrology & Geomorphology, Inc. (JEF) under contract #FCD 95-35 to support the District's in-house design of drainage improvements for Tatum Wash.

Project Description

The preferred alternative for the District's Tatum Wash Drainage Improvement Project consists of the following features (FCDMC, 1996a):

- Phase 1 - Shea Boulevard Sediment Basin. An on-line sediment trap basin will be constructed on a vacant parcel within the Tatum Wash floodplain upstream of and adjacent to Shea Boulevard. The sediment trap will be designed to prevent excessive sediment and debris from entering the existing City of Phoenix 78-inch storm drain located under Shea Boulevard. The storm drain, which outlets on a private golf course within the Indian Bend Wash floodplain, will intercept a portion of the runoff from Tatum Wash via a 66-inch concrete pipe which serves as the outlet from the proposed sedimentation basin. The sediment trap basin will provide minimal flood protection to the residential area located north of Shea Boulevard.

- Phase 2 - Phoenix Mountain Preserve Detention Basin. A detention basin, or a series of basins, capable of storing the 100-year flood and reducing the peak flow in Tatum

Wash to about 621 cfs, will be constructed within the Phoenix Mountain Preserve. The outflow from the detention basin will be conveyed through the natural channel of Tatum Wash to the sediment trap basin constructed for Phase 1 and the existing City of Phoenix Shea Boulevard storm drain. Construction of the Phase 2 detention basin(s) within the Phoenix Mountain Preserve is contingent on approval by the City of Phoenix, and will be implemented under their direction. The District's current conceptual design plan calls for a single detention basin located immediately upstream of the Phoenix Mountain Preserve boundary.

As currently proposed, the Tatum Wash Drainage Improvement Project does not include any alternatives that include channelization, levee construction, or programmed channel or vegetation maintenance.

Study Objectives

The objective of the Tatum Wash Sedimentation Study was to evaluate potential sediment impacts on the District's proposed drainage improvement project for Tatum Wash.

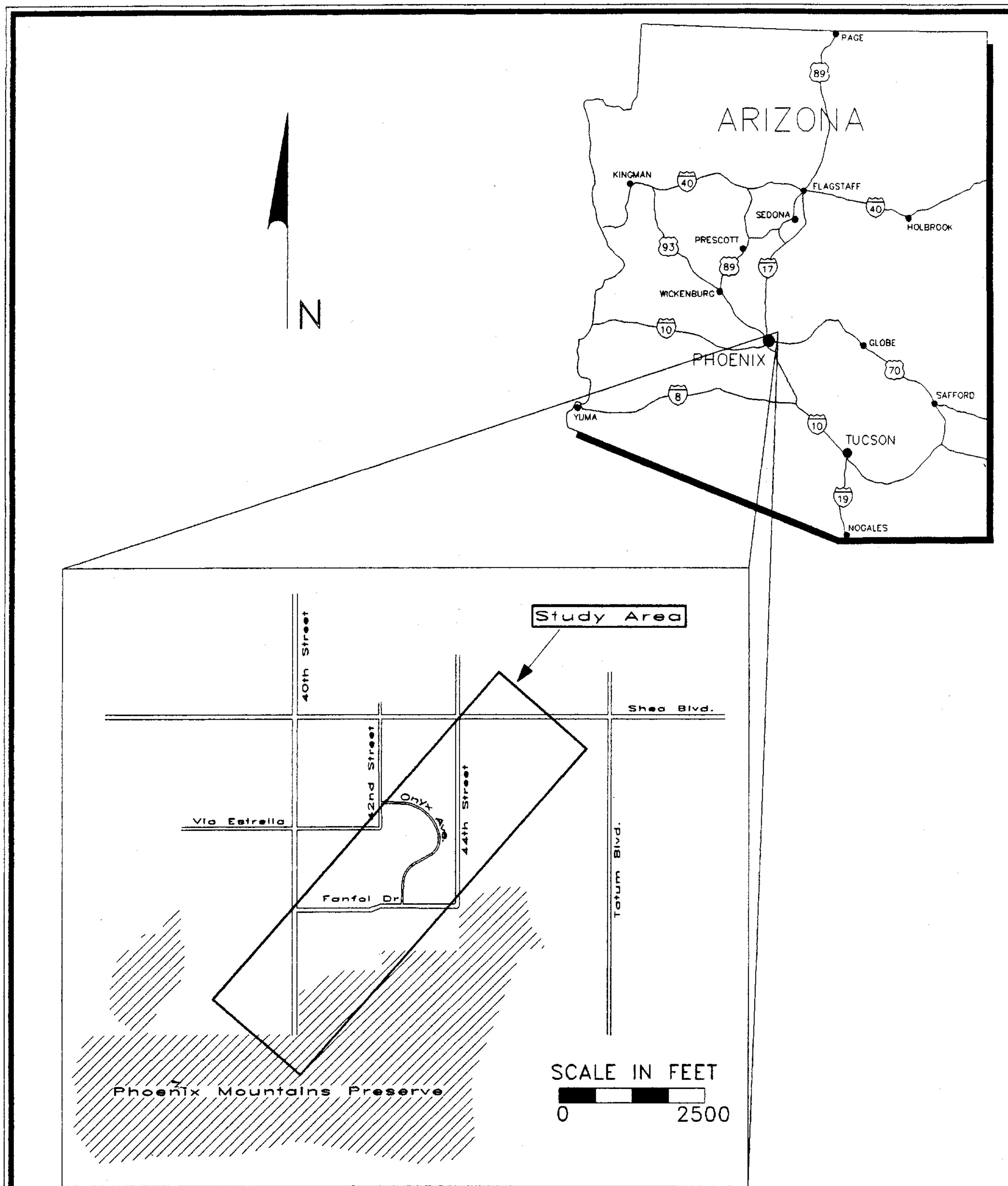
Specific technical analysis prepared as part of the sedimentation study included the following tasks:

- Hydrology - Review FCDMC HEC-1 Models
- Hydraulics - Review and Extend FCDMC HEC-2 Model
- Sedimentation Engineering - Estimate Sediment Yield
- Sedimentation Engineering - Conduct Geomorphic Analysis
- Sedimentation Engineering - Prepare HEC-6 Sediment Continuity Analysis
- Channel and Basin Design Recommendations - Consider Sediment Impacts
- Project Maintenance and Operations - Estimate Requirements

The results of the technical analyses are described in the remainder of this report. The information presented in this report was based on the conceptual project information available at the time the study and analyses were completed. Unless specifically designated as such, the information, recommendations and conclusions of this report are not intended as final design plans, specifications, or documents.

Study Limits

Tatum Wash extends from its headwaters in the Phoenix Mountain Preserve to the confluence with Indian Bend Wash. The study reach consists of the portion of Tatum Wash located between northern boundary of the Phoenix Mountain Preserve to the proposed sedimentation basin adjacent to and upstream of Shea Boulevard, within the City of Phoenix. The study area is generally located within Section 30, Township 3 North, Range 4 East.



Tatum Wash Sedimentation Study
Flood Control District of Maricopa County

JE Fuller / Hydrology & Geomorphology, Inc.

January, 1997

Figure 1-1

Project Location

Sheet 1 of 1

Section 2:
Hydrologic Modeling

Introduction

HEC-1 hydrologic models (USACOE, 1990) for the 2-, 10-, 50-, and 100-year events for the Tatum Wash watershed existing conditions were prepared by District staff. "With-project" conditions HEC-1 model were prepared by JEF, Inc. to simulate the effects of the project drainage improvements. The objective of hydrologic modeling tasks were to develop hydrologic information for use in the sedimentation engineering analyses.

Specific hydrologic modeling tasks performed by JEF, Inc. included the following:

- Evaluate District's HEC-1 Model. JEF, Inc. reviewed the District's HEC-1 model to determine its suitability for use in a sedimentation study. The review focused on the following items: (1) Recurrence Intervals. The HEC-1 model should predict runoff for the 2-, 10-, 50-, and 100-year events; (2) Tributary Locations. The HEC-1 model should provide discharges, runoff volumes, and hydrographs at key concentration points required for the sedimentation analysis, such as tributaries, where sediment supply and/or peak discharge may increase; (3) Discharge Estimates. The HEC-1 model should provide results compatible with regional discharge estimates, and gauged rainfall/runoff information if available.

- Determine Existing Conditions Design Discharges. JEF, Inc. obtained peak discharge rates, hydrographs, and runoff volumes from the District's HEC-1 model at key concentration points for existing (pre-project) conditions.

- Evaluate With-Project Hydrology. JEF, Inc. modeled the effects of the Phase 1 Shea Boulevard sediment trap basin and the Phase 2 Phoenix Mountain Preserve detention basin by modifying the District's HEC-1 model, using information obtained from the conceptual design plans for the proposed basins prepared by the District (1996).

FCDMC HEC-1 Model

The District provided a document entitled *Report on Hydrology of Tatum Wash* prepared by the FCDMC Hydrology Branch (1995), and a diskette with input files for existing conditions 6-hour, 100-year HEC-1 models for the Tatum Wash and Shea Wash watersheds. HEC-1 models for the 2-, 10-, and 50-year recurrence intervals for the Tatum Wash Watershed were later provided by Afshin Ahouraiyan of the FCDMC Hydrology Branch. The District developed the 2-, 10-, and 50-year Tatum Wash HEC-1 models by modifying the precipitation input records in the 100-year HEC-1 model. The District made no modifications to the 100-year HEC-1 model time of concentration, channel routings, rainfall losses, or other modeling parameters to generate the lower recurrence interval HEC-1 models. Review of the District's HEC-1 models by JEF, Inc. concluded that the models provided discharges, runoff volumes, and hydrographs at a sufficient number of concentration points for use in the sedimentation study (JEF, 1996a).

Existing Conditions Design Discharges

Existing conditions design discharges for the Tatum Wash Sedimentation Study, based on the HEC-1 models provided by the District, are summarized in Table 2-1.

Table 2-1. Tatum Wash Sedimentation Study
Existing Conditions Design Discharges Estimated Using HEC-1 (cfs)

Concentration Point	Geographic Location	Recurrence Interval			
		2-Year	10-Year	50-Year	100-Year
CP2e	Shea Boulevard	334	848	1798	2315
CP2d1	44th St./Onyx Drive	333	843	1786	2301
CP2c	Section # 5150.8	331	833	1762	2268
CP2b	Mountain View	330	830	1752	2261
CP2a2	Fanfol Drive	329	827	1744	2244
CP2a1	40th Street	327	818	1721	2219
CP1f	PMP Boundary	328	820	1719	2212
CP1e	End of HEC-6 Reach	283	710	1486	1911
CP1c	Within Phx. Mtn. Park	131	329	680	892
Filename	-	tm2yr.dat	tm10yr.dat	tm50yr.dat	tatmss1s2.dat

Because the peak discharges for the inflow hydrographs are similar at the concentration points within the HEC-6 modeling reach (CP1e to CP2e), a single hydrograph for each recurrence interval may be used for the sediment modeling of the study reach.

"With-Project" Design Discharges

The District's existing conditions HEC-1 models for Tatum Wash were modified to model the effects of the proposed sediment trap basin at Shea Boulevard and the detention basin upstream of the Phoenix Mountain Preserve boundary. Basin geometry, storage capacities, and outflow rates were obtained from the District's *Tatum Wash Drainage Improvement Project Feasibility Study/Planning Summary Report* (1996), as summarized in Table 2-2. Design parameters for the proposed basins that were not explicitly presented in the District's Feasibility Study were estimated using engineering judgment and typical design practices for the Phoenix metropolitan area.

Table 2-2. Tatum Wash Sedimentation Study Characteristics of Proposed Tatum Wash Drainage Improvement Project Basins		
Characteristic	**Shea Blvd. Sedimentation Basin**	**Phoenix Mtn. Preserve Regional Detention Basin**
Total Volume	35 AF	135 AF
Outlet Structure	66"	no info.
Maximum Outflow Rate[1]	375	621 cfs
Surface Area	4.4 ac	no info.
Maximum Depth	18 ft.	no info.
[1]Rate reported by District. HEC-1 models summarized below indicates slightly different rates.		

In addition to the characteristics summarized in Table 2-2, the following conditions were assumed for the HEC-1 models:

- Shea Boulevard Sedimentation Basin:
    1. 20-foot setback from property boundaries
    2. 4:1 basin side slopes
    3. Outlet modeled as orifice
    4. Maximum storage/overtopping elevation of 1396 feet
    5. Depth of 14 feet at downstream side
    6. Overtopping length of 294 feet
    7. Overtopping hydraulics of broad-crested weir

- Phoenix Mountain Preserve Basin:
    1. No known elevation/storage relationship
    2. No known outlet structure size/type
    3. Use 2-point storage vs. discharge relationship (0 cfs/0 AF - 621 cfs/135 AF)

HEC-1 models for Phase 1 (Shea Boulevard sediment trap basin) and Phase 2 (Shea Boulevard sediment trap basin and Phoenix Mountain Preserve detention basin) conditions were prepared for the 2-, 10-, 50-, and 100-year recurrence intervals. The HEC-1 modeling results indicate that for Phase 1, the Shea Boulevard sedimentation basin will not significantly attenuate peak flows and will be overtopped at less than the 10-year recurrence interval. For Phase 2, the Shea Boulevard basin may be overtopped by 0.28 foot during the 100-year event, given the preliminary basin geometry used and conceptual design information available at the time the model was prepared. HEC-1 modeling results are summarized in Table 2-3.

Basin characteristics and hydrographs from the with-project conditions HEC-1 models will be used in the with-project conditions HEC-6 models are described in Section 6 of this report.

Table 2-3. Tatum Wash Sedimentation Study HEC-1 Discharge Estimates for With-Project Conditions			
Characteristic	**Phase 1**	**Phase 2**	
	Shea Basin	**Shea Basin**	**Phx Mtn Basin**
Q100			
Peak Inflow to Basin	2315 cfs	581 cfs	2,212 cfs
Peak Outflow from Basin	2304 cfs	512 cfs	555 cfs
Maximum Volume Stored	38 AF[1]	33 AF[1,2]	110[1]
Total Storm Volume[3]	189 AF	189 AF	168
Time to Drain Basin	10 hrs	24 hrs	22 hrs
Maximum Ponding Elevation in Basin	1397.82	1396.28	-
HEC-1 Model Name	P1_100YR.HC1	P2_100YR.HC1	
Q50			
Peak Inflow to Basin	1,798 cfs	469 cfs	1,719 cfs
Peak Outflow from Basin	1,771 cfs	358 cfs	448 cfs
Maximum Volume Stored	37 AF[1]	27 AF[1]	89 AF[1]
Total Storm Volume[3]	156 AF	156 AF	139 AF
Time to Drain Basin	10 hrs	23 hrs	22 hrs
Maximum Ponding Elevation in Basin	1397.47	1394.33	-
HEC-1 Model Name	P1_50YR.HC1	P2_50YR.HC1	
Q10			
Peak Inflow to Basin	848 cfs	251 cfs	820 cfs
Peak Outflow from Basin	534 cfs	225 cfs	240 cfs
Maximum Volume Stored	33 AF[1,2]	12 AF[1]	48 AF[1]
Total Storm Volume[3]	89 AF	89 AF	80 AF
Time to Drain Basin	11 hrs	23 hrs	21 hrs
Maximum Ponding Elevation in Basin	1396.32	1388.38	-
HEC-1 Model Name	P1_10YR.HC1	P2_10YR.HC1	
Q2			
Peak Inflow to Basin	334 cfs	114 cfs	328 cfs
Peak Outflow from Basin	238 cfs	109 cfs	111 cfs
Maximum Volume Stored	13 AF[1]	7 AF[1]	22 AF[1]
Total Storm Volume[3]	42 AF	42 AF	39 AF
Time to Drain Basin	10 hrs	21 hrs	19 hrs
Maximum Ponding Elevation in Basin	1388.84	1386.06	-
HEC-1 Model Name	P1_2YR.HC1	P2_2YR.HC1	

Notes:

1. Maximum storage volume is the peak volume of water held in the basin, as estimated by the HEC-1 model. Storage volume may exceed the excavated volume of the basin if the ponded water surface is higher than the emergency spillway (overflow). Data in this table does not include use of storage volume by sediment trapped in the basin.
2. Given basin geometry assumptions made for HEC-1 modeling, described in text above, actual maximum storage in Shea Blvd. sediment trap at elevation 1396 = 31.91 AF, not 35 AF as shown in Table 2-2.
3. Total storm volume is the amount of runoff generated by the design flood hydrograph.

Summary

Hydrologic data were developed for use in the sedimentation study. HEC-1 models prepared by the District were used to simulate existing conditions, and were evaluated and modified by JEF, Inc. for "with-project" conditions. HEC-1 modeling results were used to determine design discharges, and as input for sedimentation engineering analyses described later in this report.

The HEC-1 results indicate that unless a large detention basin is constructed (e.g., the proposed Phase 2 Phoenix Mountain Preserve basin), the proposed Shea Boulevard sediment trap provides very little flood protection for the neighborhoods downstream of Shea Boulevard that have been identified as flood-prone by the District. The HEC-1 model estimates that the sediment trap basin will be overtopped during a 10-year flood. Therefore, construction of the sediment trap without concurrent construction of the Phoenix Mountain Preserve basin will protect downstream residents from some nuisance flooding, but will not provide an adequate degree of flood protection from larger floods.

Section 3:
Hydraulic Modeling

Introduction

Hydraulic modeling tasks for the Tatum Wash Sedimentation Study were performed using the HEC-2 (USACOE, 1990) computer model. A HEC-2 model for the lower portion of the Tatum Wash study reach was provided by the District. JEF, Inc. extended the District's HEC-2 model to cover the entire study reach, and used the HEC-2 modeling results to provide hydraulic data for analysis of the Tatum Wash study reach. The objectives of hydraulic modeling tasks were to evaluate hydraulic channel characteristics, and to develop hydraulic data for use in the sedimentation engineering, sediment continuity, and geomorphic analyses.

Specific HEC-2 modeling tasks performed by JEF, Inc. included the following:

- Evaluate FCDMC HEC-2 Model. The District prepared a HEC-2 model for the portion of Tatum Wash downstream of 40th Street that was intended to serve as the basis of the hydraulic analyses for the sedimentation study. JEF evaluated the District's HEC-2 model for use in the sedimentation study. The evaluation focused on the following criteria: (1) Model Results. The District's HEC-2 model structure and output should be compatible for use in evaluating hydraulic channel conditions and design alternatives; (2) HEC-6 Conversion. The District's HEC-2 model structure should allow conversion to HEC-6 format for sedimentation analysis without significant revisions to cross section spacing and geometry.

- Extend FCDMC HEC-2 Model. The District's HEC-2 model of Tatum Wash only extended from Shea Boulevard to 40th Street. JEF, Inc. extended the HEC-2 model approximately 3,000 feet upstream of 40th Street, a sufficient distance to model the sediment supply reach, which included the reach for the proposed Phoenix Mountain Preserve detention basin.

- Perform HEC-2 Analysis. JEF, Inc. used the extended HEC-2 modeling results to perform the following tasks: (1) Identify hydraulically similar channel reaches (slope, velocity, depth, width); (2) Identify existing flooding breakout points and discharge thresholds; (3) Identify channel choke points (reaches of limited capacity); (4) Identify potential areas for channel improvement that would increase channel capacity; (5) Identify the channel cross section with the least conveyance capacity for the entire study reach; (6) Estimate flow depths and velocities at road crossings; (7) Estimate existing channel capacity relative to return period; (8) Compare channel capacity to the District's proposed detention basin outflow rates and proposed downstream storm drain capacity.

FCDMC HEC-2 Model

The District provided a diskette with a HEC-2 input file ("SA1.DAT") for the portion of the Tatum Wash study reach between Shea Boulevard and 40th Street. Included with the HEC-2 input file were a topographic map base sheet (Mclain Harbors, 1994) showing HEC-2 cross section locations, the channel centerline and the approximate 100-year floodplain limits. Following review of the District's HEC-2 model, JEF, Inc. concluded that the model was adequate for use in evaluating channel hydraulics along the Tatum Wash study reach, and for conversion to HEC-6 format for the sediment continuity analysis (JEF, 1996a). Figure 3-8 serves as a location map for the HEC-2 data.

HEC-2 Model Modifications

Review comments for the District's HEC-2 model were provided by JEF, Inc. Some of the review comments and modifications to the District's HEC-2 model made by JEF, Inc. are described below:

- Model Length. The upstream limit of the HEC-2 model did not include the entire study reach, or the sediment supply reach for the upstream portion of the study reach required for HEC-6 modeling. Therefore, the model was extended as described in a later section of this chapter.
- Topographic Data. Topographic mapping provided with the District's HEC-2 model covered only the area downstream of 40th Street. Two digital terrain models were provided in AutoCAD format by the District[1] that covered the areas downstream of the Phoenix Mountain Preserve boundary and the Phoenix Mountain Preserve, respectively. There was about a two foot difference in channel elevations at the match line along the channel and floodplain of Tatum Wash between the two digital terrain models. The match line of the digital terrain models was located at the Phoenix Mountain Preserve boundary. To account for the difference in topographic data, the difference in elevation was added to all of the cross sections upstream of the Phoenix Mountain Preserve boundary.[2]
- New Cross Section and Reach Length Data. Topographic and geometric data for cross sections and channel reaches located upstream of 40th Street were obtained from the digital terrain model provided by the District.
- Starting Water Surface Elevation. The hydraulic effects (if any) of the Shea Boulevard at-grade crossing were not modeled in the District's HEC-2 model. Therefore, it was assumed that flow was at or near critical depth at Shea Boulevard, and the starting water surface elevation determined using the normal depth for the average channel slope for the reach.

[1] AutoCad files: SHT6ALL.DWG and SHT92B.DWG

[2] Topographic adjustment was accomplished using X1.9=1.85 ft.

- Shea Wash. The District's model included a portion of Shea Wash (or breakout flows from Tatum Wash along Shea Wash) which is not part of the scope of this project, and was removed from the model.
- Range of Discharges. The District's HEC-2 model included only the 100-year peak discharge. Additional flow rates ranging from 50 cfs to 2300 cfs, in 100 cfs increments, were modeled to allow analyses of hydraulic conditions for the entire 100-year hydrograph, as well as for the 2-, 10-, and 50-year hydrographs. Reach-averaged rating curves for the study reach were developed from the additional flow rate models.
- Effective flow boundaries. Effective flow boundaries were adjusted to reflect 4:1 flow expansion limits and 1:1 flow contraction limits for ineffective flow areas around natural channel changes, fences and walls, homes, and other structures.
- GR points. Ground reference (GR) elevation points outside the confined flow path, i.e., points on the other side of a drainage divide adjacent to the channel, were removed from the HEC-2 model, except where divided flow conditions existed.
- Breakout Locations. Several points were identified were computed water surface elevations exceeded the maximum ground elevation at the cross section end points, and where flow breakouts could occur. For the purposes of the sedimentation study, and to be consistent with the HEC-1 modeling assumptions, it was assumed that no flow escaped the floodplain. That is, design discharges used in the HEC-2 models were not reduced to reflect potential breakout flows.
- Cross Section Spacing. No change in cross section spacing was required for the purposes of determining reach-averaged channel hydraulics, and for HEC-6 modeling.

The HEC-2 model filenames and descriptions are provided in Table 3-1.

Table 3-1. Tatum Wash Sedimentation Study
HEC-2 Model Filenames and Descriptions

HEC-2 Model Name	Model Description
SA1.DAT	Original FCDMC HEC-2 File
TATUM.HC2	HEC-2 Profiles for Q100, Q50, Q10, & Q2
TATUMSUP.HC2	HEC-2 Supercritical Profile for Q2-Q100
TATUM_A.HC2	HEC-2 Profiles for Q = 50-1300 cfs
TATUM_B.HC2	HEC-2 Profiles for Q = 1400-2300 cfs
MATCH_Q.HC2	HEC-2 Model to Match HEC-6 Input File

Figure 3-8 shows HEC-2 cross section locations geographic features of the study reach, limited site topography, and other features. Cross section geometry, effective flow boundaries, and computed water surface elevations are illustrated in Figure 3-9.

HEC-2 Hydraulic Analyses

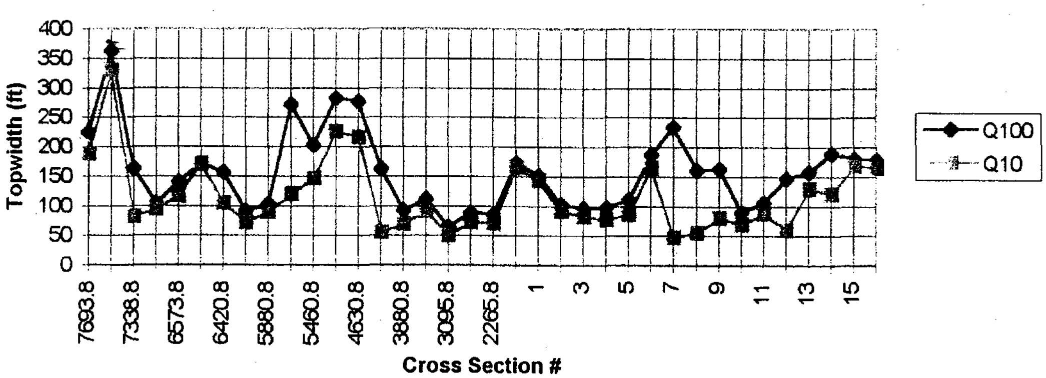
The objectives of the HEC-2 hydraulic analyses for Tatum Wash were to estimate the hydraulic characteristics of the study reach, to identify hydraulically similar subreaches within the study area, and to identify subreaches with limited conveyance capacity. Specific tasks included the following:

- Identify hydraulically similar channel reaches
- Identify existing flooding breakout points and discharge thresholds
- Identify channel choke points
- Identify potential areas for channel improvement that would increase channel capacity
- Identify the channel cross section with the least conveyance capacity
- Estimate flow depths and velocities at road crossings
- Estimate existing channel capacity relative to return period
- Compare channel capacity to the District's proposed detention basin outflow rates and proposed downstream storm drain capacity.

***Identify Hydraulically Similar Reaches*.** The HEC-2 modeling results indicate that there is no hydraulic basis for identifying subreaches within the Tatum Wash study reach. While there are geomorphic, visual, land ownership and floodplain management changes along Tatum Wash within the study area, there are no consistent, regular, and significant changes in flow depth, velocity, topwidth, energy slope, channel slope, conveyance capacity, or unit discharge that can be used to define continuous subreaches, or that can be tied to specific break points. In general, the following changes in hydraulic characteristics were computed by the HEC-2 modeling:

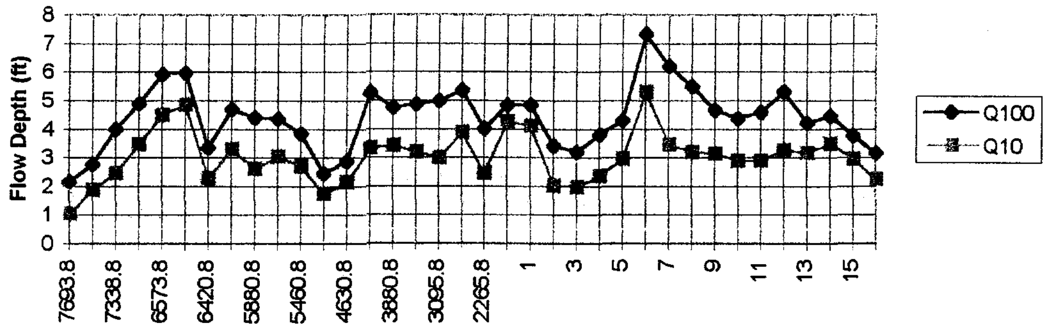
- *Topwidth.* Although the computed topwidth is highly variable, it generally increases in the downstream direction (Figure 3-1). Structures associated with the residential development along the study reach probably artificially confine the downstream portions of the study reach. That is, the natural increase in topwidth along the wash may have been greater than the existing (or modeled) topwidth of the wash. Cross section locations are shown in Figure 3-8.

Figure 3-1. Tatum Wash - Topwidth vs. Section #



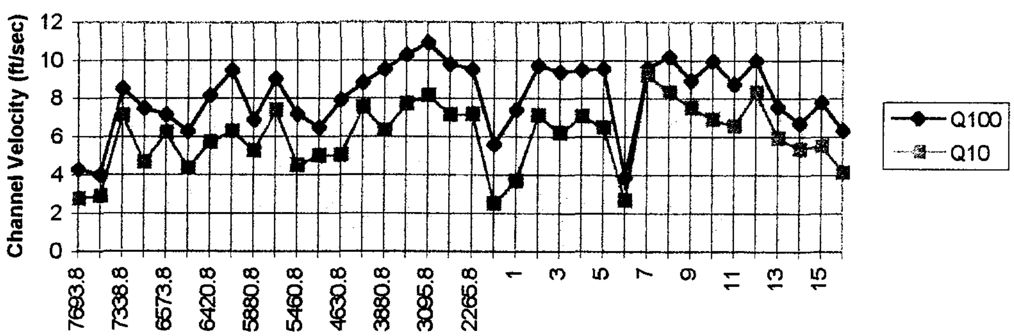
- *Flow depth.* Flow depth generally increases in the upstream direction (Figure 3-2) at a given flow rate. Flows upstream of the Phoenix Mountain Preserve boundary are generally contained in the natural channel, which has steeper, higher banks than the reaches downstream of the Phoenix Mountain Preserve. However, artificial flow containment provided by fences, walls, effective flow boundaries, and bank protection may increase flow depths in the developed (downstream) portion of the study area.

Figure 3-2. Tatum Wash - Flow Depth vs. Section #



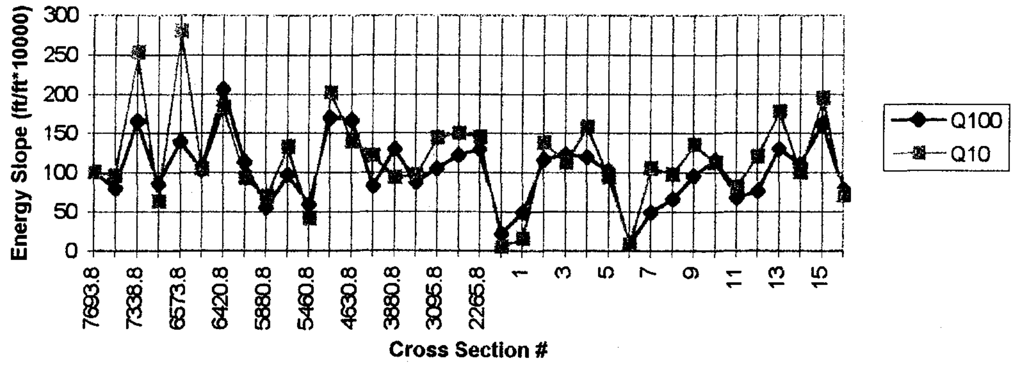
- *Channel velocity.* Channel velocity decreases slightly in the downstream direction (Figure 3-3), although this affect is less significant at higher flow rates. Cross section locations are shown in Figure 3-8.

Figure 3-3. Tatum Wash - Velocity vs. Section #



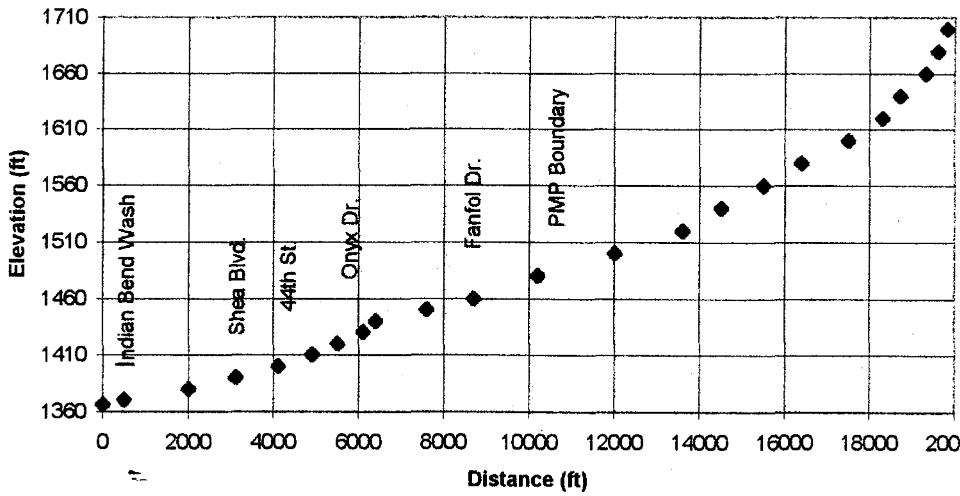
- *Energy slope.* The computed energy slope is variable, with no distinct trend within the study reach (Figure 3-4).

Figure 3-4. Tatum Wash - Energy Slope vs. Section #



- *Channel slope.* Channel slope is relatively uniform throughout the entire HEC-2 modeling reach. The minor variations in slope shown on the longitudinal profile (Figure 3-4) probably reflect minor areas of scour, bedrock control, or local bar deposits. The longitudinal profile shown in Figure 3-5 is based on 10-feet contour interval USGS topography.

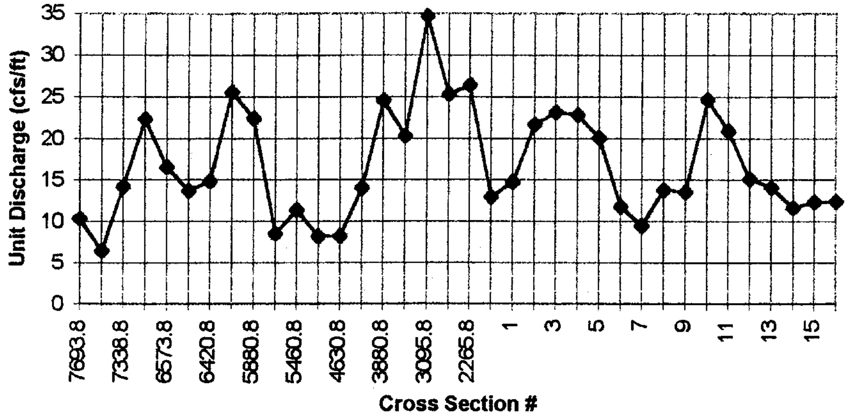
Figure 3-5. Tatum Wash Longitudinal Profile



- *Channel capacity.* Channel capacity, as indicated the HEC-2 QCH parameter, is variable within the study reach. However, the two main areas of limited capacity (described later in this chapter) were too short to be used to define separate subreaches (See Figures 3-9 & 3-10 later in this Section).

- *Unit Discharge.* Unit discharge is variable within the study reach (Figure 3-6). Although unit discharge is marginally higher upstream of Fanfol Drive (Cross Section #3535), there is no consistent trend or natural break point which can be defined using the computed unit discharge (JEF, 1996d).

Figure 3-6. Tatum Wash - Unit Discharge vs. Section #



Although the general changes in hydraulic characteristics summarized above and depicted in Figures 3-1 to 3-6 could be defined from the HEC-2 output, the changes were gradual, lacked obvious break points, or did not change by a significant amount within the study reach. In addition, the changes in the different hydraulic parameters were not concurrent at any specific reach or cross section. For these reasons, no subreaches could be defined on the basis of the HEC-2 hydraulic characteristics. HEC-2 model output summaries are provided in the Appendix. Therefore, the study reach (Shea Boulevard to the Phoenix Mountain Preserve) was considered a single reach for the purposes of hydraulic modeling. Slight variations in geomorphic channel characteristics, land management and ownership were noted, as needed, but were not used to define separate modeling reaches. The portion of Tatum Wash located upstream of the Phoenix Mountain Preserve will be considered as the supply reach for sediment modeling, although the hydraulic characteristics in the supply reach are not significantly different than those of the study reach.

Identify Flooding Breakout Points and Discharge Thresholds. Flooding breakouts can be caused by natural conditions or by man-made obstructions in or near the wash. Natural breakout discharges occur on alluvial fans and within distributary flow areas. Prior to urbanization, the downstream portion of the Tatum Wash study reach may have had a distributary flow network (See Section 4). Breakout points defined by the HEC-2 hydraulic modeling were identified by interpreting HEC-2 output, topographic mapping, and aerial photographs. Overall, the 100-year flood is contained in Tatum Wash except at two points. Discharge thresholds for breakouts based on HEC-2 "cross section extended" messages[3] are summarized in Table 3-2, and are illustrated on Figure 3-7.

Table 3-2. Tatum Wash Sedimentation Study
Discharge Thresholds for HEC-2 Cross Section Extended Message

Cross Section #	Flow Rate at Lowest Extended Section Message	Feature & Location
3880.8	1100 cfs	Stream capture point for Shea Wash near Fanfol Dr.
7338.8	1200 cfs	Shea Blvd.
6420.8	1300 cfs	Upstream of 44 th St.
6983.8	1600 cfs	Shea Blvd.
3535.8	1600 cfs	Fanfol Dr. area
4260.8	2100 cfs	Braided flow area downstream of Fanfol Dr.

The first of the potential breakout areas is located immediately upstream of Shea Boulevard. Breakout flows occur at recurrence intervals between the 10- and 50-year floods. The lack of 100-year channel capacity between Shea Boulevard and 44th Street is probably due to the following:

- Historic modification and grading of the floodplain for residential development
- Regrading associated with sediment removal from Shea Boulevard after floods
- Natural deposition of sediment in backwater upstream of the Shea Boulevard crossing

Field evidence suggests that the bed sediments immediately upstream of Shea Boulevard are significantly finer-grained than in the reaches of Tatum Wash upstream of 44th Street, supporting the hypothesis that sediment deposition occurs upstream of Shea Boulevard. Recent growth of dense vegetation in this reach of the study area may also cause sediment deposition and lead to reduced channel capacity. Finally, the historical aerial photograph and topographic maps indicate a natural loss of channel capacity near Shea Boulevard due to a distributary (or braided) flow pattern and a slight flattening of the channel slope downstream of 44th Street.

Because the defined channel of Tatum Wash ends at Shea Boulevard, breakout flow leaves the reach as unconfined urban sheet flow or as flow in the pubic right-of-way. Controlling breakout flooding at Shea Boulevard, as well as in the neighborhoods downstream of Shea Boulevard, is one of the primary objectives of the Tatum Wash Drainage Improvement Project.

[3] "Cross section extended" messages at other sections in HEC-2 output were for sections were flow was contained within ineffective flow areas not coded into the input file.

Figure 3-8

Tatum Wash Sedimentation Study

HEC-2/HEC-6 Cross Section Locations

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Legend

- 6150 — Cross Section
- (3) — Sediment Sampling Site
- → — Potential Breakout Area

CI=2 feet

Scale in Feet: 0 – 800

Topo Date: 12-91
All elevations are based on National Geodetic Vertical Datum of 1988

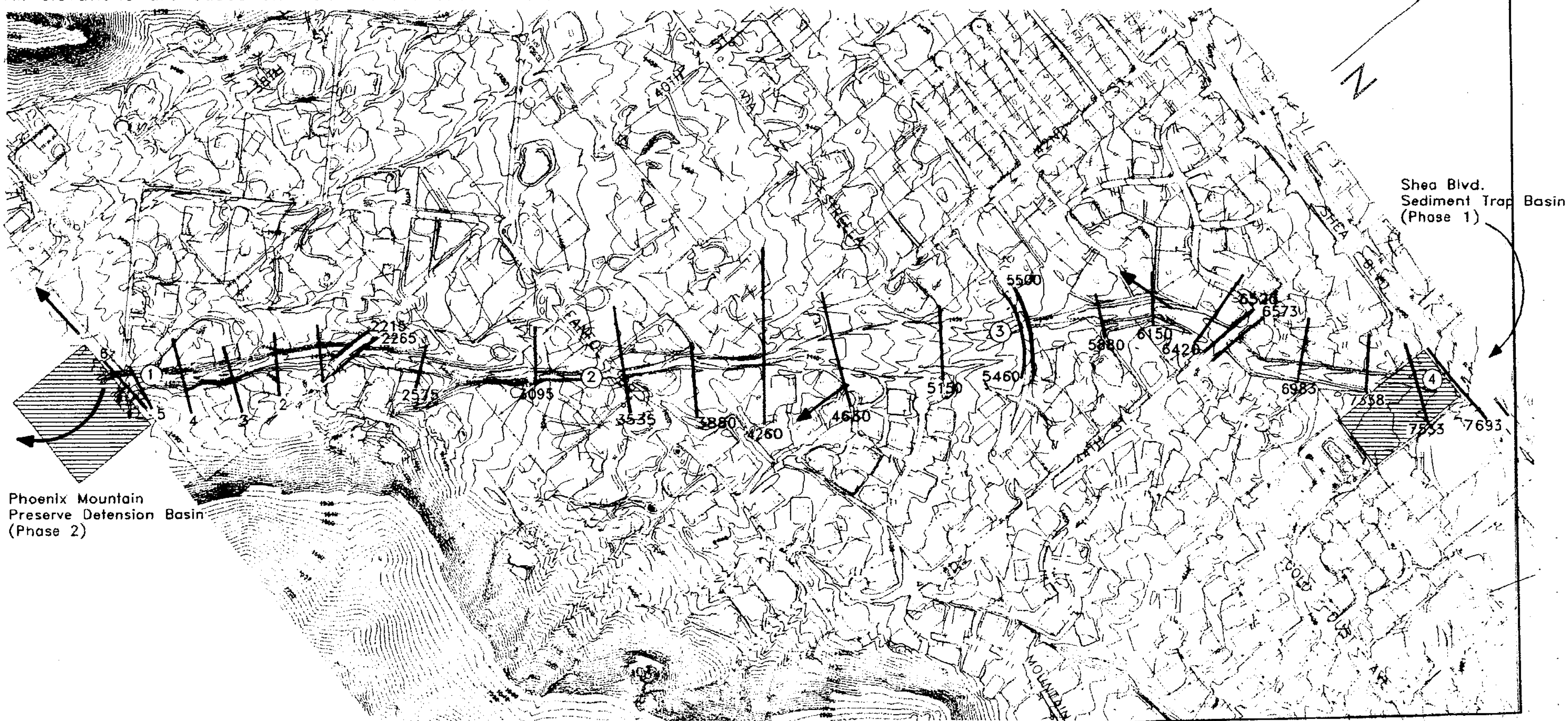

Figure 3-8

Tatum Wash Sedimentation Study

HEC-2/HEC-6 Cross Section Locations

JE Fuller/Hydrology & Geomorphology, Inc.

January, 1997	Sheet 1/1

Legend

- 6150 — Cross Section
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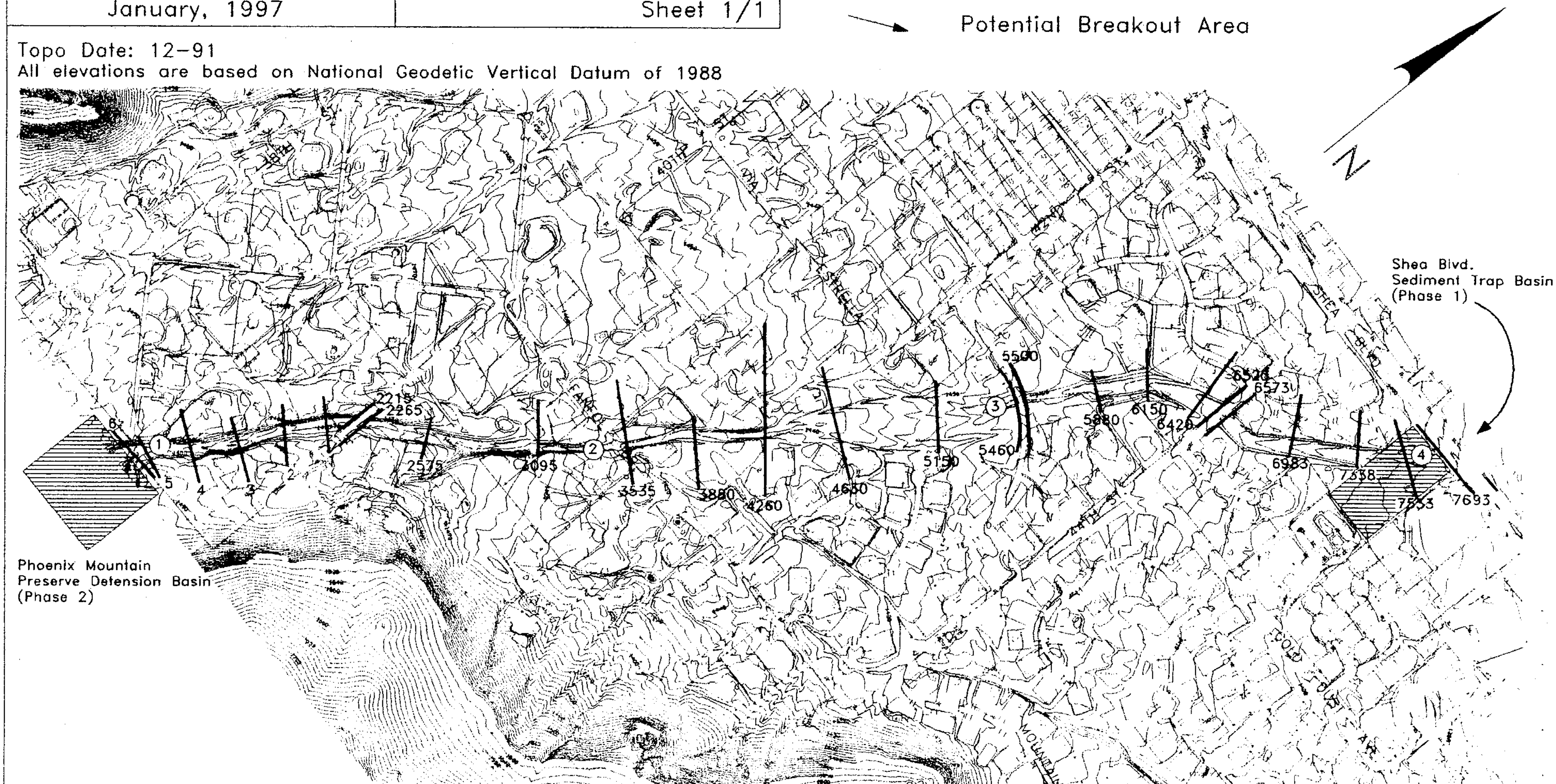
CI=2 feet

Scale in Feet: 0 – 800

Topo Date: 12-91

All elevations are based on National Geodetic Vertical Datum of 1988



The second reach of limited channel capacity in the study area occurs immediately downstream of Fanfol Drive. Breakout flows occur at discharges exceeding 1,000 cfs, a magnitude that is between the 10- and 50-year recurrence intervals. The historical aerial photograph and the existing topographic mapping of this reach indicate that a natural transition from a single channel to a braided channel occurs in this reach, before returning to a single channel pattern several hundred feet downstream. In addition, the headwaters of Shea Wash appear to have extended into the floodplain of Tatum Wash, initiating a stream capture. Headward extension of one stream into another stream (stream capture) is usually a geologically slow process, and generally can be disregarded on an engineering time scale. However, although the ultimate stream capture of Tatum Wash by Shea Wash may not occur within the engineering time scale of this study, this geomorphic process has created a mechanism for some flood runoff to break out of the main flow alignment of Tatum Wash and enter Shea Wash during flood events that exceed about 1,000 cfs (approximately the 15-year flood).

Unlike the breakout flooding near Shea Boulevard, the breakout flooding near Fanfol Drive has a less significant impact on the surrounding neighborhoods. Breakout flooding near Fanfol Drive generally returns to the defined channel of Tatum Wash downstream, or is conveyed along the channel of Shea Wash.

Man-made obstructions also create the potential for future breakouts from Tatum Wash. Four of the five road crossings in the study reach are at-grade crossings (Shea Blvd[4]., 44th St., Onyx Dr. and Fanfol Dr.) that do not significantly alter the natural flow conditions. The 3-cell box culvert crossing at 40th Street creates a hydraulic obstruction, and only has capacity for about 550 cfs[5] before overtopping. The 40th Street road profile topographic data used in the HEC-2 model indicates that the overtopping flow will be contained in the roadway section. However, observations made in the field conditions suggest that at least some of the overtopping discharge at the 40th Street culvert may flow north along 40th Street, rather than continue downstream along Tatum Wash.[6] Future replacement of the at-grade crossings in the study reach with culverts could increase the potential for other breakouts within the study reach. No plans to upgrade any of the at-grade crossings were identified during the course of this study.

Identify Channel Choke Points/ Identify Section With Least Conveyance. According to the HEC-2 model output, there are no natural "choke points" in the study reach. No potential choke-points were observed during the field visits, with the possible exception of the 40th Street culvert described above. Choke points may be defined as reaches or points in a channel that have limited conveyance capacity and cause substantial upstream backwater affects. As shown by the energy slope, velocity, depth and topwidth profiles

---

[4] The storm drain at Shea Boulevard is too small to convey any significant percentage of Tatum Wash flooding, and is therefore considered to be an at-grade crossing.

[5] Approximately the 5-year flood.

[6] For the purposes of the this sedimentation analysis, per direction of FCDMC, break out discharges were not modeled.

(Figures 3-1 to 3-6), there are no areas of significant backwater, except upstream of the 40th Street culvert. In general, where the floodplain narrows, the bank heights increase accordingly, except in the natural breakout areas described above. In addition, the relatively steep channel slope probably helps limit backwater impacts, since most flows are at or near critical depth.

Reaches of limited conveyance capacity appear to be caused by naturally low bank heights in braided flow reaches, rather than by downstream obstructions. Both of the reaches with potential breakouts are in areas of above-average channel width, and are wider downstream than at the cross section which experiences overtopping, or breakout, flows. The most significant backwater affect in the study reach is created by the contraction for the 40th Street culvert. However, due in part to the steep slope of the wash and relatively high channel banks, the backwater affect does not extend very far upstream of 40th Street.

The channel cross sections with the least conveyance capacity are located immediately upstream of Shea Boulevard. In this reach, the defined (main) channel is choked with dense vegetation, narrows to a width of less than ten feet, and the bank heights drop to less than two feet.

Identify Reaches for Potential Channel Improvement. Channel improvements are not currently part of the District's proposed drainage improvements for Tatum Wash (FCDMC, 1996). Channel improvements probably are not an element of the proposed Tatum Wash drainage improvement plan for the following reasons:

- Upstream Detention. Based on channel capacity and breakout results summarized above, no channel improvements will be required following implementation of Phase 2 of the proposed drainage improvement plan. Breakout flows generally occur at flow rates exceeding 1,000 cfs, and the maximum 100-year outflow rate from the Phoenix Mountain Preserve detention basin will be approximately 620 cfs.
- Shallow Bedrock. Shallow bedrock was observed in the channel at several locations between Fanfol Drive and 44th Street. Construction costs associated with excavation of bedrock are generally prohibitive.
- Neighborhood Reaction. Public reaction to channelization of Tatum Wash probably would not be favorable, given the type of drainage improvement alternatives preferred by residents who attended the District's public meetings (FCDMC, 1996).
- Downstream Flooding. Channelization of Tatum Wash upstream of Shea Boulevard would not alleviate flooding conditions in the neighborhoods downstream of Shea Boulevard, where there is no natural defined flow path for Tatum Wash.

Channel improvement may not be required following construction of Phase 2 of the proposed project. However, given that Phase 2 of the proposed drainage improvements, construction of the Phoenix Mountain Preserve detention basin, is contingent on action by the City of Phoenix, as well as by approval by the agencies and citizens' groups which regulate the Phoenix Mountain Preserve, the following channel improvement options are presented as interim measures for consideration with the overall project objectives:

- *Option 1: Removal of Vegetation.* Much of the main channel of Tatum Wash downstream of Fanfol Drive is overgrown with vegetation which could be cleared and maintained. Removal of channel vegetation would tend to decrease water surface elevations, and increase channel velocities. Also, because the bed sediments (bedload) is very coarse (gravel to small boulders), a minor increase in hydraulic roughness caused by excessive vegetative growth could increase sediment deposition[7] and reduce channel capacity. The channel reach downstream of Onyx Drive is most in need of vegetation maintenance. The feasibility of Option 1 is dependent on public ownership of the wash, environmental concerns, and funding for a perpetual maintenance program. Portions of the Tatum Wash floodplain are privately owned. An analysis of the sedimentation impacts of removing and maintaining channel vegetation is described in Sections 5 and 7 of this report.

- *Option 2: Construction of Levees.* Low levees, generally less than 4 feet high, could be constructed along the effective flow boundaries defined in the HEC-2 analysis. If constructed at or outside the effective flow boundaries, the levees would not increase regulatory water surface elevations or alter bed sediment transport rates. Levees could be constructed to contain the floodplain of the reach of Tatum Wash between Fanfol Drive and Onyx Drive which has poorly defined banks and is subject to breakout flows at discharges exceeding about 1,000 cfs. Shallow bedrock in much of the study reach prevents channel excavation as a feasible floodplain containment alternative. It is noted that these levees would not be required after implementation of Phase 2 of the proposed project.

- *Option 3: Improve 40th Street Culvert.* The limited capacity at the 40th Street culverts could be improved by constructing wider culvert cells (or a bridge) and by improving the capacity of the overtopping (weir) section. Alternatively, the culvert could be removed and the at-grade crossing section restored.

- *Option 4: Enforcement of Floodplain Management Regulations.* There are several walls or other structures built in within the channel and floodplain of Tatum Wash that probably obstruct flow to some degree. These structures should be regulated by the City of Phoenix floodplain management staff.

Estimate Flow Depth & Velocity at Road Crossings. Four of the five road crossings[8] in the study reach are paved at-grade crossings. Only the 40th Street crossing has a culvert, a 3-cell 4x8 concrete box culvert with an overtopping capacity of about 550 cfs. Flow depths and velocities at four at-grade exceed typical all-weather access standards (depth < 1 ft., velocity < 5 ft./sec.) during flow events equaling or exceeding the 2-year event. Flow depths and velocities for the 2-, 10-, 50-, and 100-year events at the at-grade

[7] HEC-6 modeling of vegetation impacts on the 100-year flood indicated that the amount *net* deposition would not significantly increase due to vegetative growth.

[8] Includes Shea Boulevard, which was not specifically modeled.

crossings estimated using HEC-2 are summarized in Table 3-3. Flow depths at the at-grade crossings range are greater than one foot for the two-year flood, and are generally greater than 4 feet deep for the 100-year flood. The flow velocities at the at-grade road crossings are not excessive, but are generally in the range considered unsafe for traffic, particularly at the estimated depths of flow. Velocities range from two to five feet per second for the two-year flood to up to seven feet per second for the 100-year flood.

The 40th Street culverts have capacity for about 550 cfs (approximately the 5-year flood) without overtopping. The overtopping depth during the 100-year flood at 40th Street is about 0.8 feet above the top of the culvert and road section. The HEC-2 data provided by the District for this crossing indicate that the 100-year overtopping discharge is contained in the roadway overflow section.

Table 3-3. Tatum Wash Sedimentation Study
Depth and Velocities at Road Crossings

Road Crossing	Recurrence Interval							
	2-Year		10-Year		50-Year		100-Year	
	Depth (ft)	Velocity (ft/sec)	Depth (ft)	Velocity (ft/sec)	Depth (ft)	Velocity(ft/sec)	Depth (ft)	Velocity(ft/sec)
44th Street	4.2	3.4	4.9	4.3	5.6	5.8	6.0	6.3
Onyx Drive	1.8	3.3	2.7	4.5	3.6	6.2	3.8	7.2
Fanfol Drive	2.2	5.3	3.2	7.7	4.4	9.5	4.9	10.3
40th Street	0	0	0.3	2.5	0.7	4.5	0.8	5.6

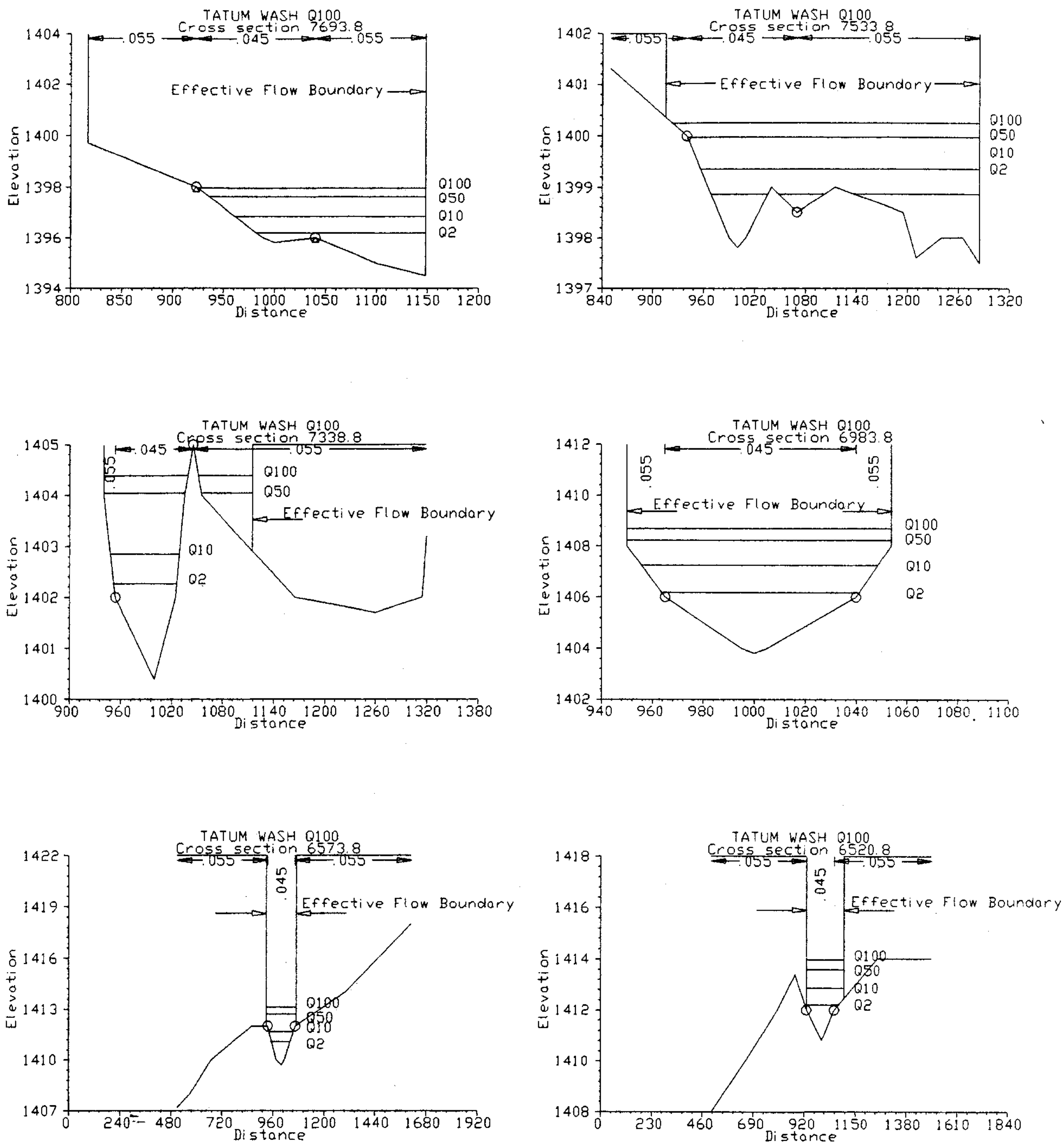
Notes:
1. Depth reported is approximate depth over roadway surface, flow through culvert is not reported.
2. HEC-2 cross sections used: 44th St.(#6520.8); Onyx Dr. (#5460.8); Fanfol Dr. (#3535.8); 40th St. (#2215.8)

Compare Channel Capacity to Recurrence Interval. Channel capacity was estimated by examining cross section plots showing channel geometry and the estimated water surface elevation, and by noting the flow rate at which a "cross section extended" message was included in the HEC-2 output (Table 3-2). Cross section plots showing the estimated 2-, 10-, 50-, and 100-year water surface elevations and other geometric data are shown in Figure 3-9. Figure 3-10 shows the variation of the HEC-2 channel discharge (QCH) [9] within the study reach for the 2-, 10-, 50-, 100-year floods. Approximate flood recurrence interval magnitudes for Tatum Wash are listed in Table 3-4.

Table 3-4. Tatum Wash Sedimentation Study
Approximate Flood Recurrence Interval Rates

Recurrence Interval	Flow Rate (cfs)
2-Year	330
10-Year	850
50-Year	1,800
100-Year	2,300

[9] The HEC-2 QCH variable indicates the amount of discharge between the left and right bank stations. If the computed water surface elevation exceeds the bank station elevation QCH will be less than the total discharge, as shown in Figure 3-10. QCH = total Q if flow is contained within the channel banks.



Tatum Wash Sedimentation Study
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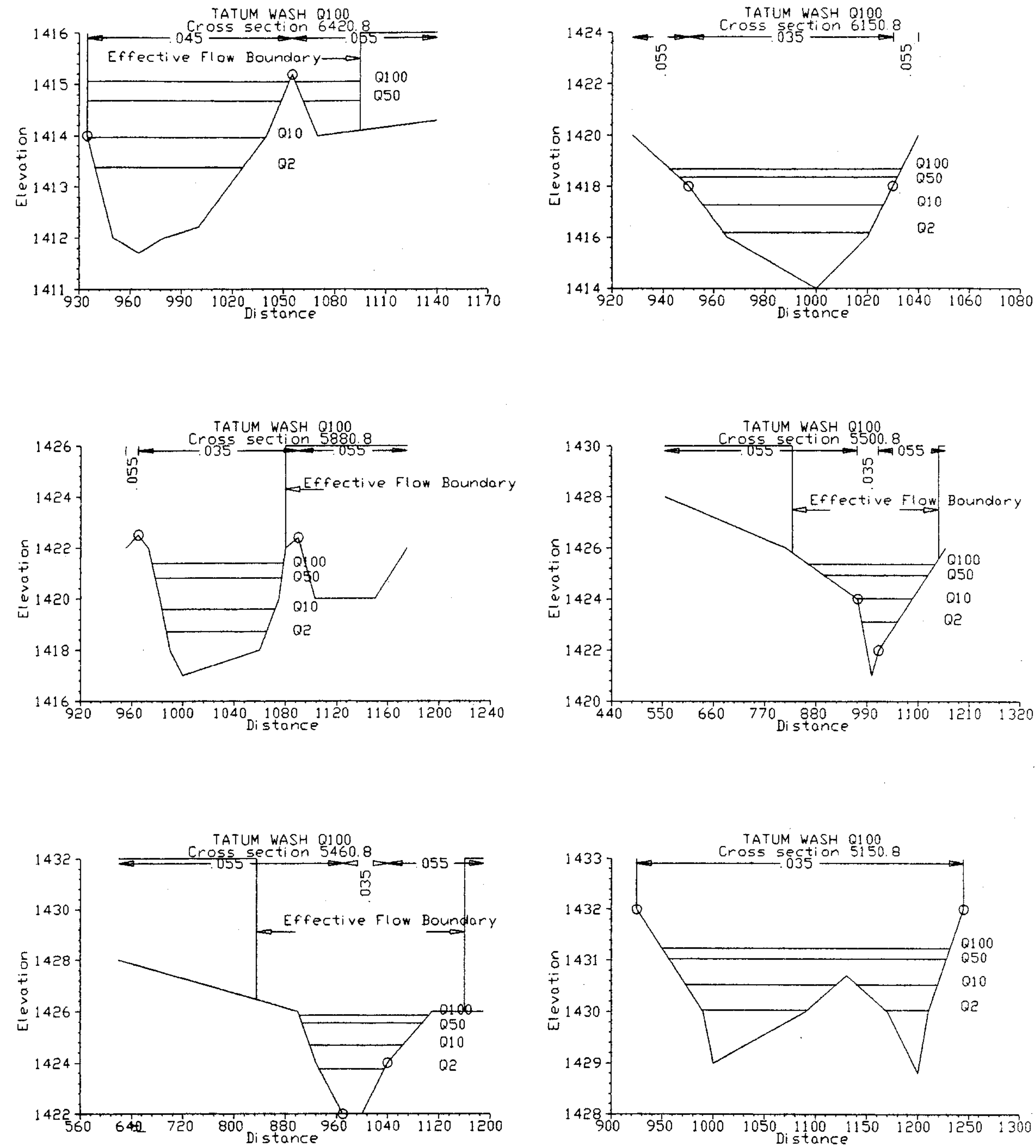
Figure 3-9

Tatum Wash Cross Sections

Sheet 1 of 5



Tatum Wash Sedimentation Study Flood Control District of Maricopa County JE Fuller / Hydrology & Geomorphology, Inc.	Figure 3-9 Tatum Wash Cross Sections
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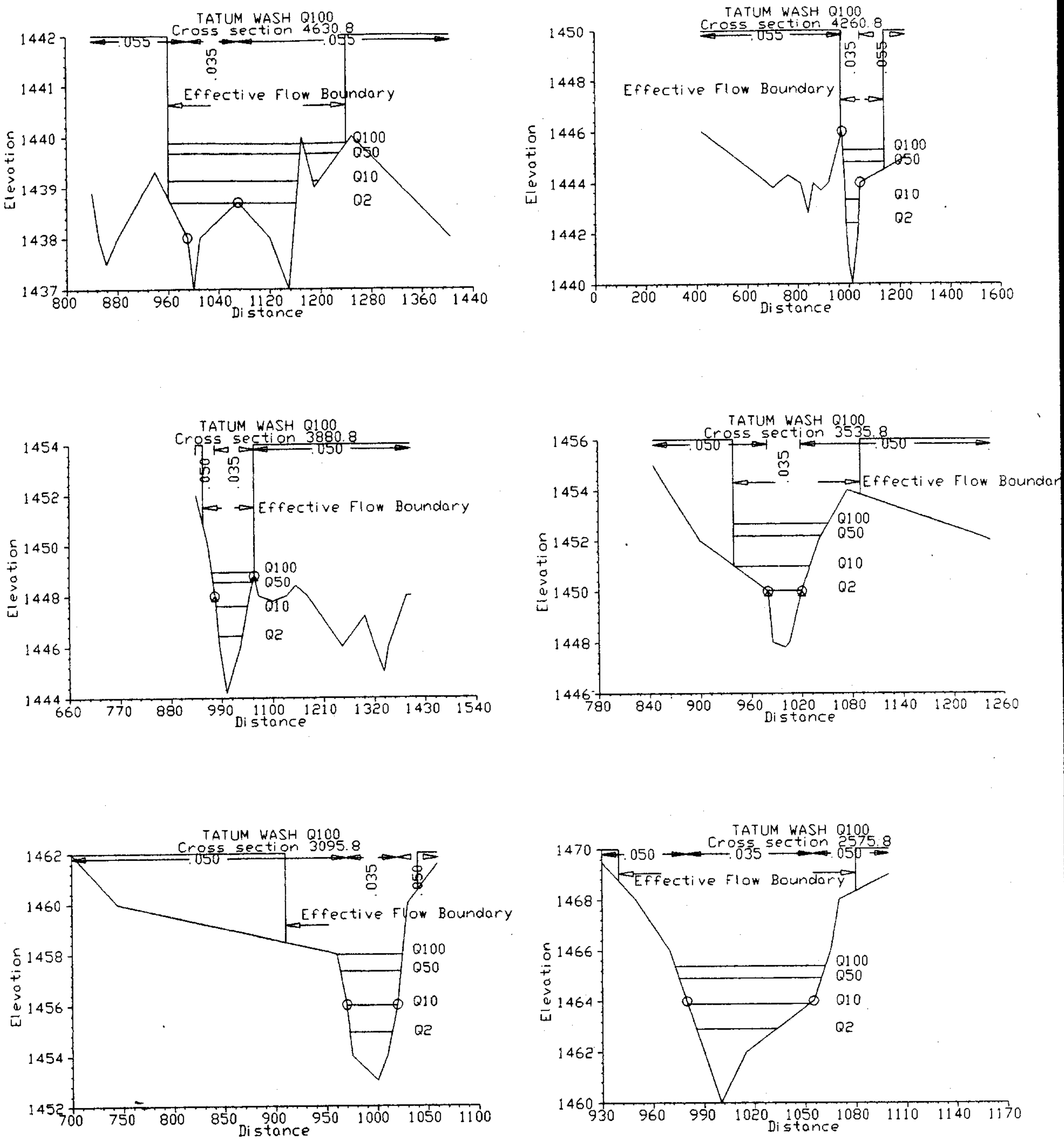
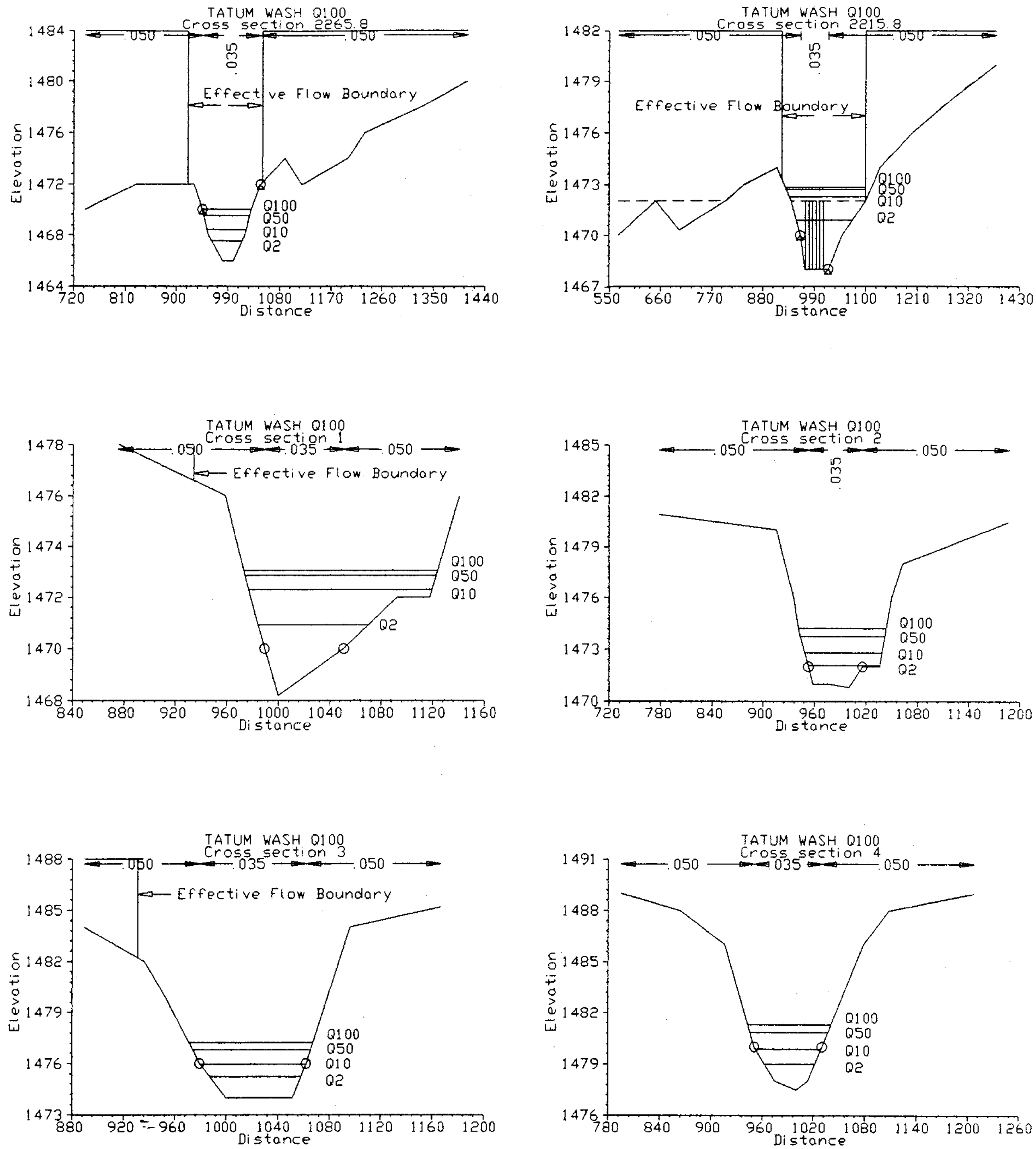


Tatum Wash Sedimentation Study Flood Control District of Maricopa County JE Fuller / Hydrology & Geomorphology, Inc.	Figure 3-9 Tatum Wash Cross Sections
January, 1997	Sheet 3 of 5



Tatum Wash Sedimentation Study

Flood Control District of Maricopa County

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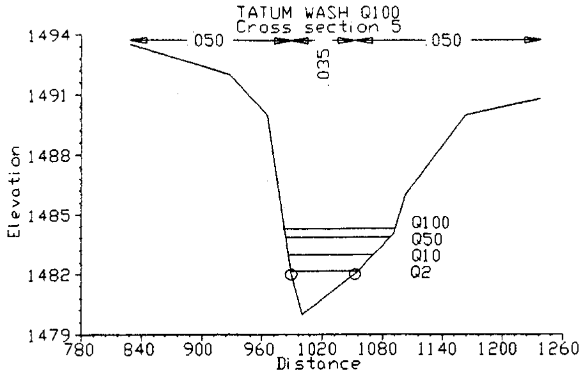
Figure 3-9

Tatum Wash Cross Sections

Sheet 4 of 5



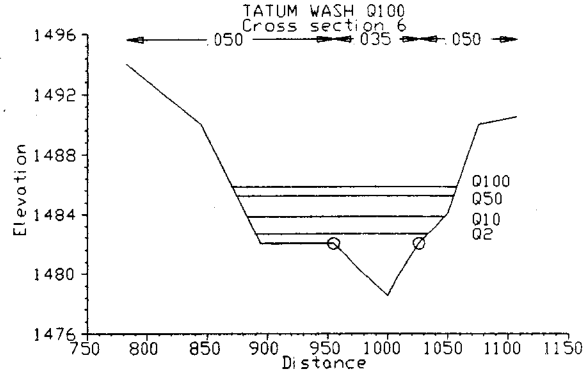


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Figure 3-9

Tatum Wash Cross Sections

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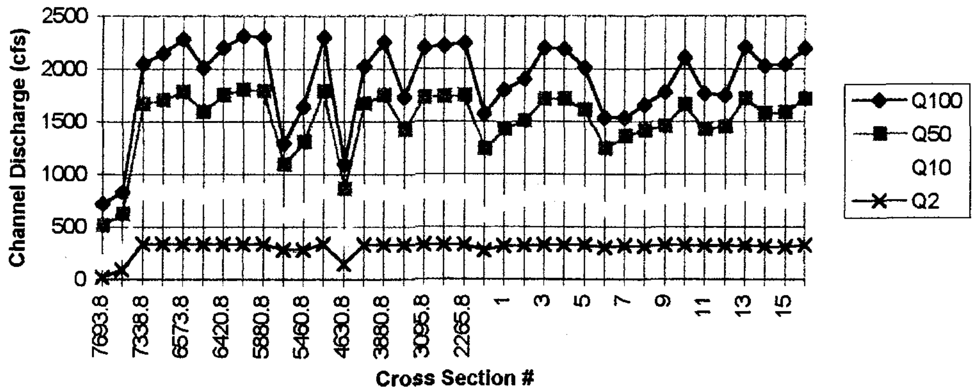
In general, the channel upstream of Fanfol Drive contains the 100-year discharge within a well-defined cross section. In this reach, the channel banks are steeper and higher than the computed water surface elevations. Downstream of Fanfol Drive, the main channel is more braided and less well defined, with lower banks along the main channel which do not contain the 100-year flow at some cross sections. With the exception of the portion of Tatum Wash approaching Shea Boulevard, the entire channel contains the 10-year flood. Most of the channel in the study reach contains the 50-year flood.

Figure 3-10. Tatum Wash HEC-2 Channel Discharge (QCH) vs. Section #



Compare Channel Capacity to Detention Basin Outflow Rates. Phase 2 of the District's proposed drainage improvement plan for Tatum Wash calls for a detention basin upstream of the Phoenix Mountain Preserve boundary that will have a maximum outflow rate of 621 cfs. According to the HEC-2 model, a flow rate of 621 cfs would be contained in Tatum Wash except at Shea Boulevard and 40th Street. Potential overflows at 621 cfs at Shea Boulevard would be captured by the Phase 1 sediment trap basin. Reducing peak discharges to less than about 550 cfs[10] would eliminate the existing breakout flows, including overflow of the 40th Street culvert, except in the sections immediately upstream of Shea Boulevard. Given the capacity of the 40th Street culvert, it may be prudent to design the Phoenix Mountain Preserve detention basin for a maximum outflow rate of about 550 cfs.

Outflows from the Phase 1 sediment trap basin do not impact the study reach. HEC-1 modeling for with-project conditions described in Section 2 of this report indicated that the proposed Phase 1 sediment trap basin would be overtopped during the 10-year event prior to completion of Phase 2 of the project (Table 2-3).

Supercritical Flow Analysis. In response to review comments by the District suggesting that the potential for supercritical flow be investigated more thoroughly, the subcritical

[10] HEC-1 modeling of "with-project" conditions performed for this study computed a peak outflow rate of 555 cfs using the District's concept design data for the Phase 2 detention basin.

HEC-2 models described above were revised to model supercritical flow by making the following modifications:

- Cross sections. The order of the cross sections was reversed.
- Roughness coefficients. N values were not changed.
- Discharges. Discharges were not changed.
- Special culvert routine. The special culvert records for the 40th Street culverts (Section #2215.8) were removed and replaced with known water surface elevations entered on X5 records. The HEC-2 program cannot perform special culvert modeling for supercritical profiles. It was assumed that supercritical water surface elevations at the 40th Street culvert would be similar to subcritical water surface elevation given that the culvert operates under inlet control at low discharge and overtops (weir flow; critical depth) at discharges exceeding 550 cfs.

Supercritical profiles were prepared for the 2-, 10-, 50-, and 100-year events. Table 3-5 shows a comparison of some key reach-averaged hydraulic parameters for the subcritical and supercritical HEC-2 profiles. Table 3-6 lists the cross sections where critical depth was assumed for both the subcritical and supercritical HEC-2 100-year. Comparison of the results of the subcritical and supercritical HEC-2 profiles indicates that the reach-averaged hydraulic parameters are not that different. The results also show that the profiles are neither strongly supercritical nor strongly subcritical. Critical depth messages were generated for more than half the cross sections for both profiles.

Table 3-5. Tatum Wash Sedimentation Study
Comparison of Subcritical and Supercritical HEC-2 Model Results

Recurrence Interval (yrs)	Depth (ft)	Topwidth (ft)	Velocity (ft/s)	Channel Discharge (cfs)	Energy Slope (ft/ft)	Effective Flow Area (ft^2)
Subcritical Profile						
100	4.4	157	8.1	1893	103	343
50	4.0	145	7.5	1503	106	285
10	3.0	115	5.9	742	118	169
2	2.1	85	4.5	303	118	86
Supercritical Profile						
100	4.0	147	9.5	1938	169	275
50	3.6	137	8.8	1535	173	226
10	2.7	104	7.0	753	187	127
2	1.8	72	5.7	304	314	64

Table 3-6. Tatum Wash Sedimentation Study Cross Sections Assumed at Critical Depth by HEC-2					
Section #	**Subcritical Run**	**Supercritical Run**	**Section #**	**Subcritical Run**	**Supercritical Run**
16		*	2575	*	*
15	*	*	3095	*	
14			3535		
13	*	*	3880	*	*
12	*		4260	*	*
11			4630		
10	*	*	5150	*	*
9	*		5460		
8	*	*	5500	*	*
7	*		5880		*
6			6150		*
5	*	*	6420	*	*
4	*		6520		*
3	*		6573		*
2	*	*	6983		*
1		*	7338	*	*
2215			7533		*
2265	*		7693		*
NOTE: * = Critical depth message in HEC-2 output for 100-year event					

The potential for sustained supercritical flow in natural channel is a subject of continuing debate in the literature (cf. Treiste, 1992). The results of some analyses indicate that alluvial channels on piedmont surface with slopes that approach or exceed the critical slope will flow at or near critical depth (cf. Dawdy, 1979). Other investigators have concluded that steep streams with coarse bed sediments cannot sustain supercritical flow due to increased hydraulic roughness (cf. Jarrett, 1984). Tatum Wash has several of the characteristics of the streams described in the literature cited: (1) steep slope - 1.3%, (2) coarse bed material - d_{50}= 4-22 mm,[11] and (3) alluvial channel boundaries on a piedmont surface. Therefore, it is unlikely that sustained supercritical flow will occur along the wash during the design flood.

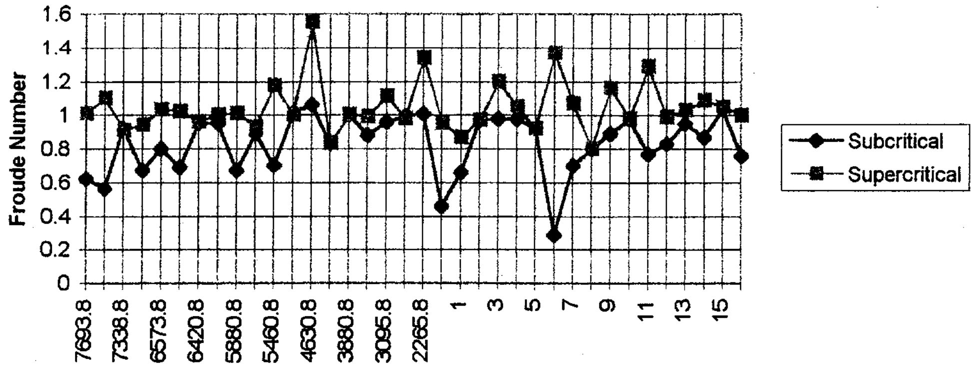
To test the hypothesis that supercritical flow is unlikely along the Tatum Wash study reach, the following evidence was considered:

- Critical Depth Messages. There are fewer critical depth messages for the subcritical 100-year HEC-2 profile (20 of 36 sections) than for the supercritical 100-year HEC-2 profile (22 of 36 sections), although critical depth messages were generated for more than half of the cross sections for both profiles. A plot of the HEC-2 computed

[11] Not including the coarser surface armor layer.

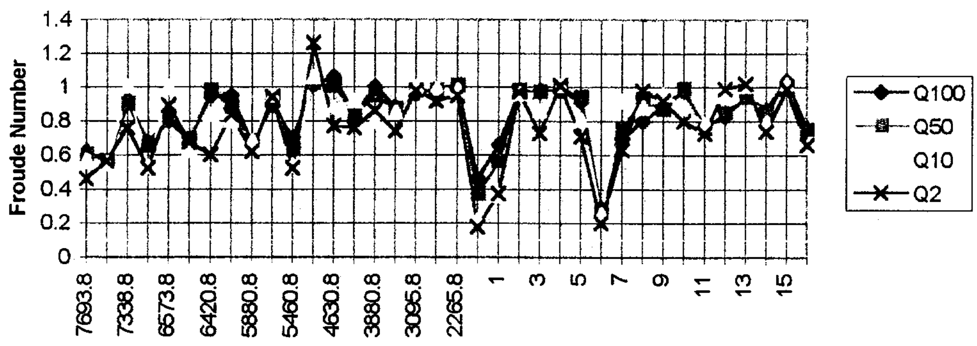
Froude number for the main channel for the subcritical and supercritical profiles is shown in Figure 3-11. The number of critical depth messages may indicate that Tatum Wash flows close to critical depth at the peak of the 100-year event.[12]

Figure 3-11. Tatum Wash - Channel HEC-2 Froude Number



- Flow Rate. The lower recurrence interval events (i.e., lower flow rates) have slightly lower Froude numbers than the higher recurrence interval events (higher flow rates). Therefore, only the flow rates for the portion of the hydrograph near the peak of the 100-year event approach critical depth.

Figure 3-12. Tatum Wash HEC-2 Channel Froude Number - Subcritical Profile



- Roughness Coefficient Sensitivity. Increasing the channel roughness coefficient (Manning's n value) by 20 percent (e.g., from 0.035 to 0.042) eliminated all but one critical depth message for the 100-year subcritical profile.[13] Use of Jarrett's roughness

[12] Alternatively, the number of critical depth messages may indicate that closer cross section spacing is required or that the geometry of individual channel cross sections is complex.

[13] An increase of 15% (n=0.040) eliminated all but two critical depth messages. An increase of 40% eliminated all critical depth messages (n=0.049). Compare to Jarrett's estimate of 0.061.

coefficient equation ($n = 0.39\ S^{0.38}\ R^{-0.16}$) indicated that an average roughness coefficient of about 0.061 should be used for Tatum Wash, which would generate strongly subcritical flow at every cross section in the HEC-2 model.

- Reach Definition. The reaches of Tatum Wash that generate the most critical depth messages, and were therefore most likely to be have near-critical or supercritical flow, were in the most confined reaches upstream of Fanfol Drive and upstream of the Phoenix Mountain Preserve boundary. Given that the reach-averaged velocities and depths for the subcritical and supercritical profiles were not that different (Table 3-5), use of the subcritical profile results would probably not result in significantly different sediment modeling results.

For these reasons, the subcritical profiles were used for the hydraulic and sedimentation analyses of Tatum Wash for the following reasons:

- It is unlikely that sustained supercritical flow occurs in the study reach.
- The subcritical profiles are conservative with respect to flow depth and area of inundation.
- The subcritical profiles reported for this study are based on relatively low n values, and are therefore conservative with respect to velocity.
- The reach-averaged hydraulic parameters estimated from results of the supercritical and subcritical HEC-2 profiles are not substantially different.
- HEC-6 does not perform well for supercritical flow.

If final floodplain delineation maps are prepared for the Tatum Wash study reach, it is recommend that a subcritical profile be used with roughness coefficients selected using Jarrett's equation for Manning's n.

Summary

HEC-2 models were prepared for the Tatum Wash study reach using topographic information and a HEC-2 model provided by the District. The HEC-2 was extended upstream from 40th Street approximately 3,000 feet. The HEC-2 modeling results were used to estimate channel capacities, hydraulic data, depths and velocities at road crossings, breakout locations, and as a basis for defining channel reaches and to recommend channel improvements. The basic HEC-2 input file was also used as the source of geometric data for HEC-6 modeling.

Section 4:
Geomorphic Analysis

Introduction

This Section summarizes the results of the geomorphic analysis for the Tatum Wash Sedimentation Study. The objective of the geomorphic analysis was to assess channel stability, and to predict expected channel response to channel and watershed modifications proposed for the Tatum Wash Drainage Improvement Project. The geomorphic analysis consisted of the following elements:

- General Geomorphic Description
- Stream Classification
- Documentation of Historical Channel Changes
- Evaluation of Channel Response to Historical Watershed Changes
- Application of Lane's Relation
- Evaluation of Longitudinal Profile
- Prediction of Equilibrium Slope
- Evaluation of Potential Channel Bed Armoring
- Application Regime Equations/ Hydraulic Geometry Relationships
- Estimation of Allowable Velocity

The Tatum Wash study reach for the project and for the geomorphic analysis extends from the Phoenix Mountain Preserve (PMP) boundary[1] upstream of 40th Street and Shea Boulevard. Unless otherwise noted, the descriptions and analyses summarized in the following paragraphs refer only to the portion of Tatum Wash within the study reach.

Geomorphic Analysis

Geomorphic Description. Tatum Wash is a small, ephemeral stream that drains the north slopes of the Phoenix Mountains. The Phoenix Mountains are a steep, but low-elevation range formed primarily from older Precambrian schist. The mountain front is deeply embayed by erosion, but may be generally delineated along the Fanfol Drive alignment. Downstream of Fanfol Drive, the wash leaves the more mountainous terrain, becomes less confined, and flows across the piedmont surface toward Indian Bend Wash. Upstream of the mountain front, within the embayment area, the piedmont surfaces are mapped (Dempsey, 1988) as middle Pleistocene-aged (250,000 to 790,000 years b.p.[2]) moderately-sorted sands to large cobbles, with well-developed argillic and calcic horizons.

[1] PMP boundary is at Doubletree Ranch Rd. alignment, @ Section 30/31 line, Township 3 North, Range 4 East.

[2] b.p. = before present.

The piedmont surfaces downstream of the mountain front are Holocene-aged (0-10,000 years b.p.) well-sorted sands and silts with minimal soil development, and are dissected by active gullies and washes. A small pediment surface may form an apron around the mountain front up-slope from the alluvial piedmont surfaces. The study reach begins upstream of the mountain front and extends about one mile downstream of the mountain front.

Upstream of the mountain front and the Phoenix Mountain Preserve boundary, Tatum Wash collects runoff from very small first- and second-order stream segments that drain the steep bedrock and colluvial slopes of the Phoenix Mountains. The main branch of the wash is a well-defined, second- and third-order stream with steep or vertical banks and very coarse (d_{50} > ½ ft.) bed material. The channel bank material includes poorly-sorted, carbonate-cemented,[1] very coarse alluvium and bedrock. Downstream of the mountain front and Fanfol Drive, Tatum Wash become less well defined and is weakly braided and/or anabranched[2] in several places. Channels banks are low, and include reaches of potential flow break outs, as indicated by the HEC-2 model (JEF, Inc., 1996a) for the study reach. Channel bed materials are coarse (d_{50} = 6.3mm) , and include areas of shallow and exposed bedrock (Table 4-1).

Table 4-1. Tatum Wash Sedimentation Study
Channel Sediment Characteristics and Bedrock Outcrop Locations

Sample #	Location	d_{10}	d_{50}	d_{90}
1	PMP Boundary (bed)	1 mm	4.8 mm	40 mm
2	Fanfol Drive (bed)	0.6 mm	5.5 mm	33 mm
3	Onyx Drive (bed)	1.5 mm	17 mm	52 mm
4	Shea Boulevard (ponding area)	< 0.072 mm	0.2 mm	15 mm
Bedrock Outcrop Locations in Channel Bed		1. 200 ft. upstream of 40th Street, right bank 2. 50 ft. upstream of Fanfol Drive 3. 100 ft. downstream of Fanfol Drive 4. @ Estrella alignment 5. 100 ft. upstream and downstream of Onyx Drive 6. @ Gold Dust Drive alignment		

Notes: 1. Sediment distributions reported in Law-Crandall (1996).
2. See Figure 5-1 for a graphical depiction of sediment gradations at the four sampling sites.

The upper watershed is relatively undisturbed due to land management practices for the area within the Phoenix Mountain Preserve. Approximately 88 percent (1.92 mi^2) of the 2.17 square miles watershed[3] is located within the Phoenix Mountain Preserve, which is an

[1] a.k.a. stage-IV carbonate, or "caliche."

[2] Anabranching is similar to a distributary flow pattern, except that the flow bifurcations for an anabranched channel tend to rejoin the main channel within a short distance. Distributary flow paths may not rejoin the main channel.

[3] Drainage area = 2.17 mi^2 at Shea Boulevard, 1.92 mi^2 at Phoenix Mountain Preserve boundary. About 50% of the land area within in the Tatum Wash watershed, downstream of the Phoenix Mountain Preserve boundary, consists of the undeveloped floodplain of Tatum Wash.

undisturbed natural area. The remaining 12 percent (0.25 mi^2) of the watershed upstream of Shea Boulevard, except for the floodplain, is fully developed with nearly all of the development consisting of ½ to 1 acre residential lots. Most of the residential lots have non-irrigated, desert landscaping or are fenced by solid block walls. Other impacts of development in the watershed along the study reach include construction of three at-grade road crossings and one box culvert, construction of bank stabilization near 44th Street, and obstruction of the natural flow path downstream of Shea Boulevard.

Flow events are rare on Tatum Wash. The District has maintained an ALERT stream monitoring station on Tatum Wash at 40th Street since 1994. To date, there have been no significant runoff events in the wash gauged at the District's streamflow station, although some smaller events that were not recorded by the gauge are thought to have occurred during this period.[1] Flood peaks and volumes were estimated by the District using the HEC-1 computer model, as summarized in Table 4-2. The average annual water yield from the watershed reported in Table 4-2 was estimated using Renard's equation developed for semiarid watersheds in the Southwest (Renard & Stone, 1982).

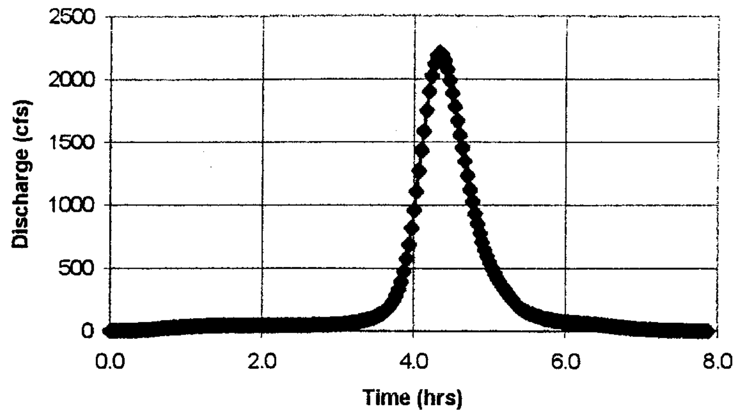
Table 4-2. Tatum Wash Sedimentation Study
Flood Frequency Estimates @ Shea Boulevard

Recurrence Interval (yrs)	Peak Discharge (cfs)	Flow Volume (AF)
2	328	42
10	848	90
50	1798	157
100	2315	189
	Average Annual Water Yield	28 AF
	Average Annual Discharge	0.04 cfs

Flood events on Tatum Wash typically are flashy, with a very short total flow duration. Analysis of the HEC-1 hydrographs (e.g., Figure 4-1) indicates that the flow duration for the modeled runoff events (approximately 8 hours) is only slightly longer than the rainfall duration used as input to the HEC-1 model (i.e., 6 hours). Most of the runoff for the flood hydrograph occurs within a two hour period. Channel transmission losses for the more frequent events are probably above-average, given the coarse bed material and high width to depth ratio of the channel. Total transmission losses for the larger flood events may be limited by the relatively low subsurface storage volume available due to shallow bedrock in parts of the study reach.

[1] A landscaping crew interviewed during a field visit recalled seeing a flood that nearly filled the 40th Street box culvert, but could not remember the date of the flood, except that it was in July or August and occurred in the last five years.

Figure 4-1. Tatum Wash Sedimentation Study
100-Year HEC-1 Hydrograph



Stream Classification. Tatum Wash has a straight braided channel pattern, with an average sinuosity[1] of 1.04. The wash has a steep, uniform slope that averages about one percent (0.011 ft./ft.). The wash itself is classified as small (< 100 ft. wide), with a narrow floodplain (2-10 times the width of the main channel), except upstream of Fanfol Drive where the channel and floodplain boundaries are coincident. There is no significant change, or consistent trend, in channel width, depth or slope along the length of the study reach (JEF, 1996a). Bank height generally decreases in the downstream direction, with the largest decrease occurring at the geologic mountain front near Fanfol Drive. Typical cross sections from upstream (#4-2a) and downstream (#4-2b) of Fanfol Drive are shown in Figures 4-2a and 4-2b.

Channel bank vegetation upstream of Fanfol Drive consists of Mesquite, Ironwood, and Palo Verde trees, cacti, and desert scrub species. Channel bank elevations downstream of Fanfol Drive are low, with vegetative cover generally similar to the channel bed vegetation. Vegetation within the channel bed consists of various desert scrub species such as creosote, brittlebush, and grasses. It is unlikely that the brushy channel vegetation could resist erosion during a large flow event. However, during low flows, channel vegetation probably increases the hydraulic roughness and induces deposition of the bed-material load, particularly in the reach downstream of Onyx Drive.

[1] Sinuosity is defined as the ratio of channel length to valley length.

Figure 4-2a. Tatum Wash
Cross Section #3095.8 - Upstream of the Mountain Front

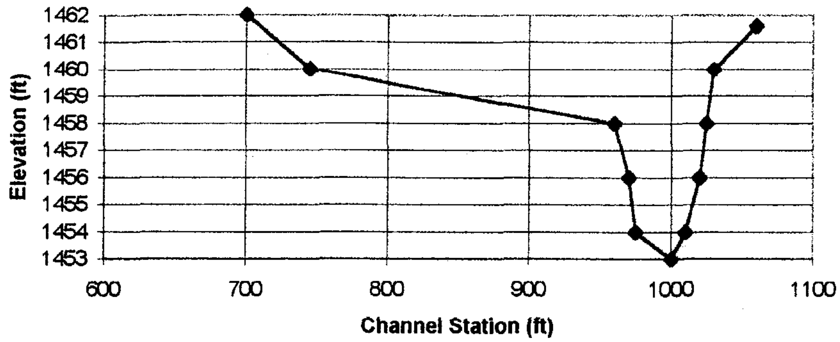
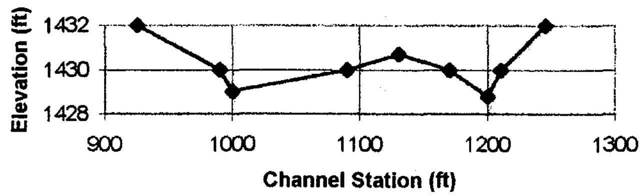


Figure 4-2b. Tatum Wash
Cross Section #5150.8 - Downstream of Mountain Front



Within its watershed Tatum Wash has a well-integrated dendritic drainage network upstream of Fanfol Drive, with well-defined washes on all of the geomorphic surfaces, except the cliffs and steep bedrock slopes. The drainage network downstream of Fanfol Drive is primarily dendritic, although some flow bifurcations have formed due to stream capture and/or loss of topographic relief, giving it a weakly distributary appearance. Topographic relief within the upper watershed is moderate (100 to 1,000 ft.), with low relief in the lower watershed (< 10 feet). A summary of stream classification data for Tatum Wash is shown in Table 4-3.

Table 4-3. Tatum Wash Sedimentation Study Stream Classification Data for Study Reach	
Category	**Classification/Description**
Stream Size	Small (< 100 ft.)
Flow Habit	Ephemeral (Avg. Annual Flow Rate = 0.04 cfs)
Flood Characteristics	Flashy, Short Duration, High Losses
Bed Material	Gravel (d_{50} = 6.3 mm)
Valley Setting	Moderate Relief (100-1,000 ft.; upstream of Fanfol Dr.) Low Relief (< 100 ft.; downstream of Fanfol Dr.)
Drainage Network	Dendritic
Floodplains	Narrow (2-10x channel width)
Incision	Incised (upstream of Fanfol Dr.) Not Incised (downstream of Fanfol Dr.)
Channel Boundaries	Semi-alluvial (some bedrock in bed and banks)
Width/Depth Ratio	High (> 100)
Bank Vegetation	Less than 50% Cover
Channel Slope	Steep (S_o = 1.1%)
Sinuosity	Straight (S < 1.05)
Braiding	Locally Braided (upstream of Fanfol Dr.) Generally Braided (downstream of Fanfol Dr.)
Anabranching	Locally Anabranched (downstream of Fanfol Dr.)
Channel Width	Random Variation
Table modeled after FHWA, 1991.	

Historical Channel Change. Historical channel changes along Tatum Wash can be inferred from historical aerial photographs and topographic maps (Table 4-4, Figures 4-3 to 4-5). In the earliest available (1957) aerial photograph (Figure 4-3), the watershed and wash are essentially undisturbed. The wash appears to have a wide channel bottom, and is lined by moderately dense vegetation. Two areas of anabranching flow are visible between 40th Street and Shea Boulevard: (1) the reach upstream of Onyx Drive[1] - HEC-2 cross sections 4260-5460, and (2) the reach between 44th Street and Shea Boulevard - HEC-2 cross section 5880-7388. The latter reach is now partially channelized and is no longer anabranched. In 1957, downstream of Shea Boulevard, Tatum Wash was poorly defined, but clearly visible in a continuous drainage path from Shea Boulevard to its confluence with Indian Bend Wash.

By 1965 (Figure 4-4), new residential development had been constructed over portions the natural flow path of Tatum Wash downstream of Shea Boulevard. A few new homes constructed in the adjacent watersheds downstream of 40th Street are the extent of the change near the study reach. By 1982 (Figure 4-4), most the streets and homes downstream of 40th Street had been constructed. In addition, the neighborhood downstream of Shea Boulevard had been built out, completely obscuring the natural flow path of Tatum Wash. However, except for new at-grade crossings at Onyx Drive and 44th

[1] Future alignments of Onyx Drive, 40th Street, and 44th Street - no streets constructed at time of photograph.

Figure 4-3
Tatum Wash Study Area
Photo Date: 1957

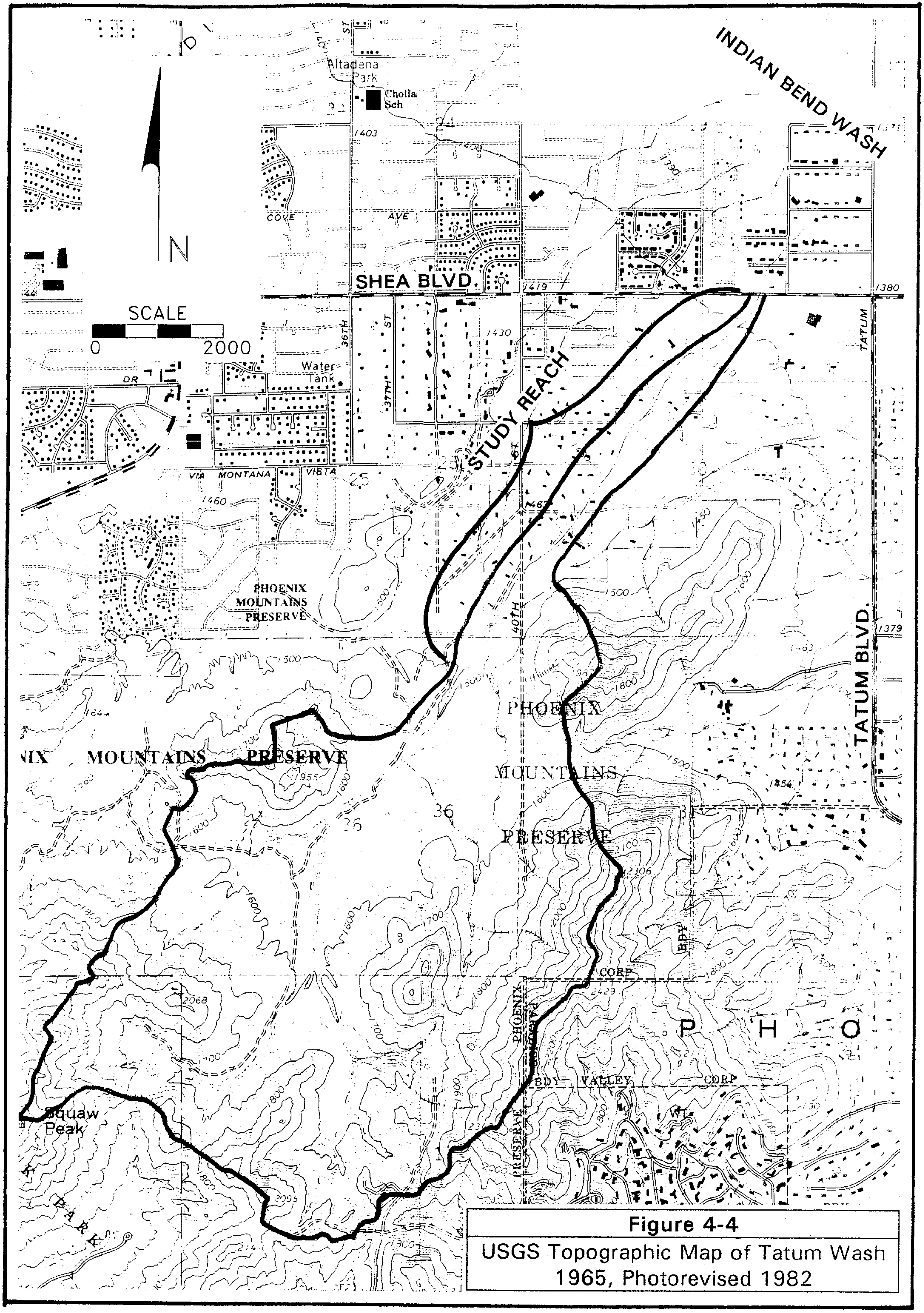


Figure 4-4
USGS Topographic Map of Tatum Wash
1965, Photorevised 1982

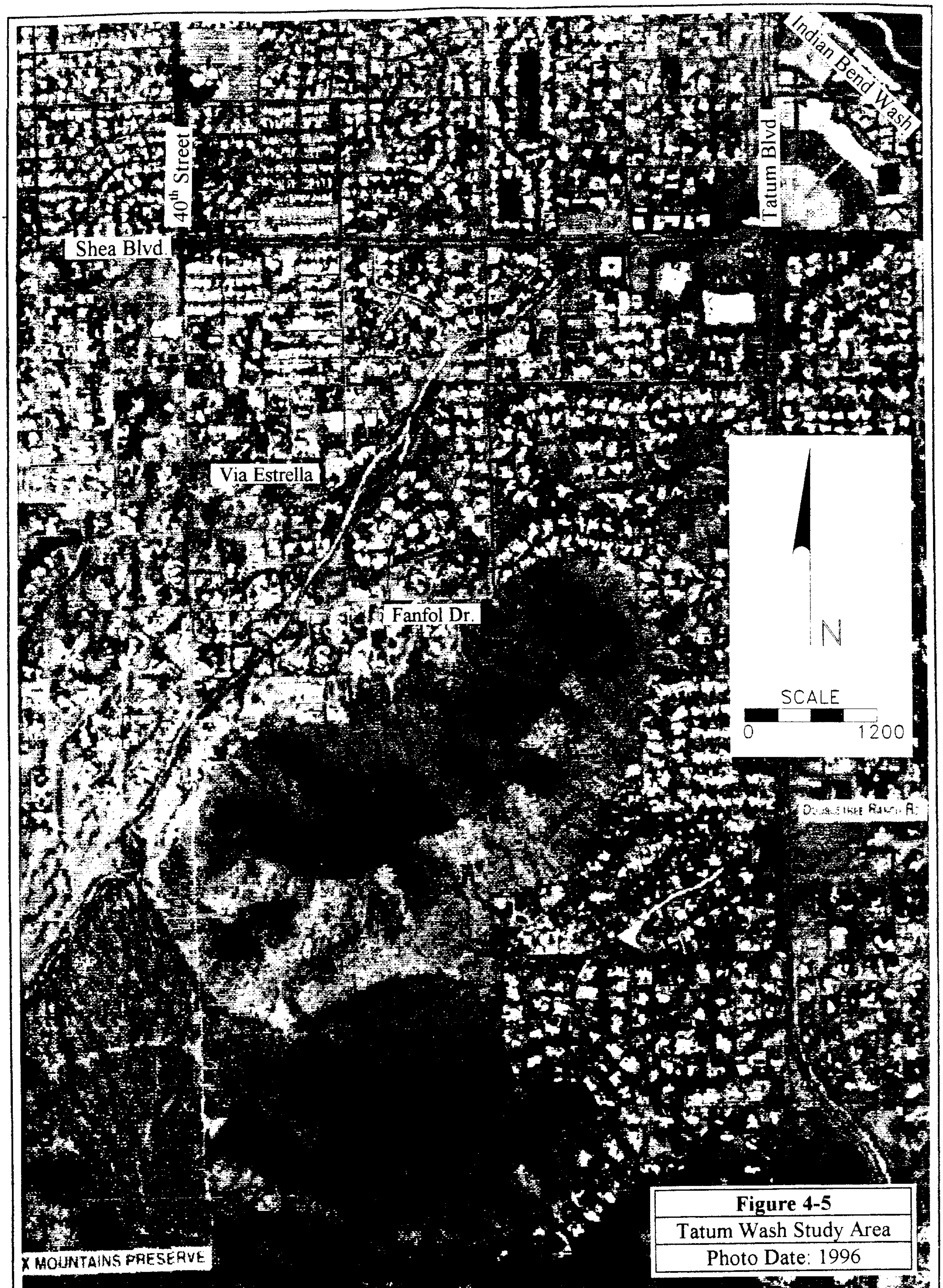


Figure 4-5
Tatum Wash Study Area
Photo Date: 1996

Street, it is unlikely that the channel of the study reach itself was affected by any of the development that occurred between 1965 and 1982. Finally, the Phoenix Mountain Preserve was established between 1965 and 1982, effectively protecting about 90 percent of the watershed from future development.

At some time between 1982 and 1994 (Figure 4-5), development along the study reach began to impact the natural geomorphology of Tatum Wash. Channel changes that occurred during this time period included construction of a box culvert at 40th Street, construction of concrete bank protection and block walls intended to contain flood flows near 44th Street, and slight encroachment of the floodplain near the new development near 44th Street. Field inspection of the study reach indicates that these most recent changes to the floodplain probably have not significantly impacted the sedimentation characteristics of the wash. Most of the encroachment has been within ineffective flow portions of the floodplain, and therefore did not significantly impact the flow hydraulics for the channel-forming events.

Table 4-4. Tatum Wash Sedimentation Study
Historical Aerial Photographs and Mapping

Date	Source	Description
1957	FCDMC Aerial Photo (Figure 4-3)	Tatum Wash and watershed mostly undisturbed by development - Few isolated homes in adjacent watersheds downstream of 40th St. Tatum Wash continuous downstream of Shea Blvd. Unpaved at-grade crossings at 40th St. and Fanfol Dr. Anabranched channel pattern at Estrella and at 44th alignments 40th St. extends into (future) PMP approx. one mile south of Fanfol Dr. No photo coverage upstream of 40th St.
1965	USGS Topographic Map (Figure 4-4)	No significant change in development since 1957 Residential development downstream of Shea Blvd obscures Tatum Wash flow path
1982	USGS Revised Topographic Map (Figure 4-4)	Phoenix Mountain Preserve established Paved at-grade drainage crossings constructed at 44th St., Onyx Dr. Extensive home construction downstream of 40th St. Build out of area downstream of Shea Blvd along former Tatum Wash alignment
1994	FCDMC Topographic Map (Figure 4-5)	Paved drainage crossings constructed Box culvert @ 40th St. At-grade crossings @ Fanfol Dr. and driveway upstream of Fanfol Dr. Complete build out of neighborhoods along Tatum Wash study reach Channel bank stabilization/flood control constructed in the following reaches: Onyx Dr. to 44th St. - both banks concrete-lined levee and block wall Downstream of 44th St. - left bank block wall, right bank concrete-lined levee

Channel Response to Historical Watershed Changes. Few significant channel responses to historical watershed changes were identified during the course of this study. The lack of channel response is probably due to the following factors:

- Lack of Watershed Changes. Because about 95 percent of Tatum Wash watershed at Shea Boulevard[1] is located within the Phoenix Mountain Preserve or in the floodplain of Tatum Wash itself, most of the drainage area has not been affected by urbanization.

[1] 100 percent of the watershed at the upstream end of the study reach at the Phoenix Mountain Preserve boundary.

- Lack of Direct Channel Modifications. Most of the development within the study reach is located outside of the 100-year floodplain. The few areas where development has encroached on the 100-year floodplain are either in ineffective flow areas and/or have been protected by concrete bank protection.

- Coarse Bed Material. The large diameter of the bed materials (Table 4-1) probably lessens the expected response to watershed impacts due to armoring, and low sediment transport rates during the most frequent runoff events.

- Shallow Bedrock. Shallow bedrock in much of the study reach (Table 4-1) probably prevents significant channel adjustments.

- Caliche. Stage III and IV carbonate development (caliche) in soils exposed in the banks of the channel upstream of Fanfol Drive probably limits the potential for significant bank erosion.

The few minor channel responses to historical changes observed within the study reach occurred in the following locations:

- At-Grade Crossing Scour holes. Small scour holes have formed on the downstream side of the at-grade road crossings at 44th Street, Onyx Drive, and Fanfol Drive. These scour holes are typically 0.5 to 1 foot deep, extend up to one road-width downstream, and are limited in places by shallow bedrock. The scour holes are localized near the road crossing and do not appear to affect the channel downstream of the crossing. Concrete headers have been constructed at several of the at-grade crossings to prevent damage to the road surface from undercutting.

- Shea Boulevard. Sediment deposition occurs upstream of Shea Boulevard, probably due to slightly lower channel velocities. Below average channel velocities occur in this area due in part to human impacts such as headwater ponding at the storm drain inlet, channel and flow expansion at the Shea Boulevard overflow crossing, excessive vegetative growth in the channel, and blockage of the natural flow path by the residential developments located downstream of Shea Boulevard.

- 44th Street Channelization. The historically anabranched reach upstream and downstream of 44th Street was channelized and narrowed between 1982 and 1994. The expected response to this channelization would be scour, although no signs of long-term scour were observed in the field, and the Shea Boulevard sediment deposition area extends into the lower end of the channelized reach.

Comparison of the 1957 aerial photograph and field photographs indicates the density of bank vegetation may have decreased during the past 40 years. Conversely, the density of mid-channel bed vegetation probably increased during this period. However, this change may be more related to the lack of any occurrence of erosive floods relative to the dates of photography, than to any systematic watershed response. Net loss of bank vegetation may be due to landscaping by local homeowners.

Lane's Relation. Over the long-term, stream channels tend adjust their morphology to achieve a balance (equilibrium) between water flow, channel slope, sediment discharge, and sediment size, among other variables. The Lane relation (Lane, 1955) qualitatively expresses this equilibrium concept as:

$$QS \propto Q_s D_{50}$$

where:

Q = water discharge
S = channel slope
Q_s = sediment discharge
D_{50} = mean bed sediment diameter

The Lane relation indicates that to maintain stream equilibrium, a change in one variable must be compensated by a corresponding change in one or more of the other variables. The Lane relation is most useful for determining the expected channel response, or direction of change of a given variable, rather than the exact magnitude of expected change. For example, the Lane Relation may be applied to Tatum Wash to evaluate the historical conditions and the proposed drainage improvements. Historically, the primary independent variables, Q and Q_s, probably have not changed due to the lack of upstream development in the Phoenix Mountain Preserve. Therefore, it is not surprising that no changes in the dependent variables, S and D_{50}, were observed within the study reach.

The Lane relation may also be applied to the District's proposed drainage improvement project for Tatum Wash. Construction of the proposed regional detention basin upstream of the Phoenix Mountain Preserve boundary for Phase 2 of the project would have the following results:

- Decrease peak discharges (Q^-)
- Increase the duration of low flow discharges (Q^+)
- Have no significant impact on flow volumes (Q^0)
- Trap sediment in the basin and decrease sediment supply downstream (Q_s^-)
- Have no direct affect on channel slope or bed sediment diameter.[1]

These effects may be expressed as:

$$Q^{-/0/+} S \propto Q_s^- D_{50}$$

Lane's Relation, as written above to describe possible geomorphic impacts from the Phase 2 detention basin, may or may not be out of balance, depending on the relative changes in water and sediment discharge, respectively. At least three responses are possible to

[1] That is, *construction* of the basin will not increase the slope or reduce the sediment size. Such changes may occur downstream following construction of the detention basin as a result of changes in discharge or sediment supply.

balance reduction in peak discharges (Q^-) due to upstream detention. First, since the sediment transport rate is exponentially related to discharge rate, a decrease in peak discharge (Q^-) tends to reduce the sediment transport rate (Q_s^-), particularly for the coarse sediment fraction, which tends to be transported only at high flow rates. Second, a reduction in the mean sediment diameter (D_{50}^-) could also balance the equation. Third, an increase in channel slope (S^+) could balance the equation. Experience indicates that a reduction in sediment discharge (Q_s^-) is the most likely response downstream of the detention basin.

However, it is noted that while the peak discharges will be reduced due to flood attenuation in the proposed detention basin, the total flood volumes are unchanged (Q^0). Therefore, the flow duration at a lower discharge rates will tend to be increased (Q^+) by the detention basin. This effect may be expressed as:

$$Q^+S \propto Q_s D_{50} \qquad \text{(for low flow rates)}$$

To balance Lane's Relation for the increase in low flow rate duration (Q^+), several channel responses are possible. First, the sediment discharge rate could increase (Q_s^+). Since sediment transport is exponentially related to flow rate, the potential increase in sediment transport would be somewhat muted due to peak attenuation in the detention basin. In addition, any increase in sediment transport would tend to favor movement of finer sediment, since the coarsest sediment fraction would tend to be stable at low flow rates. Second, the mean sediment diameter could increase (D_{50}^+). Coarsening of the bed sediment is likely due to selective movement of finer sediment during sustained low flow discharges. Third, the channel slope could decrease (S^-). Experience indicates that an increase in sediment diameter and decrease in channel slope[1] (armoring) are the most likely channel responses.

Therefore, Lane's Relation indicates that the expected impact of the proposed detention basin for Phase 2 of the Tatum Wash Drainage Improvement Project would be to decrease the sediment transport occurring naturally at high flow rates during the largest floods, and to increase the volume of fine sediment moved at low flow rates (relative to natural conditions). These changes in sediment transport conditions would have the effect of increasing the bed sediment size (D_{50}^+) by selectively removing more fine sediments from the bed compared to natural conditions. By removing fine sediments, the mean diameter of channel sediment will tend to increase (D_{50}^+). Removal of sediment from the channel would tend to decrease the channel slope (S^-), a process which occurs by long-term scour. The net effect of these changes would be to increase scour and armor the channel bed downstream of the proposed detention basin. The magnitude of the scour that will occur downstream of the basin is a function of the channel armoring potential, depth to bedrock, the magnitude of flows entering the basin, and the magnitude and duration of the detention basin outflows.

[1] An increase in sediment size and decrease in channel slope is achieved by sediment transport from the reach.

Since it is located at the downstream end of the study reach, construction of the proposed sedimentation trap basin upstream of the Shea Boulevard storm drain is not likely to impact channel geomorphology, unless a grade control structure is not included as part of the basin inlet design. Lack of grade control at the basin inlet would increase the channel slope, which would be expressed as:

$$Q\,S^{+} \propto Q_s D_{50}$$

This local increase in slope at the sediment trap inlet would tend to increase the local sediment discharge (Q_s^{+}) from the channel into the basin and result in headcut migration from the sediment trap inlet upstream into the study reach.

Longitudinal Profile. A longitudinal profile is a plot of stream bed elevation versus stream distance. The longitudinal profile based on the detailed, 2-foot contour interval topography for the Tatum Wash study reach provided by the District, shown in Figure 4-6, is relatively uniform (average slope = 0.011 ft./ft.) with several local, low-amplitude perturbations.[1] These local perturbations, or slope changes, are probably caused by control of the channel slope by shallow bedrock or by small scour holes downstream of the at-grade road crossings. The channel slope increase located immediately upstream of Onyx Drive may also be partly due to the anabranching channel pattern. Since the channel becomes wider and shallower with anabranching, the channel slope tends to steepen to provide sediment continuity.

Figure 4-7 shows the longitudinal profile of Tatum Wash from the (historical) confluence with Indian Bend Wash to the drainage divide in the Phoenix Mountain Preserve, based on topographic data from the USGS topographic maps (USGS, 1982). The longitudinal profile shown in Figure 4-7 is concave up, which is typical for dendritic (tributary) drainage systems.[2] The slope break located near Onyx Drive is more pronounced in Figure 4-7 than in Figure 4-6 due to the scale of topography and the extended profile limits. Given that bedrock crops out in the bed of the channel between Fanfol Drive and Onyx Drive, it is likely that the slope break is caused by the loss of bedrock control of slope near Onyx Drive. The longitudinal profile data shown in Figure 4-7 indicates that the geologic mountain front may be located closer to Onyx Drive than to Fanfol Drive, in contrast to what was indicated by the change in bank height and topographic confinement of the channel. Alternatively, the bedrock-controlled reach between Fanfol Drive (the point of loss of topographic confinement) and Onyx Drive (the downstream limit of bedrock in the channel bed) may be a pediment surface that aprons the mountain front.

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[1] The slope break at the Phoenix Mountain Preserve boundary is caused by a difference in datum or a bust in topographic data between the Mclain Harbors (1994) topography for the study reach and the 1996 FCDMC digital terrain model for the Phoenix Mountain Preserve area. The latter two sources of topography were used to generate the longitudinal profile in Figure 4-6.

[2] Many distributary drainage systems and active alluvial fan channels have convex longitudinal profiles.

Figure 4-6. Tatum Wash Longitudinal Profile

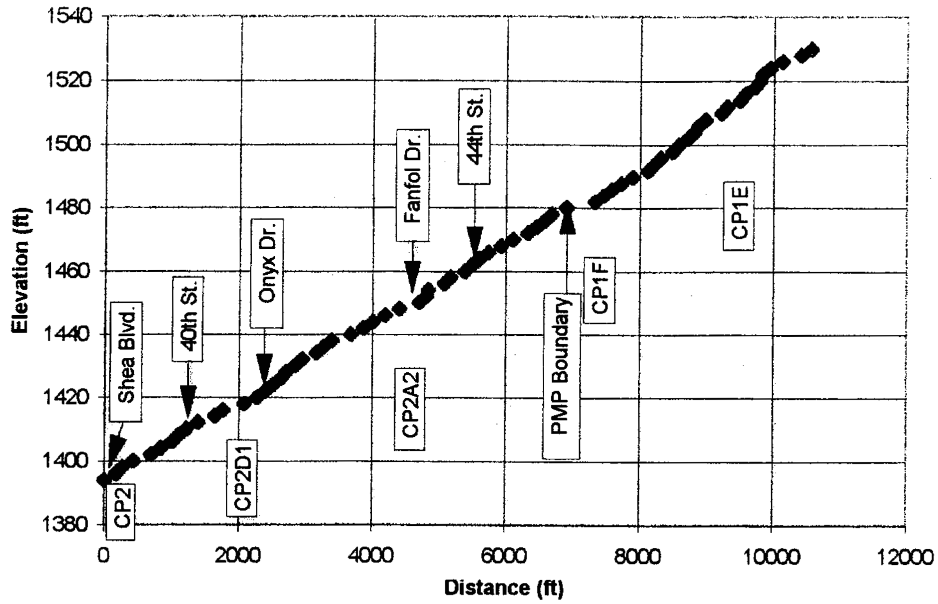
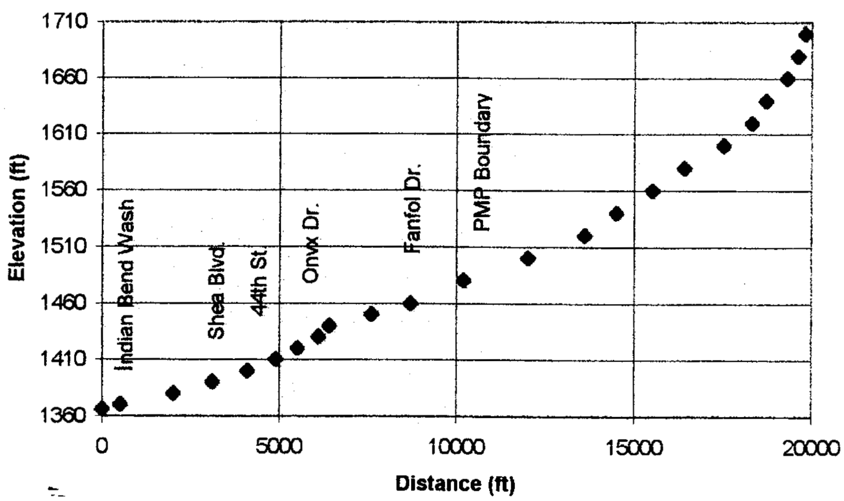


Figure 4-7. Tatum Wash Longitudinal Profile



For the purposes of the Tatum Wash Sedimentation Study, the longitudinal profile data shown in Figures 4-6 and 4-7 indicate the following:

- Scour upstream of Onyx Drive will probably be limited by shallow bedrock.
- Deposition at Shea Boulevard is not caused by a change in the natural channel slope.
- The existing channel slope is at or near the equilibrium slope.

Equilibrium Slope. Equilibrium slope is defined as the slope at which the channel's sediment transport capacity equals the incoming sediment supply (ADWR, 1985), and generally is the slope that the undisturbed, natural channel will tend towards over the long term. While there are philosophical and practical problems with applying equilibrium slope concepts to small ephemeral streams with variable channel geometry, equilibrium slope equations provide a useful order-of-magnitude assessment of the likelihood of vertical channel adjustments. A following equilibrium slope equations were applied to the Tatum Wash study reach:

- Pima County Flood Control District (PCFCD) Equation
- City of Tucson Equation
- Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) Equations
- Zeller-Fullerton Equation
- Schoklitsch Equation
- Meyer-Peter Muller Equation
- Shield's Diagram Method
- Lane's Tractive Force Method

Application of equilibrium slope equations to a specific watercourse requires hydraulic, hydrologic, topographic, and flood frequency data. Reach-averaged hydraulic data and topographic information were derived from HEC-2 modeling results for Tatum Wash described in Section 3 of this report. Hydrologic and flood frequency data were derived from HEC-1 modeling described in Section 2 of this report. Most equilibrium slope equations are based on the mean annual flood, or the "channel-forming," or "bankfull" discharge. On many alluvial streams, the mean annual flood, and the channel-forming and bankfull discharge are equivalent. However, because Tatum Wash is ephemeral and flow events are rare, the average annual discharge (Table 4-2) is difficult to determine. According to the HEC-2 modeling results, bankfull discharge within the Tatum Wash study reach ranges from 50 cfs (less than a 2-year event) to more than 2,300 cfs (100-year peak discharge). The recurrence interval of the channel-forming discharge for ephemeral streams is thought to range from 2- to 10-year event (Chang, 1988). Therefore, to account for these discrepancies in what flow rate is appropriate for equilibrium slope analyses, a range of discharges were used in the equilibrium slope equations.

The results of the equilibrium slope analyses are shown in Table 4-5. Descriptions of the equations and methodologies used are provided in the following paragraphs. More detailed information is also available from the references cited for each methodology.

Table 4-5. Tatum Wash Sedimentation Study Equilibrium Slope Analysis Results					
Method	**Equilibrium Slope (ft./ft.)**				**Estimated Channel Change/ Comments**
	Q2	**Q10**	**Q50**	**Other**	
PCFCD	-	-	-	0.0011 0.0069	Scour; Post Phase 2, 90% trapping Scour; Post Phase 2, 40% trapping
City of Tucson	-	-	-	0.0016	Scour; After Phase 2 basin built
AMAFCA				0.0016	Scour; After Phase 2 basin built
Average	-	-	-	0.0014	Scour
AMAFCA	0.017	0.015	0.013	-	Maximum slope - existing conditions
Zeller-Fullerton	0.010	0.011	0.0087	-	No change - existing conditions
Average	0.014	0.013	0.011	-	Minor Deposition
BUREC Zero-Sediment Discharge Equations					
Schoklitsch	0.0027	0.0016	0.0011	-	Scour; After Phase 2 basin built
Meyer-Peter Muller	0.0035	0.0024	0.0019	-	Scour; After Phase 2 basin built
Shield's Diagram	0.0019	0.0013	0.0010	-	Scour; After Phase 2 basin built
Lane's Tractive Force	0.0020	0.0014	0.0010	-	Scour; After Phase 2 basin built
Average	0.003	0.002	0.001	-	Scour

PCFCD Equation (PCFCD, 1984). The PCFCD equation predicts slope adjustments caused by changes in watershed and channel conditions due to urbanization, mining, or channelization. For Tatum Wash, no such changes are expected since most of the watershed is either within the Phoenix Mountain Preserve or is currently developed. However, construction of the proposed detention basin for Phase 2 of the Tatum Wash Drainage Improvement Project will result in a reduced sediment yield to the study reach. For a sediment trapping efficiency[1] for the proposed detention basin of 90 percent estimated from HEC-6 model output (JEF, 1996h), the PCFCD equation indicates that the equilibrium slope for Tatum Wash will be about 0.0011 ft./ft. (0.1%), an order of magnitude lower than the existing channel slope. For a trapping efficiency of about 40 percent, estimated using the Churchill method (JEF, 1996h), the PCFCD equation predicts an equilibrium slope of about 0.0069 ft./ft. (1 %).

A slope adjustment from 0.01 ft./ft. to 0.001 ft./ft. or 0.069 ft./ft. translates into degradation of up to 20 or 8 feet, respectively, between existing adjacent road crossings in the study reach. However, since channel armoring and/or shallow bedrock is likely to prevent some of the predicted long-term degradation, a more realistic interpretation of these results is that some degree of channel scour may be expected after construction of the Phase 2 detention basin upstream of the study reach.

City of Tucson Equation (COT, 1990). The City of Tucson equation predicts the equilibrium slope for a channel downstream of a point of zero sediment supply. An on-line regional detention basin with a small outlet, large ponding area, and long drain time could

[1] Reservoir trapping efficiency in discussed in Section 5 of this report.

represent a point of zero sediment supply for the downstream reach. For the City of Tucson equation, equilibrium slope is estimated from the unit discharge for the 10-year event and the channel roughness. For Tatum Wash, the City of Tucson equation predicts an equilibrium slope of about 0.002 ft./ft. (0.2%), nearly an order of magnitude less than the existing channel slope. Again, since shallow bedrock and/or armoring probably will limit excessive long-term scour, the most realistic interpretation of these results is that some degree of scour will occur downstream of the detention basin.

AMAFCA Equation (AMAFCA, 1994). The AMAFCA equation[1] for the maximum equilibrium slope is based on the assumptions that steep, wide, rectangular alluvial streams flow at or close to critical depth and that sediment supply is transport limited.[2] For Tatum Wash, the AMAFCA equation predicts a maximum equilibrium slope of about 0.017 ft./ft. (1.7%) and 0.015 ft./ft. (1.5%) for the 2- and 10-year events, respectively, slightly steeper than the existing channel slope. For cases where the upstream sediment supply is limited (e.g., a regional detention basin), the AMAFCA equation[3] indicates that the stable slope will be about 0.002 ft./ft. (0.2%).

Zeller-Fullerton Equation (SLA, 1982; AMAFCA, 1994). The Zeller-Fullerton equation for total sediment load can be used to estimate equilibrium slope for sand and gravel bed channels with high width/depth ratios. When applied to existing conditions in Tatum Wash, the Zeller-Fullerton equation predicts an equilibrium slope of 0.01 ft./ft. (1%), approximately equal to the existing channel slope. It is noted that the Zeller-Fullerton equation was derived in part for use on streams in Arizona, from a data base that included ephemeral streams. The Zeller-Fullerton equilibrium slope equation cannot be used to directly predict the equilibrium slope following construction of the proposed Phase 2 detention basin.

The Bureau of Reclamation (BUREC, 1984) published a manual for computing scour and channel degradation downstream of dams or other structures that interrupt the natural sediment supply to the downstream channel. The BUREC manual describes the following four approaches for estimating equilibrium slope: (1) Schoklitsch Equation, (2) Meyer-Peter Muller Equation, (3) Shield's Diagram Method, and (4) Lane's Tractive Force Method. The approaches are based on the assumption of zero sediment transport and are most applicable to Tatum Wash after construction of the proposed detention basin upstream of the study reach at the Phoenix Mountain Preserve boundary. The results of all four methods indicate that the channel will tend scour after construction of the proposed Phase 2 detention basin, as shown in Table 4-5.

Summary. The scour caused by the channel's adjustment to the new (post-detention) equilibrium slope will be limited to a reach length sufficient for channel to regain a

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[1] Equation 3.59, AMAFCA, 1994.

[2] Transport limited means that the sediment inflow equals or exceeds the reach transport capacity.

[3] Equation 3.57, AMAFCA, 1994.

sediment transport balance. Therefore, the predicted equilibrium slope may occur in the channel immediately downstream of the detention basin, but further downstream from the basin outlet, the channel slope will gradually approach its pre-detention value. The length of this transition in slope adjustment is difficult to predict, but is a function of the watershed hydrology, bed sediment gradation, depth to bedrock, channel geomorphology, and other human impacts on the wash. Given the presence of shallow bedrock near Fanfol Drive, and the fully lined culvert at 40th Street, it is likely that any significant slope adjustment will occur immediately downstream of the Phase 2 detention basin outlet and upstream of 40th Street.

The equilibrium slope analysis indicates that the existing channel slope is close to the predicted equilibrium slope for the natural, undisturbed channel, according to the AMAFCA and Zeller-Fullerton equations. Therefore, no significant vertical adjustments are expected unless the existing channel is modified. Following construction of the regional detention basin proposed for Phase 2 of the Tatum Wash Drainage Improvement Project, all of the equilibrium slope equations indicate that scour is expected in the channel downstream of the basin. The actual magnitude of the expected scour will be based in part on the depth to bedrock and the potential for armoring.

Potential Channel Bed Armoring. When the channel sediment transport capacity exceeds the upstream sediment supply, the balance of the sediment load is eroded from the channel itself and the channel begins to degrade. Finer sediments can be transported at lower discharges and velocities than the coarser bed sediments. Lower discharges also occur more frequently than high discharges. Therefore, finer sediment tends to be preferentially removed from the channel bed, resulting in progressively coarser channel bed material, as long as the upstream sediment supply is limited. This process creates a surficial layer of coarse channel sediments, called an armor layer, that the stream is incapable of transporting (Yang, 1996). The BUREC (1984) has developed several methodologies for estimating the minimum sediment size required to form an armor layer, and the depth of scour required to form the armor layer, for a given flow rate. The results of application of the BUREC methodologies to the Tatum Wash study reach are summarized in Table 4-6. Channel sediment size distribution data for the study reach were reported in Table 4-1 and Figure 5-1 for comparison with the critical armoring sediment diameter.

Table 4-6. Tatum Wash Sedimentation Study Channel Armoring Analysis Results								
Method	**Critical Armor Sediment Size (mm)**				**Depth of Scour to Form Armor Layer (ft)**			
	Q2	**Q10**	**Q50**	**Q100**	**Q2**	**Q10**	**Q50**	**Q100**
Meyer-Peter Muller	24	36	44	48	0.5	2.0	*	*
Competent Bottom Velocity	34	63	105	125	1.6	*	*	*
Lane's Tractive Force	46	70	85	92	*	*	*	*
Shield's Diagram	36	55	67	73	2.0	*	*	*
Yang's Incipient Motion	36	67	112	133	2.0	*	*	*
Average	35 (1.4")	58 (2.3")	83 (3.3")	94 (3.7")	1.5	*	*	*
Note: * indicates no armor layer formed for sediment distribution in bed. Does not account for affects of shallow bedrock.								

The following conclusions can be drawn from the results summarized in Table 4-6 for the study reach:

- The channel bed scour depth is probably limited by armoring during frequent flows and small floods, but not during high flow rates during large flood events.
- The channel bed material is mobile, and will be transported during moderate to large flood events. The HEC-6 sediment transport model should use a transport function developed for coarse sediment transport.
- The depth to bedrock observed during field visits and during sediment sampling tasks is less than the armoring depth for several places in the study reach. The HEC-6 model should be coded to include the depth to bedrock, wherever the bedrock depth information is available and the HEC-6 scour depth exceeds the probable depth to bedrock.
- Following implementation of Phase 2 of the Tatum Wash Drainage Improvement Plan, the peak channel flow will be about 620 cfs, a magnitude between the existing conditions 2- and 10-year events. Therefore, the data summarized in Table 4-6 indicates that an armor layer will form after the Phase 2 detention basin is constructed. The critical armoring sediment diameter after Phase 2 is implemented will be about 50 mm, and the depth of scour to form an armor layer will be about 2 feet.

Regime Equations/ Hydraulic Geometry. Regime equations and hydraulic geometry analyses attempt to relate measurable stream characteristics, such as sediment size, mean annual discharge or bankfull discharge, to equilibrium channel geometry characteristics such as width, depth, velocity or slope. Regime theory originated from studies of non-scouring and non-silting stable alluvial canals, and has been extended to a wide variety of stream types (cf., Ackers & Charlton, 1970). Regime equations are typically based on discharge, sediment characteristics, and channel geometry. Hydraulic geometry studies are theoretically similar to regime theory, but were developed from empirical data gathered from natural streams, primarily by U.S. Geological Survey (cf., Leopold & Maddock, 1957), and are typically based solely on discharge. The following types of regime equation and hydraulic geometry analyses were applied to the Tatum Wash study reach:

- Slope-Discharge Relationships
- Channel Geometry Relationships
- Regime Equations

Regime equations and hydraulic geometry relationships are empirically derived from data sets of streams with specific characteristics (e.g., sand-bed rivers, canals, etc.), although they typically still have a large amount of scatter. Therefore, the results obtained by applying these equations to streams with different characteristics than the data sets from which they were derived must be interpreted cautiously. In general, the results are best interpreted as order-of-magnitude estimates of the expected direction of change, rather than exact predictions the magnitude of future channel adjustments.

Slope-Discharge Relationships. The slope of river has a strong influence on the channel pattern, for a given discharge. Several researchers have tried to establish a threshold slope between braided and meandering stream patterns using empirical data, flume studies, and theoretical relationships. Some of these slope-discharge relationships are summarized in Table 4-7, which show that Tatum Wash is well within the expected range for a braided channel pattern. Therefore, a braided, non-meandering channel pattern is the equilibrium form for the study reach.

Table 4-7. Tatum Wash Sedimentation Study
Slope-Discharge Relationships: Threshold Slope for Braided Channels

Name	Equation	Slope (ft/ft)	Reference
Lane	$S > 0.01\ Q_m^{-0.25}$	> 0.002	MacBroom (1981)
Leopold & Wolman	$S > 0.06\ Q_{maf}^{-0.44}$	> 0.005	Leopold & Wolman (1957)
Henderson	$S > 0.64\ d_{50}^{1.14}\ Q_{maf}^{-0.44}$	> 0.001	Henderson (1966)
	Average	> 0.003	0.01 = Tatum Wash Slope

Notes: S = Slope for braided channel Q_{maf} = Bankfull discharge Qm = Average annual discharge

Because the slope-discharge relationships summarized in Table 4-7 are based on mean annual or bankfull discharge, they cannot be directly applied to Tatum Wash after construction of the Phoenix Mountain Preserve detention basin. However, since peak discharges will decrease due to attenuation in the basin, and since discharge is inversely proportional to the threshold slope for braided flow, the channel will tend to become less braided after Phase 2 is implemented.

Channel Geometry Relationships. Numerous stable channel geometry equations have been developed from channels that have been stable for a long period of time. These equations relate the bankfull channel width, depth, and velocity to a specific discharge rate, such as bankfull discharge or average annual flow. Some of these equations were applied to the Tatum Wash study reach to assess the expected direction of channel change, if any, as summarized in Table 4-8. Bankfull and average annual discharge estimates were not readily available for the study reach. Therefore, the 2-year discharge was substituted for the average annual flood and the 10-year discharge was substituted for the channel forming discharge in the channel geometry equations.

The results shown in Table 4-8 indicate that the Tatum Wash study reach is generally wider and shallower, with a higher velocity than most streams used to develop the hydraulic geometry relationships. These results are consistent with other elements of the geomorphic analysis that indicate that Tatum Wash is a bedload-dominated, braided stream that transports a very coarse sediment primarily during infrequent events. Also, the results indicate that if future drainage improvements are proposed to narrow or confine Tatum Wash[1], a narrower regime width would be feasible, but would require that velocities be substantially reduced by artificially decreasing the slope or increasing the channel roughness. Because the Phoenix Mountain Preserve detention basin will reduce peak discharges, the data summarized in Table 4-8 indicates that Tatum Wash will tend to adjust its geometry to reflect lower flow rates (reduced width, depth, velocity).

Table 4-8. Tatum Wash Sedimentation Study Channel Geometry Relationships

Equation	2-Year (Average Annual Flood)			10-Year (Channel-Forming Discharge)		
	Width (ft)	Depth (ft)	Velocity (ft)	Width (ft)	Depth (ft)	Velocity (ft)
Lacey	49	4.3	2.1	78	5.9	2.5
Pettis	45	4.1	0.9	71	5.4	0.9
Bray	51	1.8	0.5	-	-	-
Ackers & Charlton	41	-	-	61	-	-
Smith	40	-	-	40	-	-
Average	45	3.4	1.2	63	5.7	1.7
HEC-2 Data - Existing Conditions	93	1.0	4.2	120	1.5	5.8

Notes/Data Source:
1. Lacey (MacBroom, 1981) - Canals in India
2. Pettis (MacBroom, 1981) - Miami River
3. Bray (Schuum, 1977) - Gravel-bed rivers
4. Ackers & Charlton (MacBroom, 1981) - Flume data
5. Smith (MacBroom, 1981)

Regime Equations. A number of regime equations have been developed from empirical data derived from stable rivers and canals. Some of these equations were applied to the Tatum Wash study reach to assess the expected direction of channel change, if any, as summarized in Table 4-9. As with the hydraulic geometry relationships, the 2- and 10-year discharges were used as a proxy for the average annual and channel-forming discharges.

[1] No such plans to narrow or confine Tatum Wash are part of the proposed project.

Table 4-9. Tatum Wash Sedimentation Study Regime Equations for Channel Geometry								
	2-Year (Average Annual Flood)				**10-Year (Channel-Forming Discharge)**			
Equation	**Depth (ft)**	**Vel. (ft)**	**Slope (ft/ft)**	**Width (ft)**	**Depth (ft)**	**Vel. (ft)**	**Slope (ft/ft)**	**Width (ft/ft)**
Lacey	1.0	4.6	-	-	1.4	6.3	-	-
Blench	1.6	2.8	-	72	2.2	3.3	-	116
Simons & Albertson	3.5	8.3	-	44	4.9	10.4	-	72
Schuum	1.3	-	-	51	-	-	-	-
Parker	0.6	-	0.026	15	0.8	-	0.019	22
Chang	2.4	-	0.0003	32	3.5	-	0.0002	50
Kellerhals	2.7	-	-	33	3.9	-	-	52
Average	1.9	5.2	0.01	41	2.8	6.6	0.01	62
HEC-2 Data - Existing Conditions	1.0	4.2	0.01	93	1.5	5.8	0.01	120

Notes/Data Source:
1. Lacey (MacBroom, 1981) - Canals in India
2. Blench (1969) - Gravel-bed rivers
3. Simons & Albertson (1963) - Alluvial channels
4. Schuum, (1971) - Alluvial rivers
5. Parker (1979) - Gravel-bed rivers
6. Chang (1988) - Gravel-bed rivers
7. Kellerhals (1976) - Gravel-bed rivers

Summary. The results shown in Table 4-9 indicate that the Tatum Wash study reach is wider, slightly shallower, with a lower velocity than most of streams used to develop the hydraulic geometry relationships, although the average results are very similar to the HEC-2 modeling results for existing conditions. The similarity of the results to the existing hydraulic conditions is probably due to the similarity of the data sets used to develop the regime equations (gravel-bed rivers) to Tatum Wash. The results shown in Table 4-9 are consistent with other elements of the geomorphic analysis that indicate that Tatum Wash is essentially a stable gravel-bed stream. Because the Phoenix Mountain Preserve detention basin will reduce peak discharges, the data summarized in Table 4-9 indicates that Tatum Wash will tend to adjust its geometry to reflect lower flow rates. That is, the equilibrium width, depth, and velocity will be reduce following implementation of Phase 2 of the proposed project.

Allowable Velocity. Allowable velocity data has long been used in channel design to estimate the velocity at which channel bed and bank sediments will begin to erode. A variety of allowable velocity data have been published by the Corps of Engineers (1970, 1990), the Soil Conservation Service (1977), and others (cf., BUREC, 1984). Allowable velocity data applied to the Tatum Wash study reach are summarized in Table 4-10.

Table 4-10. Tatum Wash Sedimentation Study Allowable Velocity Results				
Method	**Q2**	**Q10**	**Q50**	**Q100**
Computed Channel Hydraulics				
HEC-2 Mean Velocity (ft/sec)	4.2	5.8	7.5	8.1
HEC-2 Average Depth (ft)	1.0	1.5	1.9	2.2
Allowable Velocity Criteria				
Corps of Engineers (1970)				
D_{50} = 6.3 mm	2 ft/s	Exceeded for Q2		
Fine Gravel	6 ft/s	Exceeded for Q50		
Metamorphic Rock	20 ft/s	Not exceeded by Q100		
Corps of Engineers (1990)				
Cohesive Material (stiff)	6 ft/s	Exceeded for Q50		
Granular Material (5mm)	4 ft/s	Exceeded for Q2		
Soil Conservation Service (1977)				
Sediment Laden D_{50}=6.3mm	5 ft/s	Exceeded for Q10		
Sediment Laden D_{90}=42 mm	8 ft/s	Exceeded for Q100		
Note: In general, as depth increases the erosive velocity increases.				

The allowable velocity data summarized in Table 4-10 are intended only as a general indication of erosive velocities. Actual erosive velocities depend on a variety of hydraulic, geomorphic, and physical properties such as bed forms, cohesion of soil particles, soil moisture, air, water and soil temperature, turbulence, slope, sediment density, and sediment load. In general, the results shown in Table 4-10 agree with the channel armoring data summarized in Table 4-6. That is, the bed sediments in the Tatum Wash study reach will be eroded during moderate to large floods, but will be relatively stable during the low flow events.

Summary

The geomorphic analysis was completed to assess the existing channel stability and to predict the expected channel response to the proposed Tatum Wash Drainage Improvement Plan.

Existing Conditions. The following conclusions were reached regarding the existing channel stability:

- The existing channel within the study reach is at or near its expected natural equilibrium characteristics for slope, channel pattern, depth, velocity, and width compared to other gravel-bed streams.
- Bedrock in the channel bed, and caliche and bedrock in portions of the channel banks create a natural resistance to scour and erosion.
- The study reach has coarse bedload material, which is transported during the larger flow events.

- Coarse bed sediments provide some armoring and resistance to erosion for the most frequent flow events, but are transported during moderate to large flood events.
- The study reach watershed has not been significantly impacted by urbanization. Most of the watershed is located within the Phoenix Mountain Preserve natural area.
- Most of the channel within the study reach has not been disturbed by urbanization of the surrounding area, except for the bank stabilization located near 44th Street.
- Downstream of the study reach, the natural flow path of Tatum Wash has been eliminated by residential development that was constructed between 1965 and 1994. Elimination of the channel downstream of Shea Boulevard has resulted in local flooding, as well as in sediment deposition upstream of Shea Boulevard.

In summary, the existing channel of Tatum Wash has achieved a relatively stable dynamic equilibrium state within the study reach.

With-Project Conditions. The Tatum Wash Drainage Improvement Plan (FCDMC, 1996) consists of two primary elements: (1) Phase 1 - a sediment trap basin located immediately upstream of Shea Boulevard that will serve as an inlet for the existing storm drain, in addition to structural improvements to the storm drain, and (2) Phase 2 - a regional detention basin located on Tatum Wash immediately upstream of the Phoenix Mountain Preserve boundary.

Phase 1 - Shea Boulevard Sediment Trap Basin. Based on the geomorphic analysis, the following conclusions were reached regarding the expected channel response to the proposed Tatum Wash Drainage Improvement Plan:

- There will be no impacts on the study reach due to construction of Phase 1 of the Tatum Wash Drainage Improvement Plan, provided that the inlet to the sediment trap basin is adequately designed.
- Because the proposed sediment basin will be excavated below grade, some form of erosion protection will be required to prevent a headcut from migrating upstream from the excavated portion of the channel.
- Sediment is actively transported in Tatum Wash and will therefore be deposited in the sediment trap. Sediment removal will be required periodically.
- No evidence that the shallow bedrock observed in the channel near Onyx Drive is present at the proposed excavated sediment trap location was identified, or was indicated by the geomorphic analysis.

Phase 2 - Phoenix Mountain Preserve Detention Basin. Expected channel impacts from Phase 2 of the Tatum Wash Drainage Improvement Plan result from reduction of sediment supply to the study reach downstream of the proposed detention basin. Expected channel impacts caused by the reduced sediment supply include the following:

- Increased net long-term scour. Increased long-term scour is expected downstream of the proposed detention basin due to sediment trapping in the basin. Some long-term scour may be prevented by shallow bedrock, armoring, and reduced stream power caused by reduced flood peaks.

- Increased local scour. Local scour at structures downstream of the proposed detention basin, including scour holes downstream of at-grade crossings may increase due to sediment trapping in the basin. Local scour may be prevented by shallow bedrock in some areas, or by placing large diameter rip rap in areas of deeper alluvium.
- Reduced channel slope. The equilibrium slope downstream of the proposed detention basin will be less than the existing slope, especially in the reach closest to the detention basin outlet.
- Reduced flooding. Flood attenuation in the detention basin will result in lower discharges, lower flood water surface elevations, and a narrower floodplain along Tatum Wash, with less potential for break out flows to adjacent watersheds.
- Decreased total sediment yield.[1] Decreased total sediment yield will be due to sediment trapping in the upstream basin, increased likelihood of armoring of the channel downstream of the detention basin, and reduced flow depths and velocities (transport capacity) downstream of the detention basin.
- Decrease sediment maintenance. Sediment maintenance requirements for the Phase 1 sediment trap will decrease following implementation of Phase 2 due to the decreased sediment yield.
- Increased maintenance requirements. Maintenance requirements to control vegetation in the channel downstream of the detention basin may increase due to less erosive, longer duration flows.

In summary, implementation of Phase 1 will have minimal impacts on the geomorphology of the study reach. Implementation of Phase 2 will have more significant impacts on channel geomorphology, but should result in increased channel capacity and reduced sedimentation problems at the storm drain inlet. Some of the land used for the Phase 1 sediment trap may be recovered due to reduced sediment storage needs following construction of the Phase 2 detention basin.

[1] Net decrease in total sediment delivered to the sediment trap may include an increase in percent of fine sediment relative to the total load and a decrease in the volume of coarse sediments.

Section 5:
Sedimentation Engineering

Introduction

Sedimentation engineering tasks summarized in this Section include sediment sampling, sediment yield estimates, and reservoir trapping efficiency analyses. The objectives of these sedimentation engineering tasks were to predict the sediment volume delivered to the proposed basins at Shea Boulevard and in the Phoenix Mountain Preserve, and to estimate the volume of sediment that will be required to be removed from the basins.

Sediment Sampling

Sediment samples from the channel bed of the Tatum Wash were obtained by Law/Crandall (Law/Crandall, 1996), a geotechnical engineering firm under contract to the District. Sediment samples were collected at four sites located about 2,000 feet apart between Shea Boulevard and the Phoenix Mountain Preserve boundary. The sampling procedure and results were described in a report prepared by Law/Crandall (1996). Law/Crandall also performed particle size distribution analyses (sieve tests) on the four samples.

The four sampling sites were described as follows:

- Site #1. Site #1 was located in the bed of Tatum Wash at the Phoenix Mountain Preserve boundary. A sampling pit was excavated to a depth of about six feet. The channel bed and subsurface material consisted of primarily of loose gravel and small cobbles.

- Site #2. Site #2 was located in the bed of Tatum Wash about 30 feet upstream of Fanfol Drive. The sampling pit was excavated to the refusal depth of about three feet, at the upper surface of a well-cemented carbonate (caliche) layer. The channel bed and subsurface materials consisted primarily of gravels with some cobbles, with a moderately well-developed armor layer at the surface.

- Site #3. Site #3 was located in the bed of Tatum Wash about 50 feet upstream of Onyx Drive. The sampling pit was excavated to the refusal depth of about 30 inches, at the upper surface of an irregular conglomerate (bedrock) layer that crops out at the surface in other parts of the channel upstream and downstream of the sampling site. The channel bed and subsurface materials consisted primary of gravels and cobbles, with a slight armor layer at the surface.

- Site #4. Site #4 was located at the thalweg of Tatum Wash about 50 feet upstream of the edge of pavement of Shea Boulevard. The sampling site consisted of a sandy area in the middle of the well-vegetated floodplain. The sampling pit was excavated to a depth of about five feet. The channel bed and subsurface material consisted of sandy silt and gravel.

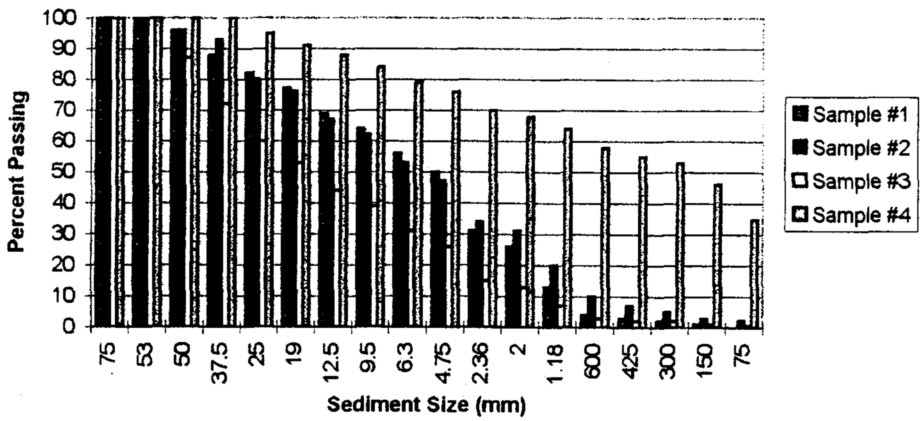
Sieve analysis results for the four sediment samples are shown in Figure 5-1. As shown in Figure 5-1, the bed sediment size distribution is not significantly different for Sites #1-3. The sediment gradation at Site #4, at Shea Boulevard is signficantly finer, due to local deposition, dense vegetation, and sediment maintenance practices.

Table 5-1. Tatum Wash Sedimentation Study Channel Sediment Gradations

Sample #	Location	d_{10}	d_{50}	d_{90}
1	PMP Boundary	1 mm	4.8 mm	40 mm
2	Fanfol Drive	0.6 mm	5.5 mm	33 mm
3	Onyx Drive	1.5 mm	17 mm	52 mm
4	Shea Boulevard	< 0.072 mm	0.2 mm	15 mm

Notes: Sediment distributions reported in Law-Crandall (1996).

Figure 5-1. Tatum Wash Sediment Sampling Results



As shown in Table 5-1 and Figure 5-1, sediment gradations reported for sampling sites #1 and #2, the sites upstream of Fanfol Drive, are almost identical. The sediment gradation report for sampling site #3 (Onyx Drive) is similar to, but slightly coarser than, the gradations for sites #1 and #2, even though sample #3 was obtained from a location further downstream. Typically, channel sediments become finer in the downstream direction. No physical reason for the bed sediment to become coarser downstream os sampling sites #1 and #2 was observed in the field or predicted from the geomorphic analysis. Therefore, it was assumed that the slightly coarser gradation for sample #3 was an anomaly, perhaps due to sampling a localized coarser lens of sediment at site #3. Field observations support the hypothesis that the bed sediments are relatively uniform over the length of the study reach.

The sediment gradation from sampling site #4 at Shea Boulevard is significantly finer than the gradations from the three sampling sites located further upstream. Field observations also support the sampling results. Finer sediment deposited in the channel upstream of Shea Boulevard reflect non-natural, low velocity sediment deposition, probably due to human impacts on the channel, as described in Section 4 of this report. Sampling site #4 is located under the footprint of the proposed Shea Boulevard sediment trap basin. Since the area at sampling site #4 is located at the downstream limit of the study reach, under the footprint of the proposed sediment trap, and because the gradations from sampling sites #1-3 are similar, a single gradation was used to represent the bed sediment size distribution for the entire study reach, for the purposes of sedimentation modeling. The single gradation for the entire study reach was selected using a "by-eye" best fit of the gradation curves from sampling sites #1, #2, and #3.

Sediment Yield

The objective of the sediment yield analysis was to estimate the average annual sediment delivered to the study reach at Shea Boulevard, as well as the sediment delivery volume for the 2-, 10-, 50-, and 100-year events. A variety of regionally-appropriate sediment yield methodologies were used to estimate the average annual sediment delivery to the study reach, and the sediment delivery volume for the 2-, 10-, 50-, and 100-year runoff events as modeled from the District's HEC-1 models.

Methodology. Sediment yield methodologies may predict the total, suspended, or bed-material sediment yield. The suspended and bed-material loads represent a portion of the total load as shown in Figure 5-2.

<table>
<tr><td rowspan="3">TOTAL LOAD</td><td>Wash Load</td><td rowspan="2">Suspended Load</td><td>Wash Load</td></tr>
<tr><td>Suspended Bed-Material Load</td><td rowspan="2">Bed-Material Load</td></tr>
<tr><td>Bed Load</td><td>Bed Load</td></tr>
</table>

Figure 5-2. Sediment Load Classification Schemes. (After SCS, 1983, Figure 4-2.)

The following sediment yield methodologies were used:

- Renard Equation
- Pacific Southwest Inter-Agency Committe Method (PSIAC)
- Dendy-Bolton Equation
- U.S. Bureau of Reclamation (BUREC) Equation
- Modified Universal Soil Loss Equation (MUSLE)
- Zeller-Fullerton Equation
- City of Phoenix Sediment Maintenance Data
- Sediment Concentration Method

Renard Equation. Renard (1972) developed an equation for predicting sediment yield from semiarid rangeland watersheds the southwestern United States. The equation, which simulates individual hydrographs and computes sediment transport for the simulated hydraulic conditions, relates average annual sediment yield to drainage area. When applied to the Tatum Wash watershed, the Renard equation predicts an average annual (total load) sediment yield of 1.1 acre-foot (AF) at Shea Boulevard.

PSIAC Method. The PSIAC procedure (ADWR, 1985) was developed for planning level analyses of sedimentation in the southwest United States. The methodology uses generalized watershed characteristics such as geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion to predict sedimentation rates. When applied to the Tatum Wash watershed, the PSIAC method predicts an average annual (total load) sediment yield of 0.9 acre-foot (AF) at Shea Boulevard.

Dendy-Bolton Equation. The Dendy and Bolton (1976) equation for average annual sediment yield is based on regression equations developed from sedimentation data from over 800 reservoirs in the United States. The equation relates drainage area and average annual runoff to sediment yield. When applied to the Tatum Wash watershed, the Dendy-Bolton equation predicts an average annual (total load) sediment yield of 0.9 acre-foot (AF) at Shea Boulevard.

BUREC Equation. The BUREC (1987) equation is based on sedimentation data from selected reservoirs in the southwestern United States, and relates drainage area to average annual sediment yield. When applied to the Tatum Wash watershed, the BUREC equation method predicts an average annual (total load) sediment yield of 3.3 acre-foot (AF) at Shea Boulevard.

MUSLE Method. MUSLE (ADWR, 1985; Weischmeier and Smith, 1978) was developed by the U.S. Soil Conservation Service to predict rates of soil erosion, and is also commonly used to predict the suspended sediment portion of sediment yield in the semiarid Southwest. MUSLE can be used to estimate sediment supplied from individual design storms, as well as for average annual sediment production. When applied to the

Tatum Wash watershed, the MUSLE method predicts an average annual (suspended load) sediment yield of 2.6 acre-foot (AF) at Shea Boulevard.

Zeller-Fullerton Equation. The Zeller-Fullerton bed-material sediment discharge equation was developed from a combination of the Meyer-Peter, Muller bedload equation and Einstein's suspended bed-material equation. The Zeller-Fullerton sediment yield estimate is based on the hydraulic characteristics of the stream, and is mostly readily applied to specific flood events. When applied to the Tatum Wash watershed, the Zeller-Fullerton equation predicts a sediment yield (bed-material load) for the average annual flood[1] of 0.1 acre-foot (AF) at Shea Boulevard.

City of Phoenix Sediment Maintenance Data. In recent years, the City of Phoenix has had to remove sediment from Shea Boulevard after flow events that exceeded the capacity of the existing storm drain inlet at Shea Boulevard. Although no systematic sediment removal data are available from the City of Phoenix, anecdotal and photographic information indicates that grain sizes up to cobble-sized particles are deposited, and that the sediment fills the roadway section at least up to the curb elevation. Assuming a six-inch curb elevation and a 90 ft. by 300 ft. deposit, a sediment yield volume of 0.3 acre-feet is likely for a typical flood event that overflows Shea Boulevard, not including material conveyed past Shea Boulevard or deposited outside the right-of-way. Unfortunately, there were no data available from which to relate the City's anecdotal sediment data to a specific flood recurrence interval. The City of Phoenix sediment maintenance data may be applied as a minimum estimate of sediment yield.

Sediment Concentration Method. Sediment yield can be estimated if flow volumes and sediment concentrations are known. Unfortunately, no direct sediment sampling data are available for Tatum Wash, and direct streamflow measurements are limited. Therefore, sediment yield estimates cannot be derived directly from gauged flow and sediment data. However, HEC-1 model output may be used to estimate flow volumes for specific recurrence intervals, and likely average and maximum sediment concentrations for Tatum Wash may be assumed from published sediment sampling data for other Arizona watercourses. HEC-1 flow volume estimates for the 2-, 10-, 50- and 100-year events were summarized in Table 2-3.

Engineering judgment must be used to estimate sediment concentration, due to the lack of measured sediment data for Tatum Wash or from small watersheds adjacent to Tatum Wash. Given the watershed characteristics,[2] it can be assumed that the potential for debris flows and hyperconcentrated sediment flows is low. Therefore, theoretical sediment concentration limits for hyperconcentrated sediment flows may be used as the maximum upper limit of sediment concentration on Tatum Wash. Costa (1984) reports that a

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[1] Specific event, not the average annual sediment yield.

[2] Such as thin soil cover, sparse vegetation, large distance from the steepest slopes in the upper watershed to the study reach, low runoff volumes, and high percentage of bedrock outcrop cover.

sediment concentrations limit of 40 percent[1] (400,000 ppm) has been proposed as the boundary between extreme (<40%) and hyperconcentrated (>40%) sediment loads. The boundary between high and extreme sediment loads is proposed at 20 percent (200,000 ppm). While direct measurements of sediment concentrations during floods on small ephemeral washes in Central Arizona are scarce, some suspended sediment measurements have been published for a few Arizona streams. Selected suspended sediment measurements are summarized in Table 5-2.

Table 5-2. Tatum Wash Sedimentation Study
Suspended Sediment Measurements for Selected Arizona Watercourses

Watercourse	Sediment Concentration (ppm)	Source of Data
Alamo Wash	945-2,300	USGS Sampling (CH2M HILL, 1995) - 10 samples
Tanque Verde Creek	1,535-1,935	USGS Sampling (Laney, 1973) - 4 samples
Rillito Creek	1,910-39,500	USGS Sampling (Laney, 1973) - 7 samples
Santa Cruz River	4,300-46,600	USGS Sampling (Laney, 1973) - 17 samples
Moenkopi Wash	31,000-131,000	USGS Sampling (USGS, 1974) - summer storm
Note: Costa & Baker (1981) report a peak suspended sediment concentration 680,000 ppm for a summer flood on Kanab Ck, UT.		

With the exception of the data from Moenkopi Wash, an ephemeral stream in Northern Arizona, the data shown in Table 5-2 were not obtained from streams at flood stage, or from floods caused by summer storms. Sediment concentrations during summer floods are typically higher than sediment concentrations during low flows or winter storms. Therefore, given the range of published suspended sediment data for some Arizona streams, it seems reasonable to assume an upper limit of 10 percent (100,000 ppm) for the sediment concentration for floods on Tatum Wash. Sediment concentrations as much as 20 percent may be possible, based on theoretical information published in the literature, and were analyzed for comparative purposes.

Using the assumed sediment concentration, the sediment yield for specific flood events or average annual conditions can be estimated directly as a percentage of the computed HEC-1 water volume. The sediment yields estimated from this method probably represent the maximum, or upper threshold, of sediment yield from the watershed. For Tatum Wash at Shea Boulevard, the average annual sediment yield estimated from sediment concentration assumptions ranges from 2.8 (10%) to 5.6 AF (20%), depending on the assumed average sediment concentration.

HEC-6 Modeling. Sediment yield estimates for specific flood events can be obtained from HEC-6 modeling results, described in more detail in Section 6 of this report. HEC-6 sediment yield was determined using the "Sediment Transported Through Section" field of the output files, for the cross section located at Shea Boulevard. Two sediment transport functions were used in the HEC-6 modeling, the Ackers-White equation and the Toffaleti-

[1] Sediment volume as percent of water volume.

Meyer Peter Muller equation. Sediment yield estimates based on each transport function are reported for Tatum Wash. Note that the HEC-6 models were developed primarily to predict movement of the bed-material load, rather than the total load. Therefore, HEC-6 results probably underestimate the actual sediment yield. Sediment yield estimates for the 2-, 10-, 50-, and 100-year events were obtained from the HEC-6 results.

Results. The sediment yield methodologies used for Tatum Wash predict a range of estimates for average annual sediment yield and sediment loads for specific flood events. The Renard, PSIAC, Dendy-Bolton, and BUREC methodologies were primarily used to predict the total average annual sediment yield. The MUSLE methodology was used to predict the suspended material portion of the average annual sediment yield, as well as suspended material loads for specific events. The Zeller-Fullerton, sediment concentration, and HEC-6 methodologies were primarily used to generate sediment load estimates for the 2-, 10-, 50-, and 100-year events. The results of the sediment yield estimates are summarized in Tables 5-3, 5-4, and 5-5.

Table 5-3. Tatum Wash Sedimentation Study
Average Annual Sediment Yield Results

Methodology	Average Annual Yield (AF/year)		Notes/Reference
	CP1F (Phoenix Mtn. Park)	CP2E (Shea Blvd.)	
Renard	1.0	1.1	Renard & Stone, 1982
PSIAC	0.8	0.9	ADWR, 1985
Dendy-Bolton	0.8	0.9	Dendy & Bolton, 1976
BUREC	3.0	3.3	BUREC, 1987
MUSLE	2.3	2.6	Suspended Load; ADWR, 1985
Concentration	2.5-5.0	2.8-5.6	Represents probable maximum load
Average	1.9	2.1	

Note: Average computed by the mean of estimates, without considering the high and low estimate.

Table 5-4. Tatum Wash Sedimentation Study
Sediment Load @ Shea Boulevard for Specific Flood Events

Event	Method			
	MUSLE Suspended Load (AF)	Zeller-Fullerton Total Bed-Material Load (AF)	Sediment Concentration Method (AF)	
			10%	20%
2-Year	2.0	0.1	4.2	8.4
10-Year	5.0	0.2	8.9	17.8
50-Year	10.4	0.4	15.6	31.2
100-Year	13.3	0.5	18.9	37.8
Average Annual	2.6	0.1	2.8	5.6

Table 5-5. Tatum Wash Sedimentation Study Sediment Load at Shea Boulevard for Specific Flood Events - HEC-6 Model Results		
Event	**Transport Function**	
	Ackers-White (AF)	**Toffaleti Meyer-Peter Muller (AF)**
2-Year	0.02	0.05
10-Year	0.06	0.15
50-Year	0.11	0.30
100-Year	0.14	0.40

Of the sediment yield methodologies described above only the Zeller-Fullerton and HEC-6 methods may be used to predict sediment yield downstream of the on-line detention basin to be constructed in Phase 2 of the project, since they are based on channel hydraulics. The Zeller-Fullerton method indicates that the sediment yield based on hydraulic conditions after construction of the Phase 2 Phoenix Mountain Preserve detention basin will be nearly identical to the existing conditions yield. That is, the affect on sediment transport caused by the reduction in discharge rates is compensated by the increase in flow duration due to upstream detention. The HEC-6 modeling indicates that a 32 to 50 percent reduction in the 100-year sediment yield[1] at the Shea Boulevard sediment trap basin will occur following construction of the Phase 2 Phoenix Mountain Preserve detention basin. The reduction is sediment yield after construction of the Phase 2 basin is due in part to reduced flow velocities, depths, and discharges resulting from upstream detention, as well as to sediment trapping within the Phoenix Mountain Preserve basin. With-project HEC-6 sediment trapping estimates are discussed in the Reservoir Trapping Efficiency Section below.

After initial review of sediment yield estimates, the District requested that sediment yield estimates for other detention basins on streams similar to Tatum Wash be provided for comparison. This information is provided in Table 5-6. Because the estimates shown in Table 5-6 are based on the same methodologies used for the Tatum Wash sediment yield analysis, they may not provide an objective standard for evaluating the Tatum Wash results. Of the sediment yield methodologies described in Tables 5-3 to 5-5, only the BUREC and Dendy-Bolton methods are derived strictly from actual reservoir sedimentation data, although even reservoir sedimentation data may not provide an objective comparison if the watershed characteristics from the reservoir data set are not similar to the Tatum Wash watershed characteristics. Therefore, engineering judgment is required in evaluating and selecting the design values of sediment yield.

[1] 32% reduction in 100-year yield based on Toffaleti Meyer-Peter Muller transport function. 50% reduction in 100-year yield based on the Ackers-White transport function. Reduction for 2-year event is 19-41%, respectively.

Table 5-6. Tatum Wash Sedimentation Study Sediment Yield Estimates for Detention Basins in Similar Watersheds	
Basin /Project Name	**Average Annual Sediment Yield Estimate**
Casandro Wash Detention Basin	0.3 AF/yr/mi^2
Rawhide Wash Detention Basin	0.3 AF/yr/mi^2
Rillito Creek Recharge Dam	0.1 AF/yr/mi^2
Bunkerville Detention Basin	0.9 AF/yr/mi^2
Town Wash Detention Basin	0.9 AF/yr/mi^2

Summary. Experience on small mountain watersheds in Central and Southern Arizona indicates that standard sediment yield methods often underestimate the potential sediment load that can be delivered during floods. Many small dams, detention basins, and other flood control structures have experienced excessive sediment deposition that was not adequately accounted for by the standard sediment yield methodologies. The discrepancy between predicted and actual yield is demonstrated by comparing the sediment yield estimates shown in Table 5-3 and 5-4, with the measured sediment concentrations shown in Table 5-2 and the yield estimates based on sediment concentration shown in Table 5-4. Therefore, to be conservative and to reflect local experience, the recommended estimate for Tatum Wash is based primarily on sediment yield estimated from an assumed sediment concentration of 10 percent (100,000 ppm), as shown in Table 5-7.

Table 5-7. Tatum Wash Sedimentation Study Recommended Estimates of Sediment Yield		
Event	**@ PMP Basin**	**@ Shea Blvd.**
2-Year	4 AF	4 AF
10-Year	8 AF	9 AF
50-Year	14 AF	16 AF
100-Year	17 AF	19 AF
Average Annual	3 AF	3 AF

It is noted that the recommended estimate of the average annual sediment yield of 3 acre-feet per year for Tatum Wash is similar to the BUREC method yield estimate, which is based on reservoir sedimentation measurements from small watersheds in the Western United States. The recommended sediment yield estimates are also very similar to the MUSLE suspended load yield estimates. Finally, it is important to note that while the estimates shown in Table 5-7 are recommended as the basis of engineering design, both larger and smaller yields of sediment are possible, given the range of sediment concentrations measured on Arizona streams. The maximum reasonable upper limit of sediment yield to the Shea Boulevard basin was estimated at about 6 acre-feet per year, and 38 acre-feet for the 100-year event, based on a 20 percent sediment concentration throughout the entire flood hydrograph.

Reservoir Trapping Efficiency

Reservoir trapping efficiency is defined as the ratio of the quantity of deposited sediment to the total sediment inflow. That is, the percentage of the total sediment load entering the reservoir that does not pass through the outlet is the trap efficiency percentage. The trapping efficiency is primarily dependent upon the sediment particle fall velocity and on the rate of flow through the reservoir. Particle fall velocity is influenced by the size and shape of the inflowing sediment particles, the viscosity of the ponded water and the chemical composition of the water. Large sediment particles typically have higher fall velocities; very fine sediments have lower fall velocities. The rate of flow through the reservoir is determined by the rate of inflow with respect to the available storage and by the rate of outflow. Reservoir trapping efficiency increases with high storage volume, low outflow rates (small outlet), high average fall velocity (large diameter sediment), and long drain times.

The District's recommended flood control improvement plan for Tatum Wash calls for two basins that will trap some percentage of the inflowing sediment yield: (1) a sediment trap basin located upstream of Shea Boulevard (Phase 1), and (2) an on-line detention basin upstream of the Phoenix Mountain Preserve boundary (Phase 2). The preliminary conceptual design specifications for the Phase 1 sediment trap basin and the Phase 2 detention basin (FCDMC, 1996) are shown in Table 5-8.

Table 5-8. Tatum Wash Sedimentation Study
Characteristics of Proposed Tatum Wash Drainage Improvement Project Basins

Characteristic	Shea Blvd. Sedimentation Basin	Phoenix Mtn. Preserve Regional Detention Basin
Total Volume	35 AF	135 AF
Outlet Structure	66"	no info.
Maximum Outflow Rate[1]	375	621 cfs
Surface Area	4.4 ac	no info.
Maximum Depth	18 ft.	no info.

[1]Rate reported by District. HEC-1 models summarized below indicates slightly different rates.

Methodology. Reservoir trapping efficiency for the two proposed basins was estimated using the Churchill and Brune methods (BUREC, 1987), and using HEC-6 modeling results. The Churchill method is based on measured sedimentation data from Tennessee Valley Authority reservoirs and the ratio of the period of retention to the mean velocity through the reservoir. The Churchill method is best applied for settling basins, small reservoirs, and detention basins (BUREC, 1987), and therefore may be most applicable to the proposed Tatum Wash basins. However, since it was derived using data from perennial streams in the Eastern United States, which typically transport a higher relative percentage of fine sediments, the Churchill method will tend to underestimate the trapping efficiency for Tatum Wash.

The Brune method is essentially an envelop curve derived from measured sedimentation data from large reservoirs. Because the ponding time, average velocity, and storage volume of large reservoirs are significantly larger than the proposed basins, the Brune method tends to overestimate the trapping efficiency for the proposed Tatum Wash basins.

HEC-6 computes the volume of sediment passing each cross section. By coding the assumed basin geometry as cross sections in the HEC-6 input file, the sediment volume estimates for each cross section could be used to compute the volume of sediment entering and leaving the proposed Tatum Wash basins. Because HEC-6 does not have the capability to route a hydrograph through a reservoir, reservoir ponding was simulated by specifying an outflow elevation equal to the assumed spillway elevation to create a backwater condition that would induce sediment deposition. HEC-6 estimates based on both the Ackers-White and the Toffaleti/ Meyer-Peter Muller transport functions were prepared.

Results. Reservoir trapping efficiency estimates for the proposed Tatum Wash basins are summarized in Table 5-9. Because trapping efficiency is partially a function of the inflowing sediment load, the HEC-6 estimates of trapping efficiency for the Shea Boulevard sediment trap decreased slightly in response to modeling the Phoenix Mountain Preserve detention basin upstream. The Churchill and Brune methods do not consider sediment inflow explicitly, and therefore do not vary significantly in response construction of the upstream basin. Another difference between the results shown in Table 5-9 is that the HEC-6 transport functions used primarily simulate movement of the bed-material load, whereas the Brune and Churchill methods predict trapping of the total sediment load. Therefore, a higher trapping efficiency is computed for the coarser bed-material load.

Table 5-9. Tatum Wash Sedimentation Study
Reservoir Trapping Efficiency Results

Project Phase	Churchill Method	Brune Method	HEC-6 Acker-White		HEC-6 Toffaleti-MPM	
			Q100	Q2	Q100	Q2
Phase 1						
Shea Basin	25	97	65	78	87	94
Phase 2						
Shea Basin	25	97	93	100	98	100
PMP Basin	41	97	100	100	100	100

Notes: 1. Churchill method based on small reservoirs and detention basins
2. Brune method intended for large reservoirs

Based on the information shown in Table 5-9, it may be assumed that about 80 percent of the inflowing sediment load will be trapped in the Phase 1 Shea Boulevard sediment trap. A higher percentage of the inflowing sediment load of the more frequent floods (e.g., the two-year event) will be trapped compared to the less frequent floods (e.g., the 100-year event). Following construction of the Phase 2 Phoenix Mountain Preserve detention basin, the Shea Boulevard sediment basin will trap a higher percentage of the inflowing sediment load, and may approach 100 percent trap efficiency, according to the HEC-6 modeling.

The Phase 2 Phoenix Mountain Preserve detention basin will probably trap the entire inflowing bed-material load. The discrepancy between the Churchill method and HEC-6 method results (Table 5-9) may be interpreted as the difference between trapping of the suspended /wash load and the bed-material load. The suspended/wash load is more likely to exit the basin. Given that the Phoenix Mountain Preserve detention basin has a higher reservoir trapping efficiency than the Shea Boulevard sediment basin, even if the estimated trapping efficiency of the Phoenix Mountain Preserve basin is overestimated, it may be assumed that whatever suspended or wash load leaves the Phoenix Mountain Preserve basin will also pass through the smaller, less efficient Shea Boulevard sediment trap basin.

Sediment yield estimates may be combined with trapping efficiency estimates to obtain the required sediment storage volumes recommended for design of the proposed basins, as shown in Table 5-10. The recommended estimates in Table 5-10 are based on the following trap efficiency estimates: (1) 80 percent for the Phase 1 Shea Boulevard sediment trap, (2) 98 percent for the Shea Boulevard sediment trap after construction of the Phase 2 Phoenix Mountain Preserve detention basin, and (3) 100 percent for the Phoenix Mountain Preserve detention basin. Estimates for the Phoenix Mountain Preserve detention basin reflect the smaller drainage area, total flow volume, and smaller sediment yield at the Phoenix Mountain Preserve boundary.

Table 5-10. Tatum Wash Sedimentation Study
Recommended Sediment Design Volumes

Event	Phase 1: Shea Blvd. Basin	Phase 2: Shea Blvd. Basin	Phase 2: Phoenix Mountain Preserve Basin
2-Year	3 AF	2 AF	4 AF
10-Year	7 AF	5 AF	8 AF
50-Year	13 AF	10 AF	14 AF
100-Year	15 AF	11 AF	17 AF
Average Annual	2 AF/yr.	2 AF/yr.	3 AF/yr.

Notes:
1. Estimate for Phase 1 -Shea : recommended yield x 80% trapping efficiency
2. Estimate for Phase 2 -Shea: recommended yield x 40% reduction x 98% trapping efficiency
3. Estimate for Phase 2- PMP: recommended yield x 100% trapping efficiency

Summary

Sediment yield was estimated using a variety of methodologies developed for the semiarid Southwest. Average annual sediment yield at Shea Boulevard was estimated at about 3 acre feet per year. The 100-year sediment yield at Shea Boulevard was estimated at about 19 AF. Implementation of Phase 2 of the project will decrease the sediment load at the Phoenix Mountain Preserve boundary, although the much of resulting sediment deficit will be satisfied by eroding the channel bed and banks before flow reaches the Shea Boulevard sediment trap basin. The decreased sediment load downstream of the Phoenix Mountain Preserve basin will tend to increase scour within the study reach, except in the reaches with shallow bedrock or channel armoring by the coarse bed material.

The recommended sediment yield rates summarized in Tables 5-10 indicate that the proposed Shea Boulevard sediment trap basin has more than adequate capacity to store the estimated 100-year sediment load of 19 AF, even if the entire 100-year sediment yield were deposited in the sediment trap. The average annual sediment yield estimate of about 2 AF per year may be used to estimate sediment maintenance requirements for the proposed Shea Boulevard sediment trap basin. For example, if the entire sediment trap basin volume is available for sediment storage, then sediment maintenance must be performed about every 11 years, on average, assuming no events larger than the 2-year flood occur. If only 19 acre-feet of the total 35 acre-feet below the sediment trap basin outlet elevation are available for sediment storage, sediment maintenance would be required every six years, on average. Sediment maintenance implications of the sedimentation engineering analysis are discussed in more detail in Section 7 of this report.

Section 6:
HEC-6 Sediment Continuity Analysis

Introduction

This section summarizes the results of HEC-6 modeling for the Tatum Wash sedimentation study. The objective of the HEC-6 modeling for Tatum Wash was to evaluate sediment continuity relationships in the existing channel and proposed drainage improvements. Specifically, the HEC-6 modeling results will be used to complete the following analysis tasks:

- Identify channel reaches of probable excess sediment deposition or scour.
- Identify trends of sedimentation that vary with recurrence interval.
- Evaluate the sedimentation impacts for the proposed Tatum Wash Drainage Improvement Plan.
- Estimate the bedload sediment delivery at Shea Boulevard.
- Estimate a stable slope for each identified channel reach.
- Estimate scour depths downstream of at-grade dip crossings
- Evaluate the impact on channel velocity and sedimentation rates of increased vegetative growth(or not maintained) in the channel.

The HEC-6 models for Tatum Wash were based on the following information provided in part by others, as described in previous submittals for the Tatum Wash Sedimentation Study:

- HEC-1 Models. Existing conditions HEC-1 models were originally prepared by the District and modified for "with-project" conditions by JEF. Hydrographs from the HEC-1 models were discretized and input as a series of finite steady flows.

- HEC-2 Models. The channel and reach geometry data, roughness coefficients, and energy loss coefficients from the HEC-2 models originally developed by the District and modified by JEF for this project were used as the basis of the HEC-6 hydraulic model of Tatum Wash.

- Sediment Data. Sediment sieve data prepared by Law/Crandall (1996) were used to estimate sediment gradation data for Tatum Wash.

- Drainage Improvement Plans. Conceptual design plans described in the Tatum Wash Drainage Improvement Project Feasibility Study/ Planning Summary Report (FCDMC, 1996b) were used as the basis of "with-project" modeling.

HEC-6: Scour & Deposition in Rivers and Reservoirs Computer Model

Overview. HEC-6 was designed to simulate long-term trends of scour and/or deposition in a stream channel that result from changing the natural hydrology, channel geometry, or sediment supply. The U.S. Army Corps of Engineers describes the HEC-6 computer program as follows:

> *HEC-6 is a one-dimensional movable boundary open channel flow numerical model designed to simulate and predict changes in river profiles resulting from scour and deposition over moderate time periods. Continuous flow records may be partitioned into a series of steady flows of variable discharge and duration. For each flow, a water surface profile is calculated providing hydraulic data at each cross section. These hydraulic data, combined with the discharge and flow duration information, allow volumetric accounting of sediment within stream reaches. The amount of scour or deposition at each section may then be computed and the cross section bed elevation adjusted accordingly. Hydraulic data associated with the next discharge are then computed using the updated geometry, and the channel geometry is again updated. This process is repeated through the entire duration of flows. (paraphrased, p. 1, USACOE, 1993)*

HEC-6 Model Assumptions and Limitations. The HEC-6 computer model is based on the following explicit or implied assumptions:

- One Dimensional. Flow in the stream is one dimensional, i.e., the model does not account for secondary currents from meandering, eddying, or turbulence that cannot be addressed through the use of energy loss coefficients. Gradually-varied flow conditions usually are modeled adequately using a one-dimensional model (p. 5, USACOE, 1993).

- Steady Discharge. The HEC-6 model simulates passage of a flood or annual hydrograph (unsteady flow) as a series of discrete steady flows of known duration. HEC-6 is best suited to simulating channel changes from hydrographs that rise and fall gradually over a relatively long duration (p. 7, USACOE, 1993).

- Uniform Scour or Deposition. Any change in bed elevation resulting from scour or deposition is applied uniformly across the entire moveable portion of channel. That is, a uniform depth of sediment is added to, or subtracted from, each station (GR) point used to describe the geometry of the active channel. The formation of point or lateral bars, bend scour holes, and local scour are not simulated (p. 17, USACOE, 1993).

- Sediment Continuity. HEC-6 computes changes in bed elevation based on the principal of conservation of sediment volume -

  $\text{Sediment}_{(in)} - \text{Sediment}_{(out)} = \text{Change in Sediment Volume}$

  $\text{Change in Bed Elevation} = \text{Change in Sediment Volume} \div \text{Reach Length}$

- Initial Conditions. The initial concentration of suspended bed material is assumed to be negligible. That is, all bed material is contained in the sediment reservoir at the start of the computational interval and is returned to the sediment reservoir at the end of the interval (p. 16, USACOE, 1993)

- Time Scale. HEC-6 was developed "to predict changes in river profiles from scour and/or deposition over moderate time periods (typically years, although applications to single flood events are possible)." HEC-6 performs best for gradually changing hydraulic conditions, e.g. for large rivers with slow rising and falling hydrographs (p. 5, USACOE, 1993).

- Sediment Sources. The model assumes that there are only two sediment sources - inflowing water and the movable portion of the stream bed. HEC-6 does not consider lateral channel (bank) erosion - no sediment is supplied from the banks (p. 17, USACOE, 1993).

- Sediment Calculations. A number of transport functions are coded into HEC-6, all of which apply the transport function by grain size (p. 41, USACOE, 1993).

- Equilibrium. The HEC-6 sediment transport function algorithms assume that sediment equilibrium conditions are reached during each time step of a single event, a condition which probably is not met for very short events. If equilibrium conditions are probably not established, then the modeling results should be interpreted in a qualitative manner (p. 5, USACOE, 1993).

- Time Step. Reach hydraulics and sediment transport potential are based on the channel geometry at the beginning of the time step. Therefore, the time step must be short enough that the computed change in bed elevation during a time step does not result in significant change in channel and reach geometry. Generally, a change in bed elevation of 1 foot, or 10 percent, of the flow depth is considered significant. In addition, the time step must be long enough that the flow would have sufficient time to travel through the longest stream segment[1] (p. 58, USACOE, 1993).

Table 6-1 lists these assumptions and indicates which assumptions may or may not be applicable to the Tatum Wash study reach. Given the assumptions and conditions that are not (or are marginally) valid for Tatum Wash, the HEC-6 modeling results are best suited to predicting relative trends of expected changes in the channel profiles, rather calculating precise depths of channel scour and deposition at specific cross sections.

[1] Stream segment as defined for HEC-6 is a reach with uniform discharge, no tributaries, or special conditions.

Table 6-1. Tatum Wash Sedimentation Study HEC-6 Modeling Assumptions and Limitations	
Assumption/Limitation	**Assumption Valid for Tatum Wash?**
One Dimensional	Yes/No. Probably Gradually Varied
Uniform Scour or Deposition	No. Braided System with Bars
No Bank Erosion	Yes. Banks Generally Stable
Steady Flow Condition Modeled	No. Flash Flood Hydrograph
Sediment Continuity	Yes.
Initial Conditions for Suspended Sediment	Yes. Ephemeral Stream
Time Scale of Hydrograph	No. Flash Flood Conditions
Sediment Sources	Yes. Bed is Primary Source of Sediment
Sediment Calculations	Yes. Ackers-White Equation Used
Equilibrium Achieved in Time Step	No. Short (6 hr.) Duration Hydrograph
Time Step Length Adequate	Yes. Scour Limited in Time Steps Yes. Adequate Travel Time

Tatum Wash HEC-6 Modeling

HEC-6 models were prepared to simulate channel response along the Tatum Wash study reach for existing and "with-project" conditions for the 2-, 10-, 50-, and 100-year events.

Input Data. The following assumptions and conditions were used to prepare the HEC-6 models of Tatum Wash:

- Channel Geometry. GR data, channel lengths, and other geometric data were obtained from the District's HEC-2 model for Tatum Wash described in previous submittals. For the HEC-6 model, some channel bank stations and GR data were modified slightly to better simulate effective flow boundaries and to account for local changes in Manning's roughness values.

- Mobile Boundary Limits. The limits of the moveable portion of the channel bed were estimated from detailed site topography, aerial photographs, and field notes. Mobile boundary limits were refined based on preliminary HEC-6 modeling results.

- Hydrographs. HEC-1 hydrographs for the 100-, 50-, 10-, and 2-year event were discretized and entered into the model. The discretized hydrographs were balanced to within one percent of the HEC-1 runoff volume, and within 20 percent of the peak discharge, while maintaining the shape of the inflow hydrographs. The HEC-1 models indicate that there is a only a relatively small increase in peak discharge and runoff volume over the length of the study reach, and very little attenuation of the inflow hydrograph. Therefore, a single hydrograph was used for the entire study reach.

- Time Step. Time steps for the discretized hydrographs were selected so that the time step was longer than the travel time through the stream segment, and short enough to represent the hydrograph of the modeled event.

- Water Temperature. Water temperature was estimated based on the results of published USGS water quality sampling data from Rillito Creek near Tucson, and from average air temperatures during the monsoon season at the Paradise Valley, Arizona weather station.

- Downstream Rating Curve. The starting water surface elevation rating curve was based on the HEC-2 output (normal depth) for cross section #7633 for the existing conditions run. For the "with-project" Phase 1 and Phase 2 HEC-6 models, the sediment trap outflow rating curve from the HEC-1 routing was used to estimate the downstream starting water surface elevation at Shea Boulevard for each segment of the discretized hydrograph.

- Sediment Data. Sieve results from the Law-Crandall sediment sampling tests were used to estimate the bed sediment distribution. As discussed in Section 4 of this report, the measured gradations for sampling sites #1 to #3 were similar. The sediment gradation from sampling site #4 was not used in the HEC-6 because it was obtained from the area under the footprint of the proposed sediment trap, and because is was taken from a site located at the extreme downstream end of the study reach. Furthermore, given the small watershed size and relatively short length of the study reach, a systematic change in sediment distribution is not likely. Finally, the variation in gradation between sampling sites #1 and #2 and site #3 indicated a slight coarsening downstream, opposite of the expected trend.

  Therefore, a single average sediment distribution (by-eye fit) was used for the entire study reach. All sediments finer than the #200 grid were classified as coarse silts (no clays). Lacking better sediment data, it was assumed that the sediment distribution did not change with discharge.

- Sediment Inflow Rating Curve. The sediment vs. discharge inflow rating curve was based on reach-averaged hydraulic data and the Zeller-Fullerton sediment transport equation used for the sediment yield analysis. Lacking better sediment data, it was assumed that the sediment distribution did not change with discharge.

  Sensitivity tests on the inflow rating curve indicated that the HEC-6 model results downstream of the Phoenix Mountain Preserve boundary were not sensitive to this parameter, probably due to the extended reach length between the furthest upstream cross section (#16) and the study reach boundary (Section #6). A HEC-6 model with zero sediment inflow was prepared to test the sensitivity to the sediment inflow distribution tested. The zero sediment inflow model indicated no change in estimated scour depths downstream of the Phoenix Mountain Preserve boundary compared to the model with the Zeller-Fullerton inflow rating curve.

- Supply Reach. A sediment supply reach was included in the HEC-6 input file to allow the model to self-adjust the sediment continuity relationships upstream of the study reach, and to reduce the model's dependence on the input parameters selected. The supply reach extended approximately 2,000 feet upstream of the Phoenix Mountain Preserve boundary, and included 10 cross sections.

- Sediment Transport Function. HEC-6 models were prepared using the Ackers-White equation and the Toffaleti Meyer-Peter Muller equation. The rationale for selecting these transport functions is described in more detail below. Sensitivity tests using all of the other standard HEC-6 transport functions were conducted for the 100-year event. The Ackers-White equation was found to be most effective at transporting the coarse-grained sediment. The Toffaleti Meyer-Peter Muller equation was found to transport the largest sediment volume. The net scour and relative trends of channel profile change were not significantly different for any of the transport functions tested.

- Depth to Bedrock. In general, depth to bedrock information was not entered into the Tatum Wash HEC-6 model for several reasons. First, while field evidence suggests that shallow bedrock is present or crops out in all or parts of the channel bed of the study reach between Onyx Drive and Fanfol Drive, HEC-6 modeling results indicate that computed scour depths are generally less than 0.4 feet at most cross sections. Therefore, depth to bedrock would be irrelevant to the computed results. Second, field evidence collected during the sediment sampling tasks indicates that the bedrock layer is very irregular and discontinuous. Selection of a uniform depth of bedrock would be difficult with detailed subsurface exploration or geophysical data[1]. Finally, a zero depth of scour was specified at the four road crossings to simulate the lack of scour over the paved road surfaces or concrete culvert inverts.

- 40th Street Box Culvert. HEC-6 does not perform special bridge or special culvert computations. Therefore, water surface elevations at the 40th Street culvert were estimated using HY-8, and were entered as known water surface elevations using a combination of X5 and R Records in the HEC-6 model.

- Phase 1 Sediment Trap Geometry. The volume, stage, and outflow characteristics of the proposed sediment trap at Shea Boulevard were derived from information and conceptual design drawings prepared by the District (FCDMC, 1996b), as summarized in Tables 2-2 and 5-8. Cross sections #7693, 7533, and 7338 from the existing conditions model were replaced by cross sections that represented the geometry of the proposed sediment basin. The proposed sediment trap basin was assumed to have the

[1] That is, to account for the variable depth to bedrock, an average depth to bedrock of 0.5 to 1.0 ft. would have been used; a depth that would be greater than the net depth of scour during any time increment of the hydrographs analyzed for Tatum Wash.

following design parameters: (1) minimum bottom slope of 0.5 percent, (2) side slopes of 4:1, (3) erosion protection to prevent scour at the inlet, (4) a setback of 20 feet from all property boundaries, and (5) all geometric data as provided in the District's Feasibility Study (FCDMC, 1996b).

- Phase 1 Hydrograph. The proposed sediment trap basin is located at the downstream end of the Tatum Wash study reach, and would have no impact the upstream sediment supply. Therefore, the existing conditions hydrographs were used for the HEC-6 sediment modeling of Phase 1 of the proposed project.

- Phase 2 Detention Basin Geometry. The volume, stage, and outflow characteristics of the detention basin upstream of the Phoenix Mountain Preserve boundary were inferred from information presented in District's Feasibility Study (FCDMC, 1996b). Cross sections #6 through 10 from the existing conditions model were replaced by cross sections that represented the geometry of the proposed detention basin. The proposed detention basin was assumed to have the following design parameters: (1) minimum bottom slope of 0.5 percent, (2) side slopes of 4:1, (3) erosion protection to prevent scour at the inlet, (4) a setback of 20 feet from all property boundaries, and (5) all other data as provided in the District's Feasibility Study (FCDMC, 1996b).

- Phase 2 Detention Basin Hydrographs. HEC-6 does not have the capability to attenuate flow hydrographs to account for detention, or to model different hydrographs for a single stream segment. Therefore, the outflow hydrographs from the proposed Phase 2 detention basin, as estimated from the HEC-1 models, were used as the hydrographs for the "with-project" HEC-6 modeling.

  Use of the Phase 2 detention basin outflow hydrographs is justified for the entire Phase 2 HEC-6 model for two reasons. First, the detention basin outflow represents the flow hydrograph for the portion of the study reach that is of greatest concern, and also represents the sediment supply reach for the Shea Boulevard sediment trap. Second, the HEC-6 modeling indicates 100 reservoir trapping efficiency for the Phase 2 detention basin. Therefore, the upstream sediment supply would not impact the sedimentation rates in the study reach downstream of the detention basin.

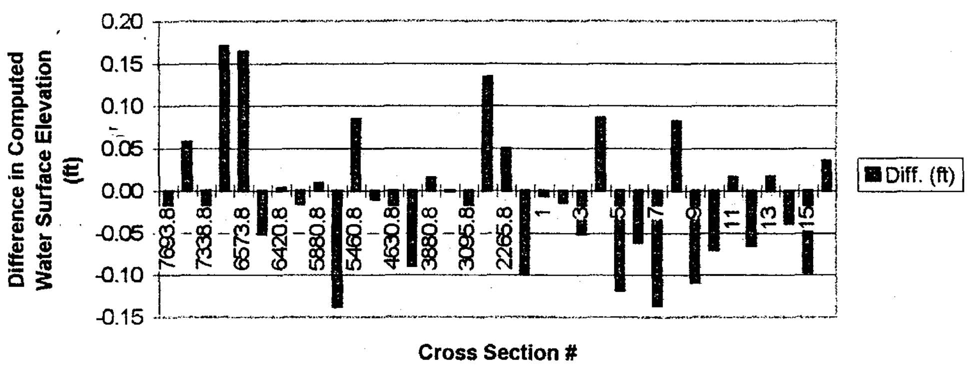
HEC-6 Model Sensitivity Tests and Calibration. Several tests of the sensitivity of the Tatum Wash HEC-6 modeling parameters were conducted.

- Data Editing and Modeling Parameter Refinement. Basic data checks and preliminary model tests were made on the HEC-6 input files, including the following:
  1. Basic geometric, hydrologic, and sediment data were checked by specifying increase levels of output on *, T1, and T4 records, and were corrected as needed.
  2. Mobile boundary limits were tested to assure gradually varied boundary conditions between sections.

3. Effective flow boundaries were added at points of rapid flow expansions and contractions.
4. Preliminary HEC-6 runs were made with I1.2 = 0 (SPI, number of Exner computation exchange increments). The models defaulted to SPI=50 at most cross sections. Therefore, I1.2 was set to 50 for the final modeling runs.
5. A constant discharge model (HI_Q.DAT) was tested using variable time steps ranging from 0.05 days to 500 days. There was no indication that the sediment volume of the active layer would limit scour calculations. The high discharge model was used, rather than testing all of the increments of every hydrograph, since the highest discharge would presumably yield the greatest scour depths and the most extreme channel conditions.
6. No streamflow or sediment gauging data from which to construct hydraulic rating curves for calibration were available.
7. The non-uniform deposition option in HEC-6 was not used, since it is available only for deposition, not scour.
8. The duration of each time step used was checked to assure that it was long enough to permit the flow to pass through the longest reach during the time step.
9. Both hydraulic parameter weighting parameter schemes were tested, no significant differences were found between them. The most stable routine (scheme #1) was selected for final modeling runs.
10. Output was checked for oscillations in computed bed elevations - none were found.

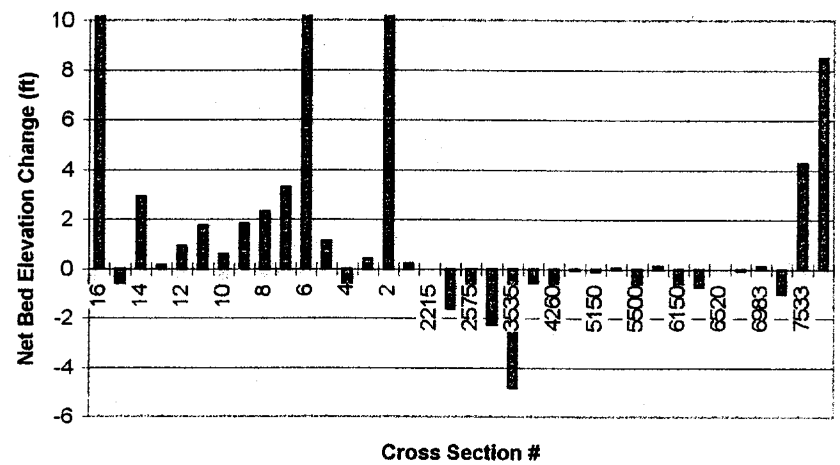
- Fixed-Bed Option. After initial debugging to address error messages and other warnings, the model was run with the sediment transport option suppressed. This run was used to compare the channel hydraulics determined by HEC-6 with the channel hydraulics computed by HEC-2. The models compared favorably, generally within 0.1 foot, as shown on Figure 6-1 and in the computation sheets provided in the Appendix.

Figure 6-1. Comparison of Fixed-Bed HEC-6 Results With HEC-2 Results (Q100)



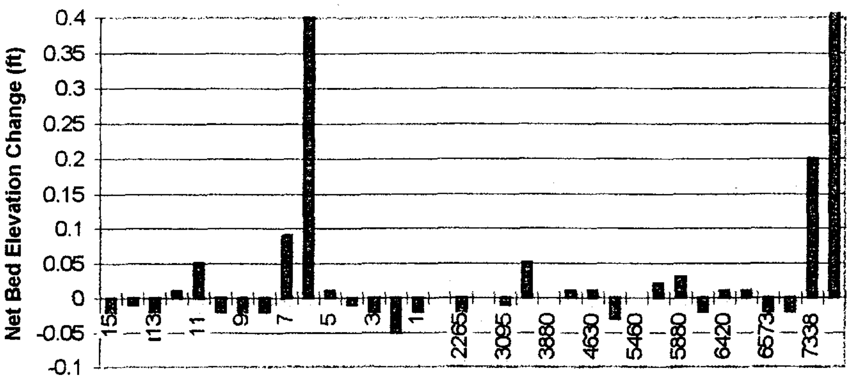
- Continuous Flow Model. Two long duration, constant discharge HEC-6 models were prepared to identify potential long-term channel changes, to test the model stability, and to identify the expected direction of scour or fill at key cross sections. The two models consisted of a 50-day duration high flow model using the 100-year peak discharge of 2,300 cfs, and a 50-day duration low flow model using a discharge of 10 cfs. The results of the high-flow model are illustrated in Figure 6-2. The high flow calibration model indicates that the reach downstream of 40th Street is subject to slight net long-term scour. Net aggradation occurs at several locations: (1) in the sediment supply reach, (2) upstream of the 40th Street culvert obstruction, and (3) at Shea Boulevard. The most significant areas of net scour occur downstream of 40th Street and near cross section #3535 (Fanfol Drive). In general, the high flow model indicates that most of the study reach is close to equilibrium, even for extreme discharge conditions.

Figure 6-2. Constant High Flow HEC-6 Calibration Model



The results of the 50-day continuous low flow HEC-6 calibration model are illustrated in Figure 6-3. The results of the low flow model indicate that very little net bed elevation change will occur at low discharge, regardless of the flow duration. Reaches of net long-term aggradation occur at the Phoenix Mountain Preserve boundary and at Shea Boulevard. In general, the magnitude of the predicted net bed elevation changes are less than ½ foot for a long duration low flow, supporting the conclusion of the geomorphic analysis that Tatum Wash is close to an equilibrium condition.

Figure 6-3. Constant Low Flow HEC-6 Calibration Model



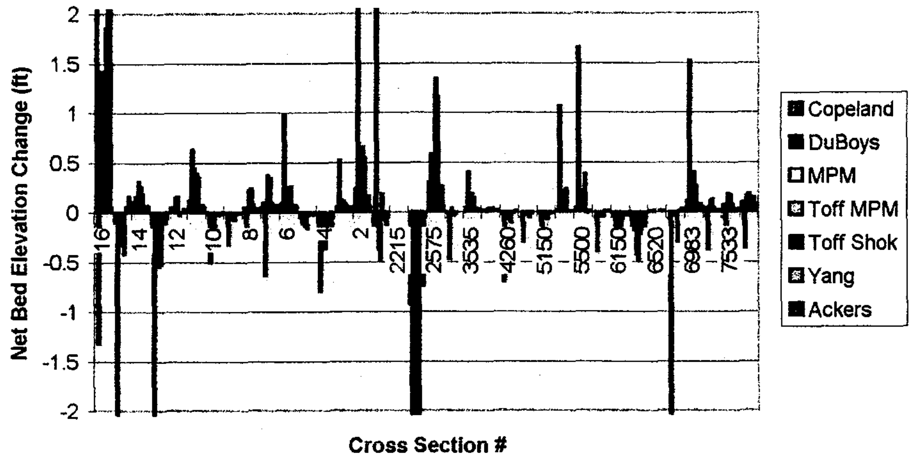
- Zero Sediment Inflow. A model was prepared with no sediment entering the upstream end of the modeling reach to test the sensitivity of the sediment load rating curve. No differences in net bed elevation change between the base conditions HEC-6 model and the zero sediment inflow HEC-6 model were computed at any point downstream of cross section #13, as shown in Table 6-2. Cross section #13 is located about 1,500 feet upstream of the Phoenix Mountain Preserve boundary. Therefore, it was concluded that the HEC-6 model results for the study reach downstream of the Phoenix Mountain Preserve were not sensitive to the sediment inflow rating curve.

Table 6-2. Tatum Wash Sedimentation Study
Difference in 100-Year Predicted Net Bed Elevation Change -
Zero Sediment Inflow vs. Zeller-Fullerton Sediment Inflow Rating Curve

Section #	Difference (ft)	Section #	Difference (ft)	Section #	Difference (ft)
16	3.2	4	0.0	5150	0.0
15	0.5	3	0.0	5460	0.0
14	0.1	2	0.0	5500	0.0
13	0.0	1	0.0	5880	0.0
12	0.0	2215	0.0	6150	0.0
11	0.0	2265	0.0	6420	0.0
10	0.0	2575	0.0	6520	0.0
9	0.0	3095	0.0	6573	0.0
8	0.0	3535	0.0	6983	0.0
7	0.0	3880	0.0	7338	0.0
6	0.0	4260	0.0	7533	0.0
5	0.0	4630	0.0	7693	0.0

- Sediment Transport Functions. A variety of sediment transport functions were tested for the 100-year HEC-6 model. While there were some minor differences in the magnitude of the predicted scour and deposition, no significant differences in predicted net bed elevation change were identified. That is, differences in net bed elevation change were generally less than one foot, as illustrated in Figure 6-4, and averaged less than 0.1 foot. Therefore, no one sediment transport function was judged as clearly better than any other transport function tested.

Figure 6-4. Comparison of Net Bed Elevation Change by Sediment Transport Functions



- Sediment Yield. HEC-6 modeling results were used to compare bedload sediment yield estimates at Shea Boulevard with sediment yield estimates made using methodologies described in Section 5 of this report. In general, the HEC-6 sediment yield estimates were equivalent to the bed-material yield estimate made using the Zeller-Fullerton equation, but were about an order of magnitude lower than the total load yield estimates made using other methodologies. These results indicate that the HEC-6 models adequately depict movement of the bed-material load, but may underestimate total sediment concentrations and transport of the suspended and wash loads. Sediment yield estimates were shown in Tables 5-3 to 5-5.

- Calibration. No historical sediment sampling or streamflow data were available for Tatum Wash. Therefore, no direct calibration of the Tatum Wash HEC-6 model was possible. However, the HEC-6 model results generally indicate equilibrium conditions for the existing channel of Tatum Wash, a result which corresponds to the results of the geomorphic analysis (See Section 4).

As a result of the HEC-6 model sensitivity tests, it was concluded that the HEC-6 models could be used to predict the direction of expected channel change on Tatum Wash, estimate sediment yield, and to identify trends of expected sedimentation.

Selection of HEC-6 Sediment Transport Functions. The HEC-6 input code includes an option for selecting one of twelve sediment transport functions, including a user-specified equation. The available transport functions include empirically-derived and theoretically-derived equations, that reflect the data sets or modeling objectives used to develop the equations. That is, each sediment transport function has a certain of conditions for which it is most appropriate. For the Tatum Wash sedimentation study, the Ackers-White and Toffaleti Meyer-Peter Muller equations were considered. The Ackers-White equation was selected as the most appropriate sediment transport function for the following reasons:

- Bed Sediment Size. The Ackers-White equations was developed from a data set that included gravel bed streams. Yang (1991) determined that the Ackers-White equation performed better for coarse sediment loads. The Toffaleti and Meyer-Peter Muller equations were developed primarily for sand bed channels (Toffaleti, 1969). Both transport functions were derived to address bed-material load. The bed material in Tatum Wash has a median sediment diameter (D50) of about 6 to 8 mm (gravel).

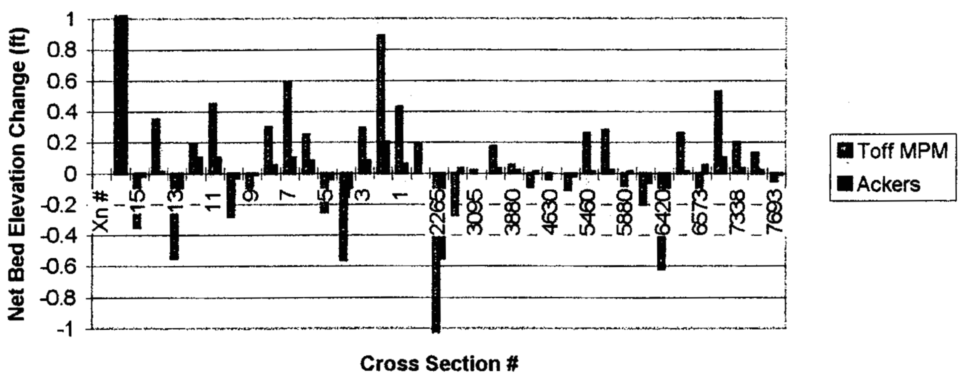
- Sediment Concentration. Yang (1991) determined that the Ackers-White equation performed better at higher sediment concentrations than the Toffaleti Meyer-Peter Muller equation. In lab tests, the Toffaleti equation performed poorly at sediment concentrations exceeding 1,000 ppm (0.1%), well below the expected concentrations for Tatum Wash. The Ackers-White equation performed well up to 50,000 ppm (5%).

- Froude Number. Yang (1991) determined that the Ackers-White equation performed better at higher Froude numbers than the Toffaleti and Meyer-Peter Muller equations. In lab tests, the Toffaleti equation performed poorly at Froude numbers exceeding 0.5, whereas the Ackers-White equation performed well at Froude numbers from 0.18 to 4.0. According to the Tatum Wash HEC-2 analysis, Froude numbers were close to 1.0 (critical), and generally exceeded 0.6.

- Slope. Yang (1991) determined that Ackers-White equation performed better at higher slope than the Toffaleti and Meyer-Peter Muller equations. In lab tests, the Toffaleti equation performed poorly at slopes exceeding 0.001 ft./ft. (0.1%), whereas the Ackers-White equation performed best at slopes ranging from 0.01 to 0.03 ft./ft. (1-3%). The average channel slope in Tatum Wash is about 0.01 ft./ft. (1%).

Sensitivity tests of all of the available HEC-6 transport functions were conducted for the 100-year event, as described previously in this Section. The Ackers-White equation was found to be most effective at transporting the coarse-grained sediment fraction. The Toffaleti Meyer-Peter Muller equation was found to transport a larger volume of sediment, and resulted in slightly larger depths of scour and deposition. The net scour and relative trends of channel profile change were not significantly different for any of the transport functions tested. Regardless of the transport function used, the direction of predicted bed elevation change was the same, only the magnitude varied slightly, as illustrated for the 100-year event in Figure 6-5. Results for both the Ackers-White and Toffaleti Meyer-Peter Muller transport functions are reported in the HEC-6 Modeling Results discussion below.

Figure 6-5. 100-Year HEC-6 Net Bed Elevation Change Toffaleti Meyer Peter Muller vs. Ackers White



HEC-6 Modeling Results

HEC-6 models were prepared to simulate channel response for the 2-, 10-, 50-, and 100-year events for existing conditions, implementation of Phase 1 of the Tatum Wash Drainage Improvement Project, and implementation of Phase 2 of the Tatum Wash Drainage Improvement Project.

Geomorphic Setting/Expected Channel Response. Based on field observations and the results of the geomorphic analysis of Tatum Wash, the following results were expected from the HEC-6 modeling.

- Equilibrium. A variety of regime, hydraulic geometry, descriptive geomorphologic methodologies and other equations indicate that the existing channel is at or near its expected natural equilibrium condition. The HEC-6 model should indicate near-equilibrium conditions for the existing channel.
- Development Impacts. The study reach and watershed have not been significantly altered by urbanization. Sediment transport should be similarly unaffected.
- Historical Channel Change. Most of the study reach has not been altered by development. Small levees and flood walls have been added at the margins of the floodplain between Onyx Drive and Shea Boulevard.
- Shallow Bedrock. Bedrock crops out in the channel bed between 44th Street and Onyx Drive. Bedrock depths should be coded into the HEC-6 input files where the predicted scour depths intersect the depth to bedrock.

- Deposition at Shea Boulevard. Sediment sampling data indicate that some deposition of sediment occurs immediately upstream of Shea Boulevard. The HEC-6 model should predict deposition at this point.
- Detention Basin Impacts. Net scour is expected downstream of the Phase 2 detention basin due to sediment trapping in the basin. The HEC-6 model should indicate increased scour downstream of the Phase 2 detention basin.
- Stable Banks. The channel banks have been relatively stable during the period of historical record, and currently exhibit few signs of active bank erosion. Use of the rigid bank HEC-6 model is appropriate for Tatum Wash.
- Gravel Bed Stream. The bed sediments consist of gravel and small cobbles. Field evidence suggests that these bed materials are actively transported during floods. The sediment transport function selected should be effective at transporting gravel sized sediment.

Existing Conditions. The existing conditions HEC-6 models generally predict the type of channel response that was expected based on the geomorphic analysis and field observations. Net bed elevation changes from the 2- and 100-year events are summarized in Tables 6-3, 6-4 (Ackers White Equation Results[1]), 6-5, and 6-6 (Toffaleti Meyer-Peter Muller Equation Results[2]), and are graphically depicted on Figures 6-6, 6-7 (AW), 6-8, and 6-9 (TMPM). Complete HEC-6 output files are provided on a diskette attached to the Appendix. The following sedimentation trends were identified from the HEC-6 modeling results:

- Predicted net bed elevation change was minimal. For the 100-year event, the maximum predicted 100-year net bed elevation change (scour) for the entire study reach was about 0.6 feet (AW) and 1.4 feet (TMPM) at cross section # 2205, which is located downstream of the 40th Street box culvert. Accelerating flow through concrete-lined contracted channel section at the box culvert is probably the cause of the scour at cross section #2205. The maximum predicted 100-year net bed elevation change (deposition) for the entire study reach was about 0.2 feet (AW) or 0.9 feet (TMPM) at cross section #2, which is located in the backwater area upstream of the 40th Street culvert. The maximum net scour and deposition in the study reach for the 2-year event was -0.07 feet and 0.04 feet for both the Ackers White and Toffaleti Meyer-Peter Muller models.

- The reach immediately downstream of the Phoenix Mountain Preserve boundary (cross sections # 4-5) tended to experience net scour for all the hydrologic events analyzed.

- The reach immediately upstream of the 40th Street box culvert (Sections # 3-2215) tended to experience net deposition, due to backwater from the undersized culvert

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[1] Hereafter, referred to as "AW."

[2] Hereafter, referred to as "TMPM."

crossing. Net scour occurs at the cross section downstream of the culvert (Section # 2205), due to flow acceleration through the lined culvert section.

- Slight net deposition occurs in the flow expansion area downstream of Fanfol Drive due to slightly lower velocities and depths associated with the wider floodplain.

- Where the low flood wall channelization begins upstream of 44th Street (Sections # 6150-6420), slight net scour occurs.

- Net deposition occurs upstream of Shea Boulevard where the channel expands, channel vegetation density increases, and the slope decreases slightly. This result was expected given the finer sediment distribution in this reach as determined by the sieve analysis and the natural slope change in the historically braided reach.

No significant differences in predicted channel behaviors were determined by the HEC-6 modeling for difference recurrence interval events, except that the magnitude of scour and deposition was slightly greater for the higher recurrence interval events, as illustrated in Figures 6-6 to 6-9.

With-Project Conditions. Two sets of HEC-6 models were prepared to simulate each phase of the two-phased drainage improvement proposed by the District. Net bed elevation changes from the 2- and 100-year events are summarized in Tables 6-3 and 6-4 (AW), and Tables 6-5 and 6-6 (TMPM). These results are graphically depicted on Figures 6-8 and 6-9. Complete HEC-6 output files are provided on a diskette attached to the Appendix.

Phase 1. Phase 1 consists of a construction of a sediment trap basin immediately upstream of Shea Boulevard. Because the proposed sediment trap basin will be located at the downstream end of the study reach, it has no impact on sediment continuity relationships for the portion of the study reach upstream of the sediment trap. Therefore, the HEC-6 results are identical to the existing conditions model, except within the sediment trap basin itself. Sedimentation was described in detail in Section 5 of this report, and is reviewed in the *Bed-Material Load Sediment Delivery* discussion below.

Phase 2. Phase 2 consists of construction of an on-line detention basin upstream of the Phoenix Mountain Preserve boundary. The following sedimentation trends for the proposed Phase 2 improvements were identified from the HEC-6 modeling results:

- Net scour will occur in the channel reach downstream of the proposed detention basin (cross sections # 6-4), due to trapping of sediment within the basin ponding area. The outflow from the detention basin will be deprived of its bedload, and will erode the channel to recover its transport capacity. More detailed discussions of sediment trapping in the detention basin was presented in Section 5 of this report. Channel response downstream of the basin was presented in Section 4 of this report.

- Downstream of 40th Street, the sedimentation trends are essentially identical to the existing conditions and Phase 1 modeling results, except that the magnitude of predicted net scour and deposition is less for the Phase 2 model. The decrease magnitude of sedimentation trends reflects the reduced sediment transport capacity due to peak flow attenuation in the detention basin, as well as the reduced sediment load downstream of the basin.

- The total sediment yield to the Shea Boulevard sediment trap will decrease as a result of construction of the Phase 2 detention basin. The HEC-6 modeling results indicate a 50 percent (AW; 0.17 to 0.08 acre feet) or 32 percent (TMPM; 0.66 to 0.45 acre feet) decrease in sediment reaching the Shea Boulevard sediment trap basin. The effect of the Phase 2 detention basin on sediment yield was discussed in more detail in Section 5 of this report.

As described in the *Bed-Material Sediment Delivery* discussion below, sediment yields estimated from the HEC-6 output are significantly lower than yield estimates made using other methodologies, such as those presented in Section 5 of this report. Therefore, if the HEC-6 sediment volume estimates are truly underestimated[1], it is likely that the predicted scour and deposition depths are similarly underestimated. However, since the magnitude of the predicted HEC-6 net bed elevation changes are small, an increase of up to 100 percent would not significantly affect the conclusions drawn regarding expected sedimentation trends along Tatum Wash.

[1] Rather than the sediment yields by other methods being overestimated.

Table 6-3. Tatum Wash Sedimentation Study 100-Year HEC-6 Results - Net Bed Elevation Change (ft) Ackers White Equation				
Cross Section # Existing Conditions	**Existing Elev. Diff.**	**Phase 1 Elev. Diff.**	**Phase 2 Elev. Diff.**	**Cross Section # With Project**
16	4.03	4.03	3.23	16
15	-0.02	-0.02	-0.04	15
14	0.01	0.01	0.03	14
13	-0.18	-0.18	0.16	13
12	0.10	0.10	0.09	12
11	0.10	0.10	0.02	11
10	-0.03	-0.03	0.00	6.41
9	-0.01	-0.01	0.01	6.4
8	0.05	0.05	0.00	6.3
7	0.10	0.10	0.00	6.2
			0.00	6.1
			0.00	6
6	0.08	0.08	-0.10	6
5	-0.04	-0.04	-0.08	5
4	-0.15	-0.15	-0.10	4
3	0.08	0.08	-0.01	3
2	0.20	0.20	0.10	2
1	0.06	0.06	0.05	1
2215	0.00	0.00	0.00	2215
2265	-0.55	-0.55	-0.17	2265
2575	0.03	0.03	-0.07	2575
3095	0.00	0.00	0.00	3095
3535	0.03	0.03	0.03	3535
3880	0.02	0.02	0.00	3880
4260	0.01	0.01	0.00	4260
4630	0.00	0.00	0.00	4630
5150	-0.02	-0.02	-0.01	5150
5460	0.01	0.01	0.00	5460
5500	0.02	0.02	0.00	5500
5880	0.01	0.01	0.00	5880
6150	-0.06	-0.06	-0.02	6150
6420	-0.22	-0.22	-0.07	6420
6520	0.01	0.00	0.00	6520
6573	0.05	0.02	-0.04	6573
6983	0.10	0.11	0.07	6983
7338	0.03	-0.02	-0.01	7338
		0.00	0.00	0.3
		0.03	0.02	0.2
7533	0.02	0.04	0.03	0.1
7693	-0.01	0.00	0.00	0.01

Table 6-4. Tatum Wash Sedimentation Study 2-Year HEC-6 Results - Net Bed Elevation Change (ft) Ackers White Equation				
Cross Section # Existing Conditions	**Existing Elev. Diff.**	**Phase 1 Elev. Diff.**	**Phase 2 Elev. Diff.**	**Cross Section # With Project**
16	1.72	1.72	1.72	16
15	-0.04	-0.04	0.00	15
14	0.00	0.00	0.04	14
13	-0.03	-0.03	0.04	13
12	0.01	0.01	0.03	12
11	0.04	0.04	0.00	11
10	0.00	0.00	0.00	6.41
9	-0.02	-0.02	0.00	6.4
8	0.00	0.00	0.00	6.3
7	0.04	0.04	0.00	6.2
			0.00	6.1
			0.00	6
6	0.04	0.04	-0.02	6
5	-0.01	-0.01	-0.02	5
4	-0.02	-0.02	-0.02	4
3	0.00	0.00	-0.01	3
2	0.01	0.01	0.01	2
1	0.03	0.03	0.03	1
2215	0.03	0.03	0.01	2215
2265	-0.07	-0.07	-0.07	2265
2575	-0.01	-0.01	-0.01	2575
3095	0.00	0.00	0.00	3095
3535	0.01	0.01	0.01	3535
3880	0.00	0.00	0.00	3880
4260	0.00	0.00	0.00	4260
4630	0.00	0.00	0.00	4630
5150	-0.01	-0.01	-0.01	5150
5460	0.00	0.00	0.00	5460
5500	-0.02	-0.02	-0.02	5500
5880	0.00	0.01	0.00	5880
6150	0.00	0.00	-0.01	6150
6420	-0.01	-0.01	0.00	6420
6520	0.00	0.00	0.00	6520
6573	-0.01	-0.01	-0.01	6573
6983	0.01	0.02	0.02	6983
7338	0.01	-0.01	-0.01	7338
		0.00	0.00	0.3
		0.01	0.00	0.2
7533	0.01	0.01	0.01	0.1
7693	0.03	0.00	0.00	0.01

Table 6-5. Tatum Wash Sedimentation Study 100-Year HEC-6 Results - Net Bed Elevation Change (ft) Toffaleti Meyer-Peter Muller Equation				
Cross Section # Existing Conditions	**Existing Elev. Diff.**	**Phase 1 Elev. Diff.**	**Phase 2 Elev. Diff.**	**Cross Section # With Project**
16	1.64	1.64	2.01	16
15	-0.35	-0.35	-0.31	15
14	0.35	0.35	0.61	14
13	-0.55	-0.55	0.62	13
12	0.19	0.19	0.43	12
11	0.45	0.45	0.03	11
10	-0.28	-0.28	0.00	6.41
9	-0.14	-0.14	0.01	6.4
8	0.30	0.30	0.00	6.3
7	0.59	0.59	0.00	6.2
		0.25	0.00	6.1
		-0.25	0.00	6
6	0.25	-0.56	-0.36	6
5	-0.25	0.29	-0.33	5
4	-0.56	0.89	-0.42	4
3	0.29	0.43	-0.14	3
2	0.89	0.19	0.44	2
1	0.43	-1.41	0.26	1
2215	0.19	-0.27	0.05	2215
2265	-1.41	0.02	-0.76	2265
2575	-0.27	0.18	-0.29	2575
3095	0.02	0.05	0.02	3095
3535	0.17	-0.09	0.11	3535
3880	0.05	-0.04	-0.01	3880
4260	-0.09	-0.11	-0.07	4260
4630	-0.04	0.26	-0.01	4630
5150	-0.11	0.28	-0.12	5150
5460	0.26	-0.07	0.18	5460
5500	0.28	-0.20	0.12	5500
5880	-0.08	-0.62	0.04	5880
6150	-0.20	0.19	-0.10	6150
6420	-0.62	-0.24	-0.22	6420
6520	0.26	0.58	0.13	6520
6573	-0.18	-0.39	-0.34	6573
6983	0.53	0.00	0.42	6983
7338	0.20	0.00	-0.27	7338
		0.38	0.00	0.3
		0.00	0.01	0.2
7533	0.13		0.28	0.1
7693	-0.05		0.00	0.01

Table 6-6. Tatum Wash Sedimentation Study 2-Year HEC-6 Results - Net Bed Elevation Change (ft) Toffaleti Meyer-Peter Muller Equation				
Cross Section # Existing Conditions	**Existing Elev. Diff.**	**Phase 1 Elev. Diff.**	**Phase 2 Elev. Diff.**	**Cross Section # With Project**
16	1.72	1.14	1.00	16
15	-0.04	-0.22	-0.09	15
14	0.00	0.08	0.42	14
13	-0.03	-0.18	0.26	13
12	0.01	0.08	0.06	12
11	0.04	0.24	0.00	11
10	0.00	-0.04	0.00	6.41
9	-0.02	-0.12	0.00	6.4
8	0.00	0.02	0.00	6.3
7	0.04	0.26	0.00	6.2
			0.00	6.1
			0.00	6
6	0.04	0.24	-0.09	6
5	-0.01	-0.06	-0.12	5
4	-0.02	-0.11	-0.13	4
3	0.00	-0.02	-0.07	3
2	0.01	0.08	0.09	2
1	0.03	0.23	0.20	1
2215	0.03	0.46	0.04	2215
2265	-0.07	-0.34	-0.30	2265
2575	-0.01	-0.13	-0.12	2575
3095	0.00	0.01	-0.01	3095
3535	0.01	0.04	0.05	3535
3880	0.00	-0.01	0.00	3880
4260	0.00	-0.01	0.00	4260
4630	0.00	-0.02	-0.01	4630
5150	-0.01	-0.06	-0.08	5150
5460	0.00	0.06	0.05	5460
5500	-0.02	0.03	-0.08	5500
5880	0.01	0.05	0.06	5880
6150	0.00	-0.01	-0.02	6150
6420	-0.01	-0.03	0.00	6420
6520	0.00	0.00	0.05	6520
6573	-0.01	-0.10	-0.13	6573
6983	0.02	0.14	0.17	6983
7338	-0.01	-0.14	-0.12	7338
		0.00	0.00	0.3
		0.00	0.01	0.2
7533	0.00	0.08	0.07	0.1
7693	0.01	0.00	0.00	0.01

Figure 6-6. Tatum Wash 100-Year HEC-6 Results - Net Bed Elevation Change: Existing, Phase 1, & Phase 2 Models Ackers White Equation

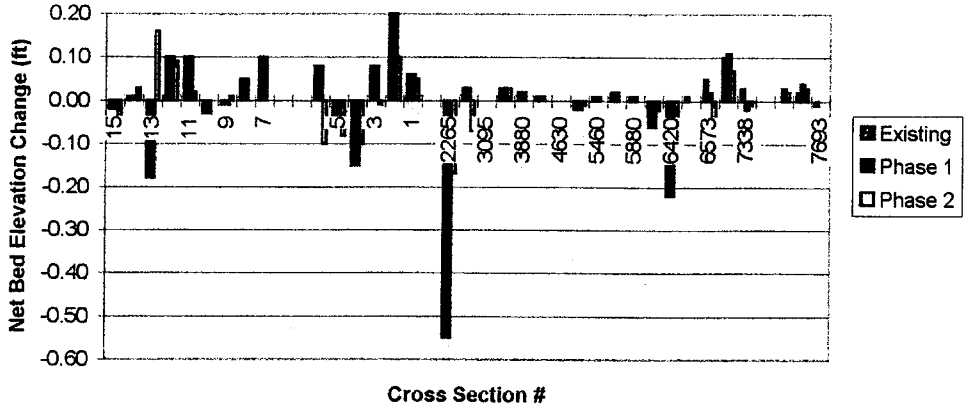


Figure 6-7. Tatum Wash 2-Year HEC-6 Results - Net Bed Elevation Change: Existing, Phase 1, Phase 2 - Ackers White Equation

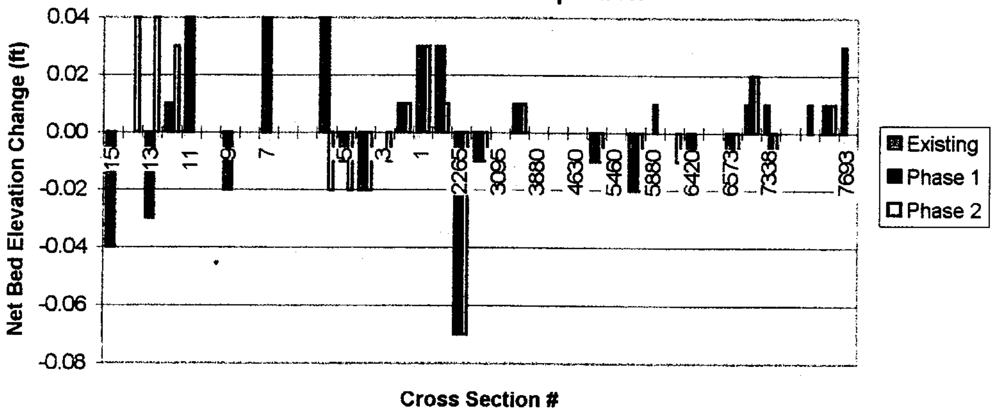


Figure 6-8. Tatum Wash 100-Year HEC-6 Results - Net Bed Elevation Change: Existing, Phase 1, & Phase 2 Models - Toffaleti Meyer-Peter Muller Equation

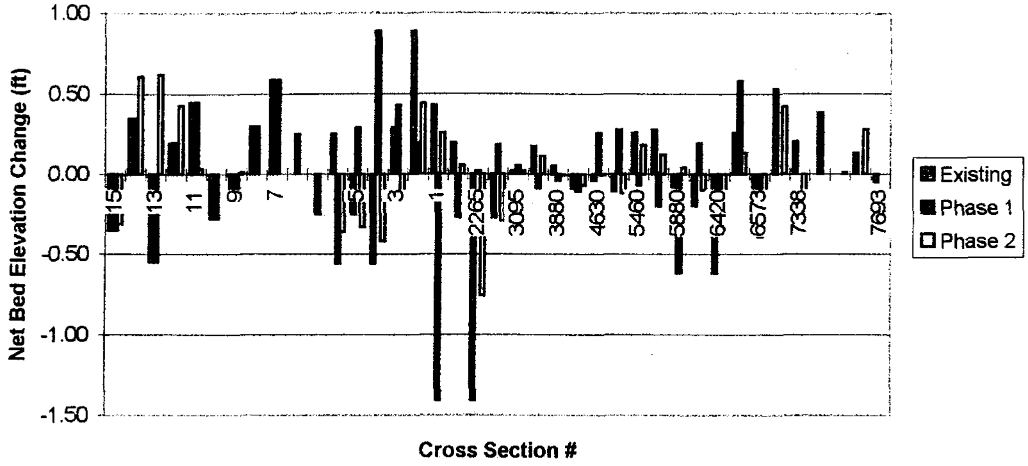
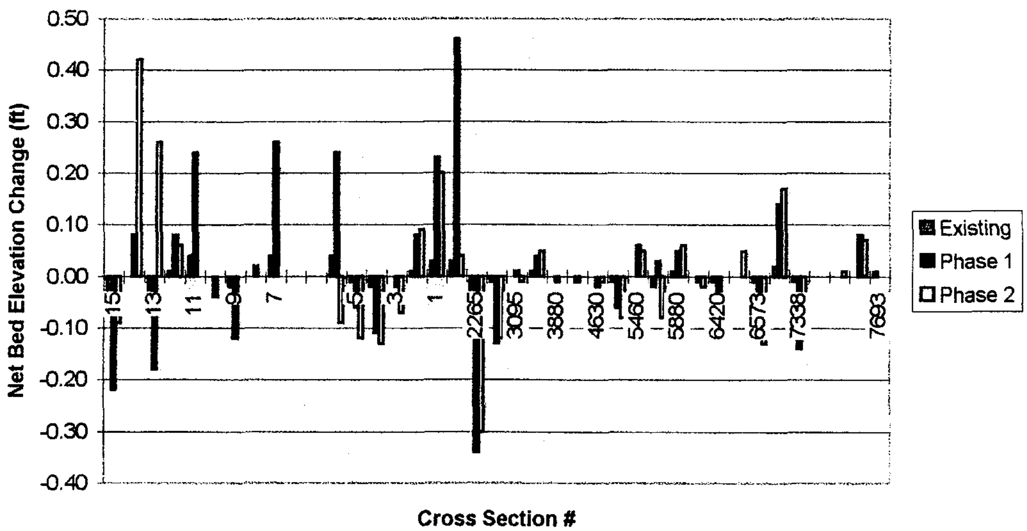


Figure 6-9. Tatum Wash 2-Year HEC-6 Results - Net Bed Elevation Change: Existing, Phase 1, Phase 2 Models Toffaleti Meyer-Peter Muller Equation



Bed-Material Load Sediment Delivery. The results of the HEC-6 modeling were used to estimate the sediment yield at Shea Boulevard for existing conditions, for comparison with estimates of sediment yield made using conventional techniques, as reported in Section 5 of this report. HEC-6 sediment yields at Shea Boulevard and at the Phoenix Mountain Preserve boundary estimated using the Ackers White and Toffaleti Meyer-Peter Muller equations are summarized in Table 6-7.

Table 6-7. Tatum Wash Sedimentation Study Sediment Load at Shea Boulevard for Specific Flood Events - HEC-6 Model Results				
Event	**@ Shea Blvd. (AF)**		**@ Phx. Mth. Park (AF)**	
Existing Conditions				
	Ackers White	**Toffaleti MPM**	**Ackers White**	**Toffaleti MPM**
2-Year	0.02	0.05	0.02	0.06
10-Year	0.06	0.15	0.04	0.14
50-Year	0.11	0.30	0.07	0.26
100-Year	0.14	0.40	0.09	0.32
Phase 1 Project Conditions				
	Ackers White	**Toffaleti MPM**	**Ackers White**	**Toffaleti MPM**
2-Year	0.03	0.13	0.02	0.06
10-Year	0.06	-	0.04	-
50-Year	0.12	-	0.07	-
100-Year	0.17	0.66	0.09	0.32
Phase 2 Project Conditions				
	Ackers White	**Toffaleti MPM**	**Ackers White**	**Toffaleti MPM**
2-Year	0.02	0.11	0.02	0.08
10-Year	0.03	-	0.04	-
50-Year	0.07	-	0.07	-
100-Year	0.08	0.45	0.08	0.30

In general, the HEC-6 sediment yield estimates were about an order of magnitude lower than the previously reported sediment yield estimates computed using the Modified Universal Soil Loss Equation (MUSLE) or sediment concentration methods, but compared moderately well to estimates of bed-material load made using the Zeller-Fullerton equation. Comparison with the sediment delivery rate estimates summarized in Table 6-7 indicate that either: (1) the HEC-6 model underestimates sediment transport rates in the study reach, or (2) less sediment will accumulate in the sediment basin at Shea Boulevard than was predicted from the sediment yield analysis. Given that the Ackers-White and Toffaleti Meyer-Peter Muller transport functions used in the HEC-6 models are primarily bed-material load equations, it is likely that total sediment load delivered to the sediment trap and detention basin will be larger than the amount predicted by the HEC-6 models. Therefore, the HEC-6 sediment yield volume estimates should not be used for design purposes. It is important to note that the data shown in Table 6-7 is for a single design event, and does not account for sediment yield from more frequent, "typical" storms, or for flood magnitudes other than the four recurrence intervals shown.

The HEC-6 results were also used to estimate the reservoir trapping efficiency of the two proposed basins by comparing the total inflowing sediment load with the sediment load leaving the basin. Reservoir trapping efficiency estimates based on HEC-6 output were reported in Table 5-9. In general, reservoir trapping averaged about 80 percent for the Shea Boulevard sediment trap during Phase 1 of the project, and about 100 percent for both basins during Phase 2 of the project. Trapping efficiency estimates were higher for the higher recurrence interval events.

Scour Downstream of At-Grade Crossings. Although the HEC-6 model was not designed to estimate local scour downstream of at-grade crossings, general trends in sedimentation can be predicted based on the HEC-6 model output. The at-grade road crossing reaches and the 40th Street culvert reach were coded with a zero bedrock depth and lower Manning's n value than the adjacent channel reaches in the HEC-6 input files. Consequently, net scour was predicted downstream of several of the crossings, as summarized in Table 6-8.

Table 6-8. Tatum Wash Sedimentation Study
Scour Downstream of Road Crossing Estimated from HEC-6 Output

Location	Cross Section #	Ackers White	Toffaleti MPM	Q=2,300 cfs, 50 days
Existing Conditions				
40th Street	2265.8	-0.55 ft.	-1.41 ft.	-1.60 ft.
Fanfol Drive	3535.8	0.03 ft.	0.17 ft.	-4.82 ft.
Onyx Drive	5500.8	0.02 ft.	-0.20 ft.	-1.95 ft.
44th Street	6573.8	0.05 ft.	-0.18 ft.	-0.06 ft.
Phase 2 Project Conditions				
40th Street	2265.8	-0.17 ft.	-0.30 ft.	-
Fanfol Drive	3535.8	0.03 ft.	0.05 ft.	-
Onyx Drive	5500.8	0.00 ft.	-0.08 ft.	-
44th Street	6573.8	-0.04 ft.	-0.13 ft.	-

Notes: Continuous discharge of 2,300 cfs for 50 day period from high flow calibration run

As shown in Table 6-8, the magnitude of the scour downstream of the road crossings predicted by HEC-6 decreased for the simulation of the Phase 2 project conditions, probably due to decrease discharge and sediment transport rates. Based on the geomorphic analysis and local field experience, increased local scour is normally expected downstream of an on-line detention basin. It is noted that more accurate scour depths could be estimated using local scour equations, and should be computed to reflect the local depth to bedrock and channel armoring potential.

Stable Slope Evaluation. Stable slope cannot be readily estimated using the HEC-6 models of Tatum Wash for the following reasons:

- Event-Based Modeling. The HEC-6 models prepared for the Tatum Wash Sedimentation Study were for specific flood hydrographs, and do not depict long-term average flow conditions.

- Ephemeral Stream. The normal, long-term average discharge rate on Tatum Wash is effectively 0 cfs.[1]

- Bedrock Control. The geomorphic analysis concluded that the subsurface bedrock geology may in part control the slope of the study reach, which would not be affected by human impacts on the channel.

HEC-6 calibration runs (Figure 6-2) using constant discharges may provide some insight to expected long-term trends of slope adjustment. According to the HEC-6 predicted net bed elevation changes shown in Figure 6-2, Tatum Wash has a tendency to increase its slope usptream of 40th Street (aggrade), decrease its slope downstream of 40th Street, and increase its slope at Shea Boulevard. These results are somewhat in contrast to the results of the geomorphic analysis which indicated that equilibrium or net scour (slope decrease) is expected for the study reach, particularly after implementation of Phase 2 of the project.

Vegetation Impacts on Sedimentation. Much of the channel of Tatum Wash downstream of Fanfol Drive has the potential to become overgrown with brushy vegetation and small trees, at least during the periods between large erosive floods. To test for possible sedimentation impacts from excessive vegetative growth in the channel, HEC-6 models with low and high Manning's N values were prepared for the 100-year event, for the portion of the study reach between Shea Boulevard and the Phoenix Mountain Preserve boundary. The low N value model (n = 0.025) was intended to simulate channel conditions after removal of channel vegetation. The high N value model (n=0.055) was intended to simulate expected vegetative growth in the channel. Overbank N values and other hydraulic, hydrologic, geometric, sedimentological characteristics were not changed from the existing conditions HEC-6 model for the 100-year event. Net bed elevation changes for each model are summarized in Table 6-9.

Not surprisingly, given the low magnitude of net bed elevation changes predicted for the existing conditions HEC-6 models, the difference in net bed elevation for the low-n and high-n HEC-6 models was minimal. However, the difference in the volume of sediment delivered to the downstream end of the study reach varied significantly. For the 100-year low-n model (channel vegetation maintained), the HEC-6 results indicated a sediment delivery volume at Shea Boulevard of 0.35 acre feet (711 tons). For the 100-year high-n model (excess vegetative growth in the channel), the HEC-6 results indicated a sediment delivery volume at Shea Boulevard of 0.13 acre feet (256 tons), only 36 percent of the low-n volume estimate. Therefore, it may be concluded that sediment deposition in the Shea Boulevard sediment trap will increase if the channel vegetation is removed, either through scheduled maintenance or as the result of flood erosion.

[1] The long-term average discharge rate was estimated at about 0.04 cfs using the Renard estimate of mean annual flow volume (JEF, 1996e).

Table 6-9. Tatum Wash Sedimentation Study Comparison of Low N and High N HEC-6 Results Net Bed Elevation Change (ft) - Ackers White Transport Function			
Cross Section # Existing Conditions	**Low N Elev. Diff.**	**High N Elev. Diff.**	**Relative Difference (ft)**
6	0.08	0.08	0.00
5	-0.04	-0.04	0.00
4	-0.15	-0.15	0.00
3	0.08	0.08	0.00
2	0.20	0.20	0.00
1	0.06	0.06	0.00
2215	0.00	0.00	0.00
2265	-0.44	-0.61	0.17
2575	-0.02	0.06	-0.08
3095	-0.03	0.02	-0.05
3535	-0.21	0.08	-0.29
3880	-0.19	0.03	-0.22
4260	0.00	0.00	0.00
4630	-0.08	0.00	-0.08
5150	0.02	-0.01	0.03
5460	0.18	0.00	0.18
5500	-0.03	0.01	-0.04
5880	-0.04	0.01	-0.05
6150	0.03	-0.02	0.05
6420	-0.02	-0.11	0.09
6520	0.01	0.00	0.01
6573	-0.22	-0.02	-0.20
6983	0.09	0.06	0.03
7338	0.05	0.01	0.04
7533	0.08	0.01	0.07
7693	0.22	-0.01	0.23

Summary and Conclusions

In general, the HEC-6 model predicts near-equilibrium existing conditions for Tatum Wash, and minimal changes due to implementation of the proposed drainage improvements. Other conclusions for the HEC-6 modeling include the following:

- The relatively low sediment volumes transported for the events analyzed probably are due in part to the short duration of the hydrographs, which typically last less than 10 hours, with only a very brief period of flow in excess of 100 cfs. The short design hydrographs are similarly responsible for the low net scour magnitudes predicted by the HEC-6 models.

- The sediment transport functions available in HEC-6 do not adequately move the coarsest fraction of the sediment load. Field evidence, such as imbrication of boulder and cobble sediment sizes observed in the test pits, indicates that these coarse sediments have been transported in the past.

- Best use of HEC-6 results is for modeling the direction of expected channel impacts resulting from sediment trapping at the upstream detention basin for Phase 2 of the proposed project. The HEC-6 results indicate that the relative magnitude of scour or deposition will decrease after implementation of Phase of the project, primarily due to the decreased flow rates.

- Much of sediment load reaching Shea Boulevard is derived from the channel of the study reach. Construction of the Phase 2 detention basin reduced sediment load reach the Shea Boulevard sediment trap basin by about 32 to 50 percent, despite nearly 100 percent trapping efficiency in the upstream basin.

Table 6-10. Tatum Wash Sedimentation Study HEC-6 File Names	
Name	**Description**
Existing Conditions (Pre-Project)	
TATUM100.DAT	100-Year Hydrograph, Ackers-White Transport Function
TATUM50.DAT	50-Year Hydrograph, Ackers-White Transport Function
TATUM10.DAT	10-Year Hydrograph, Ackers-White Transport Function
TATUM2.DAT	2-Year Hydrograph, Ackers-White Transport Function
T100TMPM.DAT	100-Year Hydrograph, Toffaleti Meyer-Peter Muller Transport Function
T50_TMPM.DAT	50-Year Hydrograph, Toffaleti Meyer-Peter Muller Transport Function
T10_TMPM.DAT	10-Year Hydrograph, Toffaleti Meyer-Peter Muller Transport Function
T2_TMPM.DAT	2-Year Hydrograph, Toffaleti Meyer-Peter Muller Transport Function
With-Project Conditions	
P1H6_100.DAT	100-Year Hydrograph, Phase 1 of Project (Shea Blvd. Sediment Trap) , Ackers
P1H6_50.DAT	50-Year Hydrograph, Phase 1 of Project (Shea Blvd. Sediment Trap) , Ackers
P1H6_10.DAT	10-Year Hydrograph, Phase 1 of Project (Shea Blvd. Sediment Trap) , Ackers
P1H6_2.DAT	2-Year Hydrograph, Phase 1 of Project (Shea Blvd. Sediment Trap) , Ackers
P1H6TMPM.DAT	100-Year Hydrograph, Phase 1 of Project (Shea Blvd. Sediment Trap), Toff MPM
P1H6TMP2.DAT	2-Year Hydrograph, Phase 1 of Project (Shea Blvd. Sediment Trap), Toff MPM
P2H6_100.DAT	100-Year Hydrograph, Phase 2 of Project (Phx. Mtn. Pres. Detention Basin), AW
P2H6_50.DAT	50-Year Hydrograph, (Phx. Mtn. Preserve Detention Basin) , Ackers
P2H6_10.DAT	10-Year Hydrograph, (Phx. Mtn. Preserve Detention Basin) , Ackers
P2H6_2.DAT	2-Year Hydrograph, (Phx. Mtn. Preserve Detention Basin) , Ackers
P2H6TMPM.DAT	100-Year Hydrograph, Phase 1 of Project (Shea Blvd. Sediment Trap), Toff MPM
P2H6TMP2.DAT	2-Year Hydrograph, Phase 1 of Project (Shea Blvd. Sediment Trap), Toff MPM
Calibration & Sensitivity Runs	
0_IN_100.DAT	HEC-6, Zero sediment inflow run, to test sensitivity to sediment load, Ackers
LO_Q.DAT	HEC-6, Constant discharge at 10 cfs, to test model stability, Ackers
HI_Q.DAT	HEC-6, Constant Q at 2300 cfs, to test long-term trends at extreme flow, AW
MATCHQ.DAT	HEC-6, Constant Q at 2300 cfs, zero sediment transport, to test hydraulics
MATCHQ.HC2	HEC-2, Q=2300 cfs to compare computed hydraulics to HEC-6 model
YANG.DAT	HEC-6, 100-Year Hydrograph, Yang Transport Function
MPM.DAT	HEC-6, 100-Year Hydrograph, Meyer-Peter Muller Transport Function
TOFFSHOK.DAT	HEC-6, 100-Year Hydrograph, Toffaleti-Schoklitsch Transport Function
TOFFMPM.DAT	HEC-6, 100-Year Hydrograph, Toffaleti/Meyer-Peter Muller Transport Function
COPELAND.DAT	HEC-6, 100-Year Hydrograph, Copeland Transport Function
HI_N_HC6.DAT	HEC-6, 100-Year Hydrograph, Channel N Value = 0.055 (Dense Vegetation)
LO_N_HC6.DAT	HEC-6, 100-Year Hydrograph, Channel N Value = 0.025 (Remove Vegetation)
Notes: Files included on attached diskette The Duboys and Colby Equations were tested, but are not applicable to channel conditions in Tatum Wash	

Section 7:
Maintenance & Operation

Introduction

Maintenance and operations requirements for the Tatum Wash Drainage Improvement Plan were estimated based on the technical analyses summarized in Sections 2 through 7 of this report, and the project description provided by the District (1996). Specific tasks completed for the maintenance and operations assessment described below included the following:

- Estimate average annual sediment removal volumes
- Estimate sediment removal volumes for the 2-, 10-, 50- , and 100-year events
- Estimate the required frequency of sediment removal
- Recommend a sediment maintenance and inspection schedule
- Assess the need for continued maintenance of vegetation from channel reaches

Project Maintenance and Operation.

Average Annual Sediment Removal. The Shea Boulevard sediment trap basin (Phase 1) and the Phoenix Mountain Preserve detention basin (Phase 2) are both on-line facilities. Therefore, sediment from upstream channel reaches will tend to be deposited in the basins whenever runoff occurs on Tatum Wash. The volume of sediment that will collect in the proposed basins was estimated based on the sediment yield, sediment continuity (HEC-6), and reservoir trapping efficiency analyses summarized in Section 5 of this report. The estimated average annual sediment removal volume for the proposed basins is summarized in Table 7-1.

Table 7-1. Tatum Wash Sedimentation Study
Estimate of Average Annual Sediment Removal Volumes

Basin	Recommended Estimate
Phase 1: Shea Boulevard Sediment Trap Basin	2 AF
Phase 2: Shea Boulevard Sediment Trap Basin	2 AF
Phase 2: Phoenix Mountain Preserve Detention Basin	3 AF

Derivation of the sediment volumes that will be deposited[1] in the basins for Phase 1 and Phase 2 of the project was described in Section 5 of this report, and was summarized on Tables 5-3, 5-4, 5-7, and 5-10. The sediment removal volume estimates summarized in

[1] Volume deposited = sediment yield x trapping efficiency

Table 7-1 were based primarily on the assumption of an average sediment concentration of 10 percent. Use of the sediment concentration estimate is justified for planning purposes given the steep slope of the wash, past sedimentation problems at Shea Boulevard, and engineering judgment based on experience with other on-line basins in the Phoenix metropolitan area.

Event-Based Sediment Removal. The volume of sediment that will collect in the proposed basins for specific return interval events was estimated based on the sediment yield, sediment continuity (HEC-6), and reservoir trapping efficiency analyses summarized in Section 5 of this report. The recommended estimate of the required sediment removal volume from the proposed basins is summarized in Table 7-2.

Table 7-2. Tatum Wash Sedimentation Study
Estimate of Sediment Removal Volumes by Recurrence Interval

Recurrence Interval	Phase 1: Shea Blvd. Basin	Phase 2:	
		Shea Blvd. Basin	Phoenix Mountain Preserve Basin
2-Year	3 AF	2 AF	4 AF
10-Year	7 AF	5 AF	8 AF
50-Year	13 AF	10 AF	14 AF
100-Year	15 AF	11 AF	17 AF

The estimated sediment removal volumes reported in Table 7-2 are based on the assumption of 10 percent sediment concentrations and engineering judgment. Use of a somewhat conservative estimate for sediment volumes for large flood events is justified given steep slope of the wash, the high concentration of sediment in arid-region floods, and the braided channel pattern which usually indicates excess sediment loads.

The sediment removal estimates reported in Table 7-2 consider the impacts on sedimentation rates at the Shea Boulevard sediment trap by the proposed Phoenix Mountain Preserve detention basin during Phase 2 of the project. According to the District's current conceptual design, the Shea Boulevard sediment trap will have about 18 or 20 acre feet of excess storage capacity for the expected 100-year sediment volume, during Phase 2 and Phase 1 of the project, respectively.

Required Frequency of Sediment Removal. Given the sediment delivery volumes estimates summarized in Tables 7-1 and 7-2, and the proposed basin geometry reported by the District (1996; and Table 2-2), the required average frequency of sediment removal at the basins is summarized in Table 7-3 for Phase 1 and Phase 2 conditions. The estimates shown in Table 7-3 are based on the average annual sediment delivery. More frequent sediment removal will be required if runoff events with sediment volumes exceeding the average annual volume occur.

Table 7-3. Tatum Wash Sedimentation Study Required Frequency of Sediment Removal	
Project Phase/ Element	**Frequency of Sediment Removal**
Phase 1	
Shea Boulevard Sediment Trap	10 Years
Phase 2	
Shea Boulevard Sediment Trap	10 Years
Phoenix Mountain Preserve Detention Basin	5 Years

The estimate of the frequency of required sediment maintenance could be refined if more detailed data for the basins were available, particularly for the Phase 2 Phoenix Mountain Preserve detention basin. Such data would include the basin stage-storage curve, inlet design, minimum bottom slope, depth of excavation, outlet configuration, landscaping requirements, spillway design criteria, and vehicular access requirements. The sediment removal schedule shown in Table 7-3 is based on the following assumptions:

- Freeboard. It was assumed that a minimum of 15 acre feet of excess sediment storage (the 100-year removal volume) should be available at all times.
- No Flood Storage. It was assumed that the entire sediment trap volume is available for sediment storage; i.e., no storage of flood water is required, and the basin outlet configuration does not require any of the basin volume.

For the Phoenix Mountain Preserve detention basin, the sediment removal frequency is based on typical sediment storage volumes (15 acre feet, 10 percent of total volume) provided for other detention basins in the Phoenix metropolitan area. The actual frequency of required sediment maintenance for the Phoenix Mountain Preserve detention basin will depend on final design of the basin and volume of storage allocated for sedimentation, as well as on the magnitude and frequency of runoff events.

Sediment Maintenance and Inspection Schedule. Sediment inspections for the proposed basins should be conducted at least two times each year. The first inspection should occur in May of each year, prior to the onset of the "monsoon" season. Most rainfall and runoff events on Tatum Wash, and therefore, most of the sedimentation, will occur during the monsoon season. The second inspection should occur after the summer monsoons, in November or December, prior to the onset of winter rains. In addition, inspections should be scheduled if flows in excess of the 2-year event are recorded at the District's stream gauge on Tatum Wash at 40th Street.

Table 7-4. Tatum Wash Sedimentation Study Sediment Inspection Schedule and Maintenance Tasks	
Inspection Date	**Inspection/Maintenance Tasks**
May	Remove debris and trash from outlet works Inspect inlet erosion protection for sapping, movement, undercutting Inspect condition (growth) of channel vegetation
November	Remove sediment if more than 20 AF deposited (Shea Blvd. basin) Remove debris and trash from outlet works Inspect inlet erosion protection for sapping, movement, undercutting Inspect channel upstream of basin for signs of headcutting Inspect channel downstream of basin at road crossings for signs of excess scour
Post-Flood Event	Perform additional inspections for 2-year flood or larger Remove sediment if more than 20 AF deposited (Shea Blvd. basin) Remove debris and trash from outlet works Inspect condition (loss) of channel vegetation

Survey markers should be placed on the side slopes of the basins so that the depth and volume of sedimentation in the basins can be readily determined by visual inspection. The markers can also be used to estimate the depth of water in the basin, for safety purposes. Sediment should be removed from the Shea Boulevard sediment trap whenever it exceeds 20 AF, depending on the design of the outlet structure. Sediment should be removed from the Phoenix Mountain Preserve detention basin whenever it exceeds the half the volume of sediment storage design volume (assumed to be 15 AF).

The sediment maintenance tasks listed in Table 7-4 do not include inspection and maintenance required by the Arizona Department of Water Resources Safety of Dams Division.

Vegetative Maintenance. The results of the HEC-6 modeling tasks indicated that removal of channel vegetation would not significantly impact the predicted net bed elevation changes along Tatum Wash, but could significantly increase sediment delivery at the proposed Shea Boulevard sediment trap. Therefore, vegetative maintenance is not recommended for sedimentation reasons. However, inspection of the condition of channel vegetation should be included in the regular inspection program.

Prior to implementation of Phase 2 of the project, removal of channel vegetation could slightly decrease the potential for break out flows into the neighborhoods upstream of Shea Boulevard. If vegetation is removed, only the growth in the main channel (not on the channel banks) should be removed, so that the potential for bank erosion is not increased. If vegetation is removal, more frequency sediment removal may be required at the Shea Boulevard sediment trap basin. Removal of vegetation within the floodplain may require permits from environmental resource agencies.

Summary

Sediment deposition is expected in the basins proposed for the Tatum Wash Drainage Improvement Project. Regular inspections should be conducted at least twice per year, and after significant flood events, to check for loss of storage volume, clogging of basin outlet works, and erosion impacts to the basin inlets and adjacent channel reaches. Sediment maintenance (removal) should be performed when the accumulated sediment volume exceeds half the design storage volume. Sediment removal will probably be required every three to ten years, depending on the magnitude, duration, and frequency of floods and flow events.

Section 8:
Preliminary Design Recommendations

Introduction

The District has proposed a conceptual design plan for drainage improvements along Tatum Wash, as described in Section 1 of this report. Based on the results of the sedimentation study, preliminary design recommendations were proposed by JEF, Inc. for consideration as part of the final design of the project. The recommendations discussed below are based on the following:

- Level of Detail. The design recommendations reflect the level of detail available for the District's proposed drainage improvements, as well as the hydraulic, hydrologic, geomorphic and sedimentation analyses described in this report. Detailed plans for the proposed project elements are not yet available.

- Sedimentation Engineering. The design recommendations only address the sedimentation engineering aspects of the proposed project.

Design recommendations presented in this section include: (1) Channel and basin design recommendations required by the scope of services, and (2) General design recommendations for the two phases of the project.

Channel and Basin Design Recommendations

The scope of services calls for design recommendations and evaluation of the following project elements:

- Need For Grade Control Structures
- Spacing And Conceptual Design Of Grade Control Structures
- Recommended Channel Cross Section Configuration
- Scour And Deposition At Road Crossings
- Recommended Scour Protection At Road Crossings
- Optimum Sedimentation Basin Location And Alternatives
- Sedimentation Basin Size
- Sedimentation Basin Inlet And Outlet Configuration
- Sedimentation Basin Sediment Trapping Efficiency Analysis

Need for Grade Control Structures. The stable slope analyses, historical channel evaluation, and field investigation included in the geomorphic analysis summarized in Section 4, as well as the HEC-6 sediment continuity analysis described in Section 6, indicated that the existing channel slope was at or near its equilibrium slope. Therefore, for existing conditions, no grade control structures are required. Likewise, since Phase 1 of the project will have no impact on Tatum Wash upstream of the Shea Boulevard sediment trap, no grade control structures are required as part of Phase 1.

Following Phase 2 of the project, general long-term scour downstream of the Phoenix Mountain Preserve detention basin is expected. The equilibrium slope analysis indicated a possible slope adjustment from the existing slope of about 0.011 ft./ft. to a slope of about 0.002 ft./ft. immediately downstream of the detention basin (Table 4-5). Without any grade control, natural or constructed, a total long-term bed elevation change of about 10 feet is possible in the reach between the 40th Street culvert and the Phoenix Mountain Preserve detention basin outlet, based on a slope adjustment from 0.011 to 0.002 ft./ft. Therefore, grade control structures eventually may be required in the reach of Tatum Wash downstream of the proposed Phoenix Mountain Preserve detention basin, depending on factors such as depth to bedrock and the acceptable degree of channel degradation. Four options for grade control are proposed as preliminary design recommendations:

- Option 1. Construct Grade Control Structures. Standard concrete or rip rap drop structures may be placed at regular intervals to maintain the approximate existing grade. The required spacing for grade control structures is discussed below.

- Option 2. Allow Channel Degradation. The greatest degree of long-term degradation will occur in the reach immediately downstream of the detention basin, and will probably be limited to the reach upstream of Fanfol Drive. The HEC-6 models indicated that most of the sediment trapped in the Phase 2 detention basin will be re-supplied by the channel bed upstream of Fanfol Drive. The reach that will experience the greatest amount of long-term scour, located immediately downstream of the proposed Phoenix Mountain Preserve detention basin, is well-defined with stable well-vegetated channel banks, and no road crossings except the fully-lined 40th Street box culvert. Long-term degradation of five feet or more may be acceptable, and not result in any damage to private property.

  The actual magnitude of the long-term degradation downstream of the Phase 2 detention basin may be limited by shallow bedrock, armoring, or other factors. Shallow bedrock was observed in the bed of Tatum Wash, and in the soil pits between Fanfol Drive and 44th Street that will probably prevent the maximum predicted amount of long-term degradation from occurring. Long-term degradation in the reach downstream of Fanfol Drive with low channel banks would improve the conveyance capacity and help eliminate the need for flood control levees to contain the regulatory discharge.

  If Option 2 is selected, geotechnical investigations of the channel bank stability and depth to bedrock should be prepared. The bank stability analyses should consider the stabilizing effects of bank vegetation and caliche versus the destabilizing effects of undercutting by degradation.

- Option 3. Monitor Channel Degradation/Install Grade Control As-Needed. Long-term scour usually occurs over a long time period. The HEC-6 modeling results indicated that the post-detention adjustment in the bed elevation will be relatively small, compared to magnitude of the long-term of the bed elevation changes predicted using the BUREC zero-sediment discharge equations (Table 4-5). Therefore, actual damages to the channel and banks caused by long-term degradation, if any, can be monitored and addressed on an as-needed basis as part of the regular operation and maintenance plan discussed in Section 7.

- Option 4. Conduct Geophysical Exploration to Determine Depth to Bedrock. Field evidence suggest that shallow bedrock exists in the bed of Tatum Wash in most of the reach upstream of 44th Street. If the shallow bedrock exists at an acceptable depth, then it may be more cost-effective to allow the channel to scour to bedrock (if the channel does not armor itself first), than to construct artificial grade control structures. Grade control structures can then be placed in the reaches where shallow bedrock does not exist, and will not prevent unacceptable levels of long-term degradation.

Based on the sedimentation information presented in this report and engineering judgment, Options 3 and 4 are recommended for inclusion in the preliminary design of the Tatum Wash Drainage Improvement Project.

Spacing And Conceptual Design Of Grade Control Structures. Based on the post-Phase 2 equilibrium slope analysis outlined in Section 4 of this report (Table 4-5), grade control structures (Option 1 above) should be constructed about every 250 feet from the Phoenix Mountain Preserve basin to Fanfol Drive. This recommendation is based on the following assumptions:

- Phase 2 long-term equilibrium slope adjustment from about 0.011 ft/ft to 0.002 ft/ft.
- Allowable bed elevation drop at each grade control structure of 2.25 feet
- No channel armoring or shallow bedrock occurs

A conceptual design for a typical concrete grade control structure is shown in Figure 8-1. Table 8-1 shows how grade control spacing would vary with increasing maximum drop elevation at each grade control structure. The actual spacing of grade control structures should be selected based on an economic analysis, safety considerations and trail access requirements.

Table 8-1. Tatum Wash Sedimentation Study
Grade Control Spacing and Allowable Drop Elevation

Spacing Between Structures (ft)	Drop Elevation (ft)	Number Structures: Basin to 40th St.	Number Structures: 40th St. to Fanfol Dr.
250	2.0	4	5
300	2.4	3	4
400	3.2	3	3
500	4.0	2	3

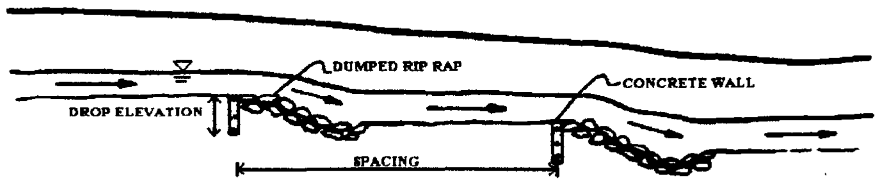


Figure 8-1. Conceptual Design of Grade Control

Recommended Channel Cross Section Configuration. No channelization was proposed as part the District's Tatum Wash Drainage Improvement Plan. No channelization is recommended based on the results of the sedimentation study. If levees are added to the proposed drainage improvement plan at some time in the future, they should be constructed at the effective flow boundaries (Figure 3-8) assumed for the HEC-2 and HEC-6 models used in this study so that the sediment transport characteristics of the wash are not altered.

Channel Modifications to Decrease Sediment Yield. At the request of the District, a proposal to reduce or eliminate sedimentation at Shea Boulevard through channel modification was evaluated. No conceptual or preliminary design specifications for the proposed channel modifications were available. However, the basic concept for channel modifications is to grade a series of adjacent channel reaches to flatter slopes separated by low drop structures. The graded channel sections would be set at a flat enough slope to induce sediment deposition and eliminate the need for a large sediment trap at Shea Boulevard.

Based on sedimentation and geomorphic analyses, the channel modification to reduce sedimentation option is not recommended for the following reasons:

- Shallow Bedrock. Shallow bedrock in the portion of the study that is wide enough to allow storage of significant sediment volumes, would hinder excavation of the channel to a flat enough slope to induce sediment deposition.
- Shallow Slope. The equilibrium slope analysis indicated that the zero sediment discharge slope was about 0.002 ft./ft., nearly an order of magnitude lower than the existing channel slope. Assuming 2.5 feet drops between adjacent section, and an average channel width of 90 feet, a total length of about 1,500 feet would be required to store the average annual sediment yield. 7,500 feet would be required to store the 100-year yield, a distance longer than the unconfined portion of study reach.

- Sediment Delivery Rates. HEC-6 model results indicate that removal of channel vegetation required to construct the channel modifications would increase the sediment transport rate, and require additional storage.
- Suspended Material Load. Channel modifications would be unlikely to capture the suspended portion of the sediment yield.
- Monitoring. Monitoring the amount of sediment deposition for maintenance purposes would be more difficult in a wide channel with a natural appearance than in a well-defined artificial sediment trap basin.
- Maintenance. Sediment removal would become would difficult because the maintenance area would be extended over a long channel distance, rather than a discrete basin, and because the zero-discharge slope would have to be re-grade after each maintenance period.
- Flood Control. Lowering the channel slope and inducing sediment deposition would tend to increase water surface elevations and increase the width and extent of the floodplain.
- Land Ownership. The channel modification option would require obtaining easements or title to all of Tatum Wash (approximately 15 acres) within the modification area.
- Permitting. Sediment removal from the channel would require 404/401 permitting.
- Neighborhood Disturbance. Excavation of the channel and periodic maintenance activities would not likely be a popular option with neighborhood groups.

Scour And Deposition At Road Crossings. The HEC-6 sediment continuity modeling did not indicate that excessive scour or deposition would occur at any of the road crossings in the Tatum Wash study reach. However, evidence observed during the field visits indicated that small scour holes have formed at the downstream side of the at-grade crossings at Fanfol Drive, Onyx Drive and 44th Street. It is recommended that large diameter rock be placed in these scour holes to eliminate the scour hole depression. The rock size may be estimated from the critical armoring diameter (Table 4-6) which indicates that a d50 of about 4 feet or 2 feet would be required for 100-year protection for Phase 1 and Phase 2 of the project, respectively.

Deposition of sediment on the at-grade road crossing will continue to occur during floods on Tatum Wash. Construction of Phase 1 or 2 of the project will not significantly alter this process, nor can the process be effectively prevented, given the current at-grade road crossing configuration. If the at-grade crossings are upgraded to culvert crossings, there is the potential that the total capacity of Tatum Wash could be reduced, and additional breakout flooding could occur. Altering the existing at-grade road crossings in the study reach is not recommended.

Optimum Basin Location And Alternatives. Preliminary design recommendations for the sedimentation basin include the following elements: (1) sediment trap basin size, (2) sedimentation basin inlet and outlet configuration - Phase 1, (3) detention basin inlet and outlet configuration - Phase 2, and (4) sedimentation basin sediment trapping efficiency analysis.

Sediment Trap Basin Size. The following preliminary design recommendations are made based on the results of this study:

- Make basin smaller. There is more sediment storage provided than is required, given that the proposed basin volume is 35 acre feet and the estimated 100-year sediment deposition volume is 15 acre-feet. Basin sizing should reflect the design requirements for the outlet. Alternatively, a portion of the basin could be designated for sediment storage, with the remainder for multiple uses.

- Make basin shallower. The following should be considered: (1) safety concerns associated with an 18 feet deep basin adjacent to the Shea Boulevard right-of-way, (2) outlet invert may be low enough to allow backflow from Shea Boulevard storm drain. The hydraulic grade line of the Shea Boulevard storm drain should be compared to the proposed outlet elevation.

Sedimentation Basin Inlet And Outlet Configuration (Phase 1). The following preliminary design recommendations are made based on the results of this study:

- Erosion Protection. Provide erosion protection for entire channel width at the inlet to the sediment trap basin to prevent headcutting upstream of inlet. Headcutting could damage private property upstream and would cause additional sedimentation in the basin. Figure 8-2 shows a conceptual design for inlet erosion protection. Erosion protection could consist of a concrete or soil-cement slope, articulated revetment, or wire-tied rip rap.
- Energy Dissipator. An energy dissipator, such as a pre-formed rip rap scour hole, should be constructed at the base of the inlet slope. The slope protection should be toed in to the base of the inlet slope and basin floor.
- Backfill Pre-Formed Scour Hole. The pre-formed scour hole basin should be backfilled for aesthetic reasons, and to facilitate sediment maintenance.
- Trash Rack. A trash rack should be designed for basin outlet to prevent floating debris from blocking inlet, and to prevent very coarse sediment from entering storm drain. The trash rack screen size should not allow any sediment sizes in the storm drain that cannot be transported by storm drain flows, or that cannot exit through the storm drain outfall.
- Outlet Clear Space. A wall between sediment trap deposition area and the outlet should be constructed to keep sediment deposition from burying outlet during floods (Figure 8-3).
- Dead Storage. The invert of the outlet should be elevated to allow deposition of ½ to 1 acre foot of sediment deposition or water storage prior to flowing into the outlet. This dead storage area will prevent fine sediments from nuisance flows from entering the storm drain, and will help prevent coarse sediments from rolling into the outlet.
- Access. An access road into basin is required for sediment maintenance and inspection.
- Depth Monuments. Sediment monitoring/survey monuments should be placed at known elevations within the sediment trap basin to allow visual inspection of the depth of sedimentation and facilitate survey of sediment volumes.

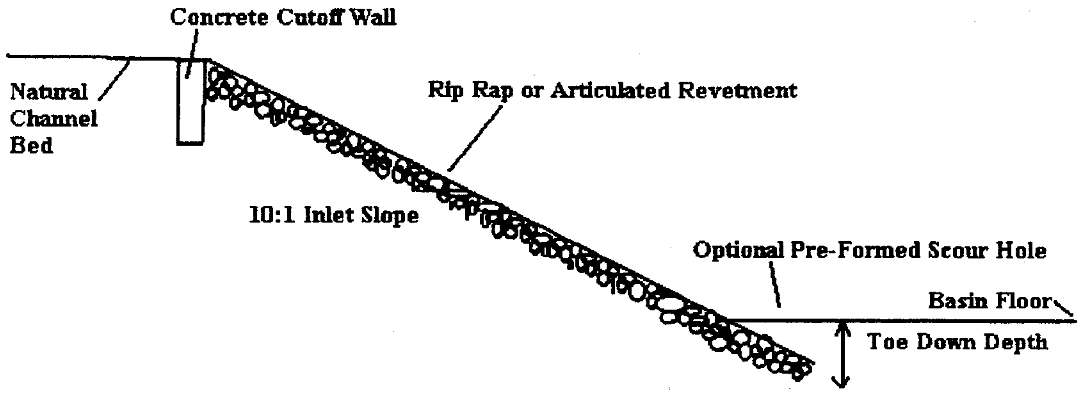


Figure 8-2. Conceptual Design of Sedimentation Basin Inlet

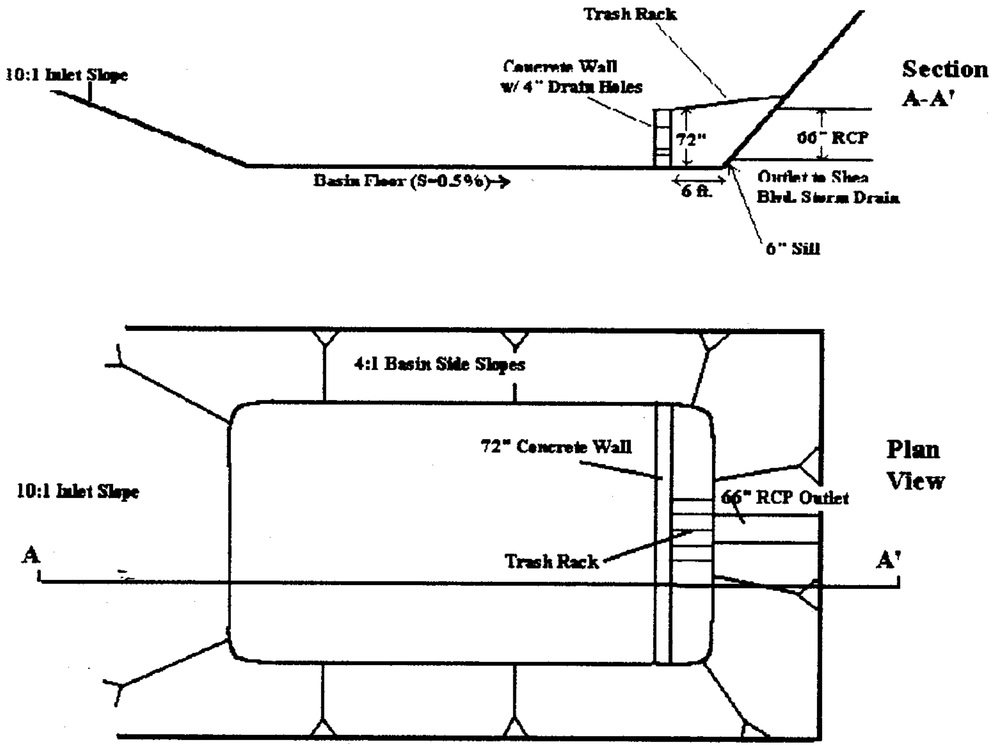


Figure 8-3. Conceptual Design of Sediment Trap Outlet (NTS)

Detention Basin Inlet And Outlet Configuration (Phase 2). The following recommendations are made based on the results of this study:

- Maximum Outflow Rate. The detention basin should be designed with a maximum outflow rates of 550 cfs to eliminate the potential for breakout flows in the channel between the Phoenix Mountain Preserve and Shea Boulevard.
- Erosion Protection. Provide erosion protection for entire channel width at the inlet to the detention basin to prevent headcutting upstream of inlet in the Phoenix Mountain Preserve. Erosion protection could consist of a concrete or soil-cement slope, articulated revetment, or wire-tied rip rap.
- Energy Dissipator. An energy dissipator, such as a pre-formed rip rap scour hole, should be constructed at the base of the inlet slope. The slope protection should be toed in to the base of the inlet slope and basin floor.
- Backfill Pre-Formed Scour Hole. The pre-formed scour hole basin should be backfilled for aesthetic reasons, and to facilitate sediment maintenance.
- Trash Rack. A trash rack should be designed for basin outlet to prevent floating debris from blocking inlet.
- Sediment Trap. A portion of the detention basin near the inlet should be designated for sediment storage.
- Access. An access road to the sediment trap portion of the basin is required for sediment maintenance and inspection.
- Depth Monuments. Sediment monitoring/survey monuments should be placed at known elevations within the sediment trap basin to allow visual inspection of the depth of sedimentation and facilitate survey of sediment volumes.

Sedimentation Basin Sediment Trapping Efficiency Analysis. The sedimentation basin trapping efficiency information was summarized in Section 5 of this report. The estimates of sediment deposition in Table 5-10 are based on the following trap efficiency estimates: (1) 80 percent for the Phase 1 Shea Boulevard sediment trap, (2) 98 percent for the Shea Boulevard sediment trap after construction of the Phase 2 Phoenix Mountain Preserve detention basin, and (3) 100 percent for the Phoenix Mountain Preserve detention basin. Estimates for the Phoenix Mountain Preserve detention basin reflect the smaller drainage area, total flow volume, and smaller sediment yield at the Phoenix Mountain Preserve boundary.

General Design Recommendations

The following general design recommendations are made based on the results of this study:

- Construct the Phoenix Mountain Preserve Detention Basin. Provision of a meaningful level of flood control for neighborhoods downstream of Shea Boulevard is contingent on implementation of Phase 2 of the project. The HEC-1 modeling results indicate that the sediment trap by itself does not provide a significant degree of flow attenuation, and will be overtopped by floods exceeding the two-year recurrence interval. The flood control plan will not be as effective if only Phase 1 of the project is built.

- Tatum Wash Should Remain Undisturbed. No channelization plans should be considered for the study reach of Tatum Wash. The existing channel is at or near equilibrium conditions. Channelization will probably disturbed the existing equilibrium and lead to undesired channel impacts.

- Phoenix Mountain Preserve Detention Basin Sediment Trap. About 17 acre-feet of sediment storage should be provided for in design of the Phoenix Mountain Preserve detention basin. The sediment trap should be located at the inlet of the basin to trap the coarse sediment. Erosion protection similar to that designed for the Shea Boulevard sediment trap should be provided at the inlet to prevent headcutting at the basin inlet slope.

- Multiple Use Facilities. The Phoenix Mountain Preserve Detention Basin should be designed as a multiple use facility, given its location at a popular entry point for the Phoenix Mountain Preserve.

Summary

Design recommendations for the Tatum Wash Drainage Improvement Project were proposed based on the results of the technical analyses performed for the sedimentation study summarized in this report.

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