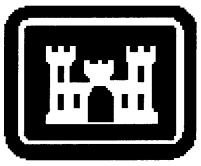
ECONOMICS



US Army Corps
of Engineers
Los Angeles District

TANQUE VERDE CREEK, ARIZONA
LIMITED REEVALUATION REPORT
ECONOMIC ASSESSMENT

Prepared for:

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I. THE STUDY

A. Study Area Location

The study area is located approximately 6 miles east-northeast of downtown Tucson in an unincorporated area generally known as the Tucson Country Club Estates. On the southern side of Tanque Verde Creek, the study area is defined as the area from approximately 2,800 feet west of Sabino Canyon Road to Craycroft Road and for a distance of approximately 1,000 feet south of the Tanque Verde Creek. The northern study area extends from the base of the bluff south to the Tanque Verde Creek between Craycroft Road and approximately 4,200 feet west of Sabino Canyon Road. The study area is essentially fully developed and no future development is anticipated.

B. Authority

This study is being conducted under the authority of the Water Resources Development Act of 1986, Public Law 99-662, 99th Congress.

C. Study Purpose and Scope

The purpose of this Limited Reevaluation Report (LRR) is to determine if the improvements proposed by Pima County, Arizona are economically justified under the existing Rillito River and Associated Streams study authority. These improvements are identified in the report titled "*Rillito River and Associated Streams Bank Stabilization and Riparian Area Preserve - Tanque Verde Creek*," dated December 1996, as prepared by the Pima County Department of Transportation and Flood Control District. This assessment is to present the economic analysis used to measure beneficial contributions to National Economic Development (NED) from erosion damage reduction.

II. EXISTING CONDITIONS

A. Flood Inundation - 100-Year Flood Plain

There are no residential structures located within the 100-year flood plain of the Tanque Verde Creek, with the exception of a secondary structure to a primary, single lot residence. The Tucson Country Club golf course appears to be the only developed property located in the 100-year flood plain. Since streambank stabilization and protection would not provide any additional flood control protection to the study reach of Tanque Verde Creek, further analysis of flood inundation damage reduction in this study is omitted.

B. Erosion Zone Limit

The hydraulic analysis indicates an average annual erosion rate of approximately 13 feet per year and a limiting meander potential for the north bank corresponding to the northern boundary of the geologic flood plain. The limiting meander potential for the south bank is an imaginary line located approximately 1,600 feet south of the projected centerline of the meander loop. Since the south bank is located approximately 500 feet from this centerline, the limiting meander potential for the south bank is approximately 1,100 feet.

III. METHODOLOGY OVERVIEW

A. Guidance and Regulations

This economic assessment is formulated to be in accordance with ER 1105-2-100 (22 April 2000) and the Risk & Uncertainty guidance of ER 1105-2-205. Further, benefits and costs expressed as annual values are calculated utilizing the FY00 discount rate of $6^{5}/_{8}$ percent with a project life of 50 years. All benefits and costs are expressed at a February 2000 price level. The base operational year is 2004.

The following analysis attempts to extend the implicit risk-neutrality of ER 1105-2-100's Chapter 6, Section IV, to urban streambank erosion. Previous Corps studies have dealt with erosion in differing manners, each with its own implied level of risk-taking behavior. In the Corps study "*Rillito River & Associated Streams Feasibility Report,*" dated 1987, the interactions between market price, damage value, and the timing of loss imply a high level of risk-taking behavior on the part of property owners. In contrast, the Corps' study "*Norco Bluffs, California*" a constant erosion rate and the net present modeling (NPV) of the expectation of loss shifts the analysis from risk-neutrality toward risk-averse. This study's analytical approach is to merge the randomness of annual erosion with the long-term expectation of erosion loss in an attempt to bring streambank erosion analysis closer to a true risk-neutral state. This analytical approach is discussed in greater detail in the next section.

B. Computer-based Models and Reference Sources

The following items were utilized for the economic assessment of Tanque Verde Creek:

Models:

(1) HEC-EAD Expected Annual Flood Damage Computation Model

Software:

(1) Microsoft Excel, Version 8
(2) Paradise @RISK, Version 3.05.0006
(3) MicroStation 95

References:

(1) Marshall & Swift Evaluation Services
(2) TRW Redi Real Estate data base
(3) Pima County study area digital CADD files
(4) DATA**QUICK**

C. Database Field Survey

Average structure value, residential land value and the average per acre land value for the Tucson Country Club were prepared by the Real Estate Division of the Corps of Engineers and employed in this analysis.

D. Topographic Mapping

Structure distance from the Tanque Verde Creek streambank was measured using MicroStation 95 and the Pima County CADD files.

IV. RISK & UNCERTAINTY MODELING

A. Synthetic Frequency-Erosion Function

Although the exact nature of the frequency-erosion function is unknown and is dependent upon numerous variables, it is still possible to develop a synthetic representation of the function. While there is still considerable uncertainty in the synthetic function, it is still a valuable tool with which to predict erosion behavior on the creek, especially when combined with a sensitivity analysis.

Development of the synthetic frequency-erosion function begins with identification of several points to be used as the backbone of the frequency-erosion function and the estimated long-term average annual erosion rate. The long-term average annual erosion rate serves as the

control point for the HEC-EAD synthesis of the frequency-erosion function. The HEC-EAD model is used in this process as a tool for the integration of data points for their comparison to the control point of long-term average annual erosion. Within the HEC-EAD model a subroutine exists for the identification of the model's internal calculations of intermediate points between the backbone points. The manipulation of these intermediate points to control the expected annual rate generated by HEC-EAD to the estimated long-term average annual rate is possible through expansion of the data points beyond the initial backbone data set. Through this manipulation of intermediate data points it is possible to construct a synthetic frequency-erosion function with a historical basis that approximates the long-term average annual erosion rate.

The engineering analysis indicates that the greatest historical erosion event observed was on the order of 200 feet. Conservatively capping erosion at 195 feet for the frequency event of 0.0001 sets the upper backbone limit for the synthetic frequency-erosion function. The engineering analysis also indicates that an erosion rate of 90 feet for the .01 frequency event is consistent with the observed data and a non-erosion frequency could be defined as the 3-year event. These points serve as the backbone events for the HEC-EAD model for the derivation of the initial frequency-erosion function along with the engineering analysis' estimate of the long-term annual erosion rate at 13 feet. Through a process of intermediate point additions and manipulations within the HEC-EAD model, Table 1 shows the HEC-EAD model inputs of frequency-erosion pairings that yield an expected annual erosion rate of 13.02 feet.

Table 1
Derivation of Synthetic Frequency-Erosion Function
HEC-EAD Frequency-Erosion Pairings

Frequency	Erosion (feet)
.30	0
.29	5
.25	20
.10	50
.01	90
.005	130
.0001	195

Although the HEC-EAD model produces a reasonable estimate of the frequency-erosion function, it is not in a form readily accessible for risk-based computer modeling. The HEC-EAD relationships must be transformed into a usable modeling form. This transformation was accomplished through the use of the expanded output matrix of HEC-EAD and the CUMUL function of @RISK. The CUMUL function takes the following form where x denotes lateral erosion and p the cumulative probability.

CUMUL(min,max,{x_1,...,x_n},{p_1,...,p_n})

The Excel data matrix for the CUMUL function is,

RiskCumul(0,210,{0.000001,0.62,2.66,4.51,5,6.93,13.34,18.74,20,24.06,34.72,45.71,50,52.76,63.63, 82.15,90,91.22,104.29,124.21,130,135.78,159.14,186.54,195},{0.7,0.70113,0.705,0.70887,0.71,0.71451, 0.73,0.74549,0.75,0.76691,0.825,0.88309,0.9,0.91014,0.945,0.97986,0.99,0.99056,0.9925,0.99444, 0.995,0.99555,0.99745,0.99935,0.9999})

The expected value of the RiskCumul function is 13.07.

B. Expectation of Erosion

At any given point in time, it is assumed that a property owner perceives risk based on the position of the property in relation to the current position of the streambank and the long-term average erosion rate. Under this concept, the property owner experiences the random fluctuations in erosion but does not alter his risk factor by this randomness.

Calculation of damage employs the Net Present Value (NPV) technique with the modification that erosion is a random annual event rather than using a constant, average annual rate as in the case of the Norco Bluffs study.

C. R&U Model Process

The R&U process is modeled in Excel employing @RISK add-ins. First, the model produces a random erosion rate based on the RiskCumul function and uniformly shifts the streambank toward the structures by this amount. Second, the NPV of the property owners expected future loss is estimated based on the current existing condition of the streambank in relation to the long-term erosion rate. This process is then repeated annually for the duration of the study life. The individual losses are summed by year and the change in the annual total is computed, producing a stream of net annual losses. This stream of future net annual losses is transformed using the NPV technique to an equivalent current dollar loss. Finally, this equivalent current dollar loss is amortized, producing an equivalent annual dollar loss.

This process was repeated 5,000 times generating a distribution of potential outcomes for statistical analysis.

1. Residential Structure and Land Loss

The NPV random erosion process above applies to residential structures and land. The only modification to the process described above is the assumption of a 13-foot condemnation zone around the structure. In the analysis, if erosion has proceeded within 13 feet of the structure but has not yet destroyed the structure, the structure is deemed uninhabitable and lost.

2. Residential Content Loss

Residential content loss applies the basic principles of the R&U model with one major exception. This exception is that a loss only occurs when the streambank's annual erosion extends from outside the 13-foot condemnation zone beyond the structure's starting location. This assures that contents are only lost when the structure is destroyed and not by condemnation.

3. Sewer Line Loss

Sewer line loss applies the same principles of residential content loss in that damage to the sewer line occurs when the random erosion process proceeds past the location of the sewer line.

V. RESIDENTIAL CONTENT VALUE

Chapter 6, Section 6-45 (2) (a) of ER 1105-2-100 requires that, for feasibility studies, all content-to-structure ratios must be based on either site-specific surveys or surveys of comparable floodplains. It also requires that in areas where surveys of comparable floodplains are used, at a minimum, a qualitative rationale must be provided to demonstrate comparability of the survey to the study floodplain. For this study, the results of the "*Tucson Area Drainage Feasibility Study, Arizona*" will be used, since they are qualitatively very similar due to their proximity to a nearby golf course and their proximity to each other. Therefore, the residential content-to-structure value percentage is 50%.

VI. EROSION ZONE INVENTORY

The erosion zone consists of residential properties, an existing sewer line, a proposed sewer line, and the Tucson Country Club. There are 56 residential structures within the 1,100-foot maximum erosion zone. Real estate values were determined by the Real Estate Division of the US Army Corps of Engineers, Los Angeles District. The estimate for total value (structure plus land) is $125 per square foot of structure. The estimated structure-only portion of total value is $85 per square foot. Content value was assumed to be 50 percent of structure value. Individual structure square footage measures were obtained from DATA**QUICK**, a real estate service. Residential structures in the study area range from 1,800 to more than 6,000 square feet in size, with the average being 3,439 square feet. The total value of residential property subject to the erosion threat is shown in Table 2. Potential Tucson Country Club golf course erosion damages are detailed in Table 3.

Table 2 **Erosion Zone Residential Inventory**	
Number of Structures	56
Average Structure Value	$292,315
Average Residential Lot Value	$137,560
Average Content Value	$146,158
Total Structure Value	$16,368,195
Total Lot Value	$7,702,680
Total Content Value	$8,184,098
Total Residential Inventory Value	**$32,254,973**

Table 3 **Potential Damages to Tucson Country Club**			
Structures & Facilities: *Pool House & Pool* *Pavilion Banquet Hall* *4 Maintenance Buildings* *Tennis House & 12 Courts*			
Golf Course Hole:	Potential for Erosion Damage		
	Green	Tee	Fairway
2	X		X
3	X	X	X
4	X	X	X
5	X	X	X
6	X	X	X
7		X	X
11	X		X
12	X	X	X
13		X	X
16	X	X	X
17		X	X

The North Rillito Interceptor, a 30" sewer line, runs along the base of the bluff on the north side of Tanque Verde Creek. For the most part, the North Rillito Interceptor ranges from 300 to 600 feet from the Tanque Verde Creek. However, immediately upstream of Craycroft Road and for a distance of approximately 1,550 feet, the North Rillito Interceptor is within 100 feet of the creek. If a line break should occur, it is impossible to close down flow without inducing sewer back-flow into residential properties due to the interceptor's gravity flow design. According to the Pima County Wastewater Management Department, it is likely that a line break during a storm event could produce a 20 million-gallon release of wastewater prior to its containment. On the south side of the Tanque Verde Creek, Pima County has awarded an engineering and design contract for the construction of the new 36" Tanque Verde Interceptor Extension sewer line. This interceptor will parallel the Tanque Verde Creek from Craycroft Road east to the Tucson Country Club. This project was approved with the 1997 sewer system revenue bond ballot initiative. Bond funding for this project is $4,050,000. Erosion protection for this project is estimated to increase its overall cost to $5,800,000.

VII. WITHOUT-PROJECT EROSION DAMAGE

A. North Rillito Interceptor

The North Rillito Interceptor (NRI) runs parallel to Tanque Verde Creek in the vicinity of Craycroft Road. Erosion has the potential to undercut NRI's supporting land and subject the sewer line to failure. NRI has a replacement value of $4,611,600 as estimated by the Wastewater Management Department of Pima County. Only the first 1,550 feet of the NRI east of Craycroft Road are considered subject to erosion in this analysis. It is estimated that the sewer line is 65 feet from the creek bank within this 1,550-foot zone. Further, it is assumed that the value of the first 1,550 feet is proportionate to the overall value of the interceptor. Under this assumption, the value of the sewer line in the 1,550-foot zone is $1,235,900. With a base year of 2004, under the R&U model of random annual erosion, there is a 9% chance that the sewer line would be damaged prior to the provision of streambank protection (based on 30,000 iterations of a 50-year study horizon). It is further assumed that if the sewer line is damaged prior to the project, the entire 1,550-foot zone will be protected from future erosion damage. Under these assumptions, the mean unweighted NPV of the damage to the sewer line is $785,700. Thus, the weighted NPV of sewer line damage is $715,000. The amortized value of the weighted damage is $49,400.

When the sewer line fails, wastewater is released into the environment. Previous Corps studies (most notably the Emergency Streambank Protection report on Walnut Canyon Creek, City of Anaheim, California) have estimated the cleanup cost from a sewer line failure in the range of 1 to 66 cents per gallon. For the purposes of this analysis, a cost of 6.4 cents per gallon is assumed. It is estimated that a sewer line failure would release 20,000,000 gallons of wastewater before containment, as previously reported. Using the random annual erosion model and the NPV technique of converting future damage at the occurrence of a sewer line break to

current dollars, the unweighted mean damage estimate is $812,000. Its weighted mean value is $738,900 with an amortized value of $51,000.

B. Tanque Verde Interceptor Extension

The Tanque Verde Interceptor Extension project should be considered implemented for the without-project condition. The potential "damage" reduction for the extension project in a with-project condition is an avoided cost saving. With a base year of 2004, a Corps project would be in place prior to the construction of the extension project avoiding the need for the $1.74 million cost of erosion protection for the extension project. On an annual basis the avoided cost savings has a value of $120,100.

C. Tucson Country Club

The Tucson Country Club was incorporated in 1947 under the laws of Arizona. The club was organized in conjunction with one of the most prestigious subdivisions in Tucson. The clubhouse, tennis courts, swimming pool, and golf course cover approximately 200 acres. The golf course is unique to central and southern Arizona not only because of its size, but because of the significant number of trees which line the fairways. The 2000 trees estimated on the course make it unique in southern Arizona. The golf course could not be replaced elsewhere because water laws now limit the number of acre-feet of water that new golf courses can utilize. Tucson Country Club is exempt from these stringent water use requirements.

The economic analysis related to the Tucson Country Club considers the impact of erosion on the corporation. Traditional approaches of evaluating changes to potential net income fail because private organizations are not structured to respond to the market forces of supply and demand as are other free market corporations. The Country Club's purpose is not to maximize profits. The Tucson Country Club has 425 Regular class members. Regular class members represent the only classification which has equity in the corporation. Recent transactions of membership certificate exchanges place the value at $30,000. At this value, the indicated nonmarket value of the Country Club would be $12,750,000. Although this is a nonmarket evaluation, a measure of the impact of erosion on the corporation is the change in membership value. Past, direct experience with flooding and erosion at the Country Club helps to define changes in membership value, as follows.

Examination of the response in membership value to the 1983 flood and erosion to one fairway will shed some light on the loss of corporate value. Membership sales averaged $14,313 in the four months prior to the flood of 1983. There were 21 sales, not including transfers to relatives, during this period. In the seven months subsequent to the 1983 flood, through July 1984, there were only 13 sales, not including transfers to relatives. During this period, the average price dropped to $9,958. This 30% decline in membership value occurred even though there was sufficient land to move the fairway slightly without rebuilding the entire hole.

Although membership value has recovered and no permanent loss occurred, it is expected that this will not be the case following an erosive event in the future. The erosion of 1983 has left the golf course without any flexibility to realign holes immediately adjacent to Tanque Verde Creek since sufficient land near the creek is no longer available and the Country Club is land locked by development. Future erosion left unabated will require redesign and reconstruction of the golf course to a less desirable "executive" course. In this case, it is reasonable to assume the corporation's value would greatly decrease given the historical response to the 1983 flood. However, unlike the long-term response to the 1983 flood, membership value would likely not recover since the effects would be permanent.

Erosion left unabated would damage the facilities and golf course holes shown in Table 3. Given the extent of this potential damage, the use of the decline experienced in 1983, 30 percent, may be considered conservatively low. An irreversible 30 percent loss in the "market value" of the Tucson County Club would be $3,825,000.

Economic reasonableness dictates the limiting of damages from the Country Club to the cost of streambank erosion protection since the existing condition on Tanque Verde Creek would allow for construction to solely protect the Country Club. It is estimated that the cost of streambank stabilization for the area of the Country Club would be approximately $2,100,000. Economically, it would be more rational for the Tucson Country Club to expend $2.1 million to protect itself rather than to suffer the $3.83 million loss to erosion. Therefore, erosion damages to the Tucson Country Club on a National Economic Development basis are $2.1 million. On an annual basis, this loss is $144,500.

It should be noted that others would derive benefits from the actions of the Tucson Country Club if it were to provide streambank erosion protection for the Club. Namely, the residential damages discussed in the following section would be eliminated with this construction and the protection of the Tanque Verde Interceptor would not be necessary in the area of the Country Club.

D. Residential Structures

The results of the 5,000 iteration runs for the R&U model for structures and land[1], and contents, as outlined in Section IV of this report, indicated a mean NPV for structure and land damage of $4,620,091 and a mean NPV of $436,402 for content damage. The respective standard deviations were $1,432,916 and $298,717. The NPV distribution for structures and land damage is shown in Figure 1. Figure 2 shows the distribution of content NPV damage. Amortizing the NPVs at $6^5/_8$ percent over 50 years yields the following annual damages:

- Annual Structure & Land Damage: $319,000
- Annual Content Damage $30,100

[1]Loss of land value occurs only at the time of structure loss. No accounting is made for incremental land losses before the loss of structure.

Total annual damage to residential structures is $349,100.

FIGURE 1

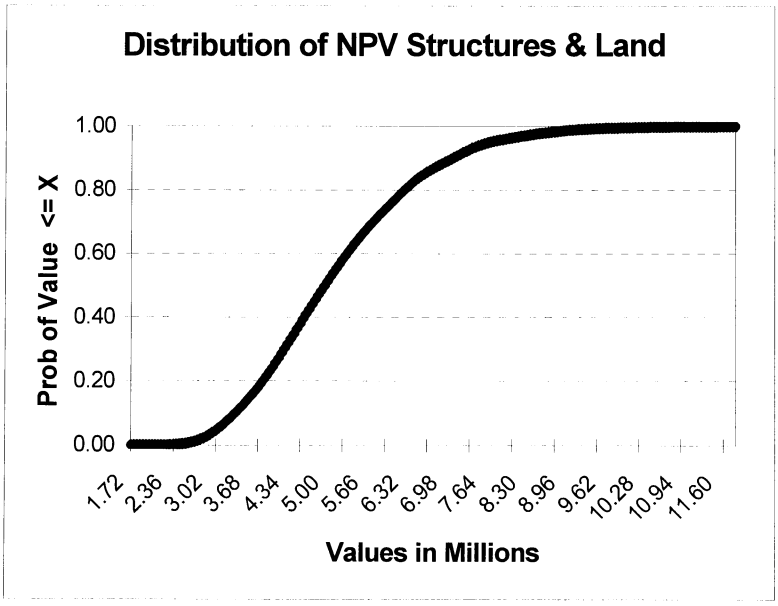
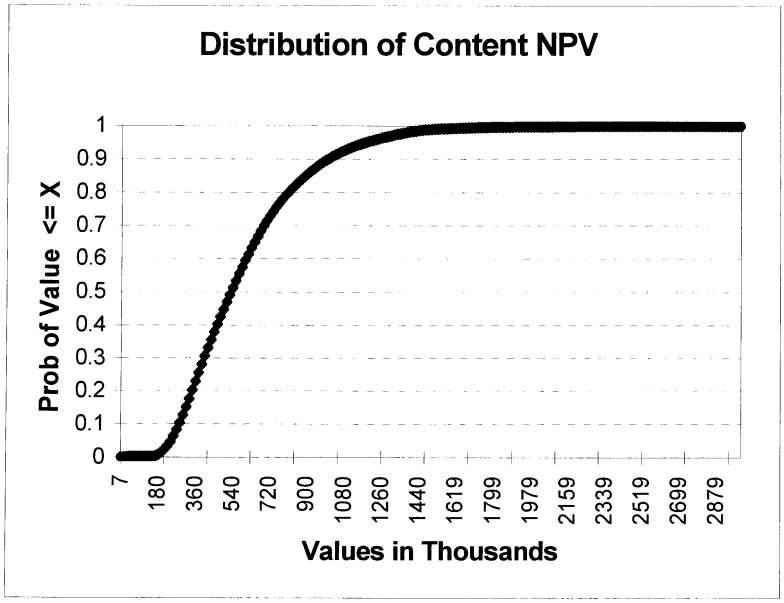


FIGURE 2



E. Without-Project Equivalent Annual Damage Summary

Table 4 presents a summary of the equivalent annual damages of the without-project condition.

Table 4
WITHOUT-PROJECT EQUIVALENT ANNUAL DAMAGES

Category	Equivalent Damage
Residential Structures & Land	$319,000
Residential Contents	$30,100
North Rillito Interceptor	$49,400
Sewer Spill Cleanup Costs	$51,000
Tanque Verde Interceptor	$120,100
Tucson Country Club	$144,500
Total	$714,100

VIII. WITH-PROJECT DAMAGE REDUCTION

The effect of the proposed streambank protection is to preclude the damages outlined above. Therefore, the annual benefit of providing streambank protection is $714,100.

A. With-Project Economics

Proposed streambank protection consists of four (4) alternatives. These alternatives are as follows.

Alternative 1: The no-action plan;

Alternative 2: The recommended plan and preferred by Pima County. This alternative fully addresses the identified problems along the Tanque Verde Creek between Sabino Canyon Road and Craycroft Road. The structural measures include installing soil cement bank protection in the existing gaps in bank protection on the south bank, and installing approximately 1,550 feet of bank protection upstream of the Craycroft Road Bridge on the north bank. The horizontal alignment of the proposed bank protection would be along smooth curves that generally follow the existing bank. Where applicable, the ends would match the existing soil cement. On the south bank, at the downstream end, the proposed soil cement would key into the bank just upstream of the confluence with Pantano Wash.

On the north bank, at the upstream end, the soil cement would key into the existing bank

and be tied back to high ground. The soil cement would match the top of the existing bank, and the toedown would extend 10 feet below the existing thalweg.

The soil cement layer would be an 8-foot thick layer of soil and portland cement that is mixed and placed in 6-inch to 1-foot thick lifts. The lifts are successively placed until the desired bank protection height is reached. Once compacted, the soil cement mixture provides a hard and durable surface that is expected to last well over the project life of 50 years.

The mitigation component of the proposed plan includes acquiring the rights-of-way to establish a permanent 500-foot buffer along the north bank. Public ownership of this land would prevent additional development and the associated flood damages, while preserving the riparian values of this heavily vegetated area.

Alternative 3: This plan would be identical to Alternative 2 except approximately 2,830 feet on the south bank just upstream of the Craycroft Road bridge would not receive bank protection. The protection on the south bank would instead tie into the existing protection upstream of the golf course and continue to just downstream of the golf course, to beyond the site of the historic meander. The unprotected portion of the south bank would be allowed to erode naturally.

Alternative 4: This plan would be identical to Alternative 2 except that the habitat area would receive erosion protection to reduce the rate of erosion and thereby increase environmental benefits. This would be accomplished by constructing a low soil cement berm adjacent to the bank of the habitat area. The berm would stabilize the slope yet be sized to allow overtopping from the 5-10 year flood so as to allow flushing flows. It is estimated that the berm would be approximately 2 feet above ground with toe-down depths the same as with the upstream and downstream slope protection (approximately 10 feet).

Alternative 2

Alternative 2 is preliminarily estimated to have a total construction cost of $3,560,400. Interest during construction (IDC), based on a one-year time frame, is $117,900. Amortization of the total economic cost ($3,678,300) yields an annual economic cost of $253,965. The annual OMRR&R cost for Alternative 2 is estimated to be $17,900. Therefore, the total annual economic cost for Alternative 2 is estimated to be $271,865. Alternative 2 would prevent all damages and has annual NED benefits of $714,100. The NED economics of Alternative 2 are shown in Table 5 below.

Table 5 ALTERNATIVE 2 NED ECONOMICS Annual Costs & Benefits February 2000 price level			
NED Costs	NED Benefits	B/C Ratio	Net Benefits
$271,865	$714,100	2.63	$442,235

Preliminary Cost Estimate - Alternative 2

Item	Units	Quantity	Unit Cost	Cost
Clearing and Grubbing	L.S.	1	$20,000.00	$20,000
Removal of Structures & Obstructions	L.S.	1	$20,000.00	$20,000
Diversion and Control of Water	L.S.	1	$20,000.00	$20,000
Dewatering	L.S.	1	$20,000.00	$20,000
Drainage Excavation	C.Y.	26,000	$3.00	$78,000
Compacted Fill	C.Y.	29,000	$3.50	$101,500
Soil Cement Bank Protection	C.Y.	43,000	$9.00	$387,000
Stabilizer for Soil Cement	Ton	8,400	$110.00	$924,000
Safety Hand Rail	L.F.	8,250	$12.00	$99,000
Subtotal				**$1,669,500**
Contingency (20% of Subtotal)				$333,900
Total Construction Cost				**$2,003,400**
Mobilization (3%)				$60,102
Design Engineering Cost (6%)				$120,204
Construction Admin. & Field Inspection (15%)				$300,510
Right-of-Way			$295,610.00	$295,610
Mitigation Land			$780,560.00	$780,560
TOTAL PROJECT COST				**$3,560,386**

Alternative 3

Alternative 3 deletes bank protection for a 2,830-foot segment on the south bank upstream of the Craycroft Road Bridge from Alternative 2. This bank protection deletion subjects the Tanque Verde Interceptor Extension project to erosion in this area reducing the avoided cost savings benefit. The estimated cost to provide erosion protection to the interceptor extension in this area is $1,052,600. At this cost level, the Tanque Verde Interceptor avoided cost benefits would be reduced by $72,700 to an annual equivalent of $47,400. Overall annual NED benefits for Alternative 3 would be $641,400. Alternative 3 is estimated to have a total construction cost of $2,710,840. Interest during construction (IDC), based on a one-year time frame, is $89,800.

Amortization of the total economic cost ($2,800,640) yields an annual economic cost of $193,400. The annual OMRR&R cost for Alternative 3 is estimated to be $17,900. Therefore, the total annual economic cost for Alternative 3 is estimated to be $211,300. The NED economics of Alternative 3 are shown in Table 6 below.

Table 6
ALTERNATIVE 3 NED ECONOMICS
Annual Costs & Benefits
February 2000 price level

NED Costs	NED Benefits	B/C Ratio	Net Benefits
$211,300	$641,400	3.04	$430,100

Preliminary Cost Estimate - Alternative 3

Item	Units	Quantity	Unit Cost	Cost
Clearing and Grubbing	L.S.	1	$20,000.00	$20,000
Removal of Structures & Obstructions	L.S.	1	$20,000.00	$20,000
Diversion and Control of Water	L.S.	1	$20,000.00	$20,000
Dewatering	L.S.	1	$20,000.00	$20,000
Drainage Excavation	C.Y.	17,445	$3.00	$52,336
Compacted Fill	C.Y.	17,364	$3.50	$60,773
Soil Cement Bank Protection	C.Y.	29,600	$9.00	$266,400
Stabilizer for Soil Cement	Ton	5,800	$110.00	$638,000
Safety Hand Rail	L.F.	5,536	$12.00	$66,426
Subtotal				**$1,163,935**
Contingency (20% of Subtotal)				$232,787
Total Construction Cost				**$1,396,722**
Mobilization (3%)				$41,902
Design Engineering Cost (6%)				$83,803
Construction Admin. & Field Inspection (15%)				$209,508
Right-of-Way			$198,345.00	$198,345
Mitigation Land			$780,560.00	$780,560
TOTAL PROJECT COST				**$2,710,840**

Alternative 4

Alternative 4 is identical to Alternative 2 with the addition of low-flow bank stabilization for the habitat area. This alternative would prevent all damages as like Alternative 2. The additional cost of low-flow bank protection is estimated at $1,021,200, resulting in a total construction cost of $4,581,600. IDC for this alternative is estimated at $151,800 which yields an economic cost of this alternative of $4,733,400. The amortized cost of this alternative is $326,800. The annual OMRR&R cost for Alternative 4 is estimated to be $17,900. Therefore, the total annual economic cost for Alternative 4 is estimated to be $344,700. The NED economics of Alternative 4 are shown in Table 7 below.

Table 7
ALTERNATIVE 4 NED ECONOMICS
Annual Costs & Benefits
February 2000 price level

NED Costs	NED Benefits	B/C Ratio	Net Benefits
$344,700	$714,100	2.07	$369,400

Preliminary Cost Estimate - Alternative 4

Item	Units	Quantity	Unit Cost	Cost
Clearing and Grubbing	L.S.	1	$20,000.00	$20,000
Removal of Structures & Obstructions	L.S.	1	$20,000.00	$20,000
Diversion and Control of Water	L.S.	2	$20,000.00	$40,000
Dewatering	L.S.	2	$20,000.00	$40,000
Drainage Excavation	C.Y.	29,000	$3.00	$87,000
Compacted Fill	C.Y.	29,000	$3.50	$101,500
Soil Cement Bank Protection	C.Y.	63,700	$9.00	$573,300
Stabilizer for Soil Cement	Ton	12,500	$110.00	$1,375,000
Safety Hand Rail	L.F.	8,250	$12.00	$99,000
Subtotal				**$2,355,800**
Contingency (20% of Subtotal)				$471,160
Total Construction Cost				**$2,826,960**
Mobilization (3%)				$84,809
Design Engineering Cost (6%)				$169,618
Construction Admin. & Field Inspection (15%)				$424,044
Right-of-Way			$295,610.00	$295,610
Mitigation Land			$780,560.00	$780,560
TOTAL PROJECT COST				**$4,581,600**

Summary of Alternatives

Table 8 summarizes the findings on the soil cement revetment alternatives.

Table 8
Summary - Soil Cement Revetment Alternatives

Alternative	Annual			
	NED Costs	NED Benefits	B/C Ratio	Net Benefits
Alternative 2	$271,865	$714,100	2.63	$442,235
Alternative 3	$211,300	$641,400	3.04	$430,100
Alternative 4	$344,700	$714,100	2.07	$369,400

Each alternative displays positive net benefits and will be a candidate for the NED plan if it satisfies the other constraints of plan formulation, especially those regarding environmental mitigation.

Incremental Analysis of Components

The Tanque Verde system consists of three elements: (1) a 4,220' bank stabilization element along the golf course on the south bank of the river, (2) a stabilization element connecting Craycroft Road to the existing bank stabilization 2,830 feet upstream on the south side of the river and, (3) a bank stabilization element on the north bank of the river stretching upstream from Craycroft Road 1,550 feet. The first element, the golf course alignment, is not incrementally analyzed as it covers virtually all of the residential structures in the study area. The second and third elements are incrementally analyzed under the following assumptions, (1) no IDC accrues and (2) element costs are proportionate to the total construction cost based on element length.

North Bank Protection - North Rillito Interceptor

Benefits for this element are the previously discussed benefit categories of (1) North Rillito Interceptor and (2) Sewer Spill Cleanup Costs. Table 4 indicates that the without project annual damages are $49,400 and $51,000, respectively. Annual benefits are $100,400, given that this element would prevent these damages. The length of the element is 1,550 feet, 19% of all non-habitat construction. The proportionate share of total construction cost (Table 5) is $380,600, having an amortized annual value of $26,300. Net annual benefits are $74,100 and with a B/C ratio of 3.8.

South Side - Craycroft Road to Existing Protection

The benefits for the bank stabilization element from Craycroft Road to 2,830 feet upstream where protection currently exists take the form of an avoided cost savings in the design of the Tanque Verde Interceptor (TVI). If no erosion protection is provided, the Sewer

Department will expend $1.75 million to protect TVI from erosion. The annual cost of this expenditure is $120,800.

The prorated total construction cost of the Corps plan for the 2,830 feet of TVI protection is $667,800. The annualized value of this expenditure is $46,100. Thus, implementing the Corps plan would produce a net avoided annual cost savings of $74,700 with a benefit/cost ratio of 2.6.

B. Plan Selection

Table 8 indicates that the addition of the 2830-foot segment on the south bank of the Tanque Verde Creek is incrementally justified. A detailed analysis of this fact is presented above, as well as, the incremental justification of the northern bank component. As described earlier, the difference between Alternative 2 and 3 is that Alternative 2 contains the 2830-foot protection on the southern bank. An examination of the change in net benefits between Alternatives 2 and 3 reveals a net benefit increase of $12,135 with the change in project scope from Alternative 3 to Alternative 2. These added positive net benefits are attributable to the 2830-foot segment.

If the incremental justification of the 2830-foot south bank segment is acknowledged, further detailed analysis of Alternative 3 would not be warranted as NED requirements would dictate plan selection towards Alternative 2, unless there was a locally preferred exception. Given the absence of a locally preferred exception, further detailed analysis of Alternative 3 has not been conducted for this economic assessment.

As a result of the preliminary findings on costs and benefits, Alternatives 2 and 4 remain as potential NED candidates. However, the environmental assessment of these plans, as detailed in Appendix B-5: Incremental Cost Analysis and Habitat Evaluation of the Environmental Assessment (EA), indicates that the acquisition of the 48-acre preserve area will not fully mitigate the environmental impacts associated with the construction of Alternative 2. Specifically, the EA states:

> *"The mitigation goal for the Recommended plan is to maintain a minimum of 40.46 AAHUs [average annual habitat units]. With the preserve, a deficiency of 1.6 AAHUs remains. The 48-acre preserve is, therefore, not adequate mitigation for Alternative 2."*

The EA further indicates that Alternative 4 exceeds the minimum goal of 40.46 AAHUs by 4.43 AAHUs (44.48 AAHUs in total) making Alternative 4 consistent with the goals of plan formulation. Alternative 4 is identified as the NED plan, for the above reasons, and is the plan selected for detailed cost (M-CACES) and benefit analysis.

C. Selected Plan

The plan selected for recommendation is Alternative 4. This plan was selected because it most closely meets the planning objectives identified for this study, including:

- Provides reduction of flood hazards and associated inundation damages along Tanque Verde Creek;
- Provides protection and, where appropriate, enhancement of existing riparian and wildlife resources of the existing stream environments;
- The selected plan is complete in and of itself and should not require additional improvements in the future;
- The selected plan is "justified" in the sense that total beneficial effects associated with the objectives are equal to or exceed the total adverse effects associated with the objectives; and
- The plan is generally acceptable to the public.

The following discussion presents Alternative 2 at a higher level of consideration, M-CACES level, for analysis of its benefits and costs.

Project Description

The selected plan, Alternative 4, fully addresses the identified problems along the Tanque Verde Creek between Sabino Canyon Road and Craycroft Road while including both structural and non-structural measures. The structural measures include installing soil cement bank protection in the existing gaps in bank protection on the south bank, and installing approximately 1,550 feet of bank protection upstream of the Craycroft Road Bridge on the north bank. The horizontal alignment of the proposed bank protection would be along smooth curves that generally follow the existing bank. Where applicable, the ends would match the existing soil cement. On the south bank, at the downstream end, the proposed soil cement would key into the bank just upstream of the confluence with Pantano Wash.

On the north bank, at the upstream end, the soil cement would key into the existing bank and be tied back to high ground. The soil cement would match the top of the existing bank, and the toedown would extend 10 feet below the existing thalweg. In addition, limited bank protection will be constructed for the preserve area. This limited bank protection will be a low soil cement berm (approximately 5,000 feet in length) with "weep holes" to maintain the hydrologic connection between the creek and the preserve. The berm will stabilize the slope and allow for the continued overtopping of flood waters with events greater than approximately 10-years in size by its low 2-foot height.

The soil cement layer would be an 8-foot thick layer of soil and portland cement that is mixed and placed in 6-inch to 1-foot thick "lifts." The lifts are successively placed until the

desired bank protection height is reached. Once compacted, the soil cement mixture provides a hard and durable surface that is expected to last well over the project life of 50 years.

The proposed action would affect desert riparian habitat, including mesquite bosque habitat, along Tanque Verde Creek. A total of approximately 9.9 acres of habitat would be lost, including approximately 1.9 acres of moderate to high quality mesquite bosque habitat and 8.0 acres of disturbed desert wash habitat. Impacts to wildlife in the disturbed desert wash area will be minor because relatively few species inhabit these areas, and most are relatively common. Impacts to wildlife found in the mesquite bosque habitats would include temporary and permanent displacement and mortality of some wildlife that is unable to escape.

Mitigation of the proposed plan, in addition to the berm, involves acquiring the rights-of-way to establish a permanent 500-foot buffer along the north bank. Public ownership of this land (approximately 48 acres) would prevent additional development and the associated flood damages, while preserving the riparian values of this heavily vegetated area.

Project Performance and Residual Flooding

The soil cement bank stabilization will provide a hard and durable surface that is expected to last well over the project life of 50 years and will prevent future movement of the banks in the protected areas. Alternative 4 will not increase nor decrease the current level of overbank flood protection. The 100- and 500-year overflows for the Tanque Verde Wash will remain as present.

Plan Benefits

The Selected Plan would prevent erosion damage to residential structures, the North Rillito Interceptor, and the Tucson Country Club; while providing for an avoid cost saving benefit to the construction of the Tanque Verde Interceptor Extension project and the prevention of damage from sewage releases. The equivalent annual damage prevented by the plan is $714,100, as shown below.

Table 9 Equivalent Annual Damage Prevention (February 2000, price level)	
Category	**Damage Prevention**
Residential Structures & Land	$319,000
Residential Contents	$30,100
North Rillito Interceptor	$49,400
Sewer Spill Cleanup Costs	$51,000
Tanque Verde Interceptor	$120,100
Tucson Country Club	$144,500
Total	**$714,100**

Detailed Cost Estimate

Table 10 presents a summary of the detailed M-CACES cost estimate for the selected plan. The costs for all structural flood control elements, right-of-way, mitigation, and costs associated with operating, maintaining, replacing, repairing, and rehabilitating (OMRR&R) the selected plan are included.

Table 10 Summary of Detailed Cost Estimate

(May 2000, price level)

Item	Cost
Clearing and Grubbing	$20,000
Removal of Structures & Obstructions	$20,000
Diversion and Control of Water	$40,000
Dewatering	$40,000
Drainage Excavation	$87,000
Compacted Fill	$101,500
Soil Cement	$573,300
Pozzolan, for Soil Cement	$1,375,000
Safety Hand Rail	$98,990
Subtotal	$2,355,790
Contingency (20% of Subtotal)	$471,160
Total Construction Cost	$2,826,950
Mobilization	$54,610
Design Engineering Cost	$170,916
Construction Admin. & Field Inspection	$452,944
Right-of-Way	$295,610
Mitigation Lands	$780,560
TOTAL PROJECT COST	$4,581,590
IDC	$151,765
Gross Investment	$4,733,355
Annualized Cost (50-yrs, $6^{5}/_{8}\%$)	$326,800
OMRR&R	$17,900
Total Annual Cost	**$344,700**

The B/C ratio for the Selected plan ($714,100/$344,700) is 2.07 with net positive NED benefits of $369,400.