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FINAL REPORT
SOUTH BRANCH, UPPER CARMACK
SUB-BASIN MANAGEMENT STUDY
PHASE II

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I. INTRODUCTION

This report presents the results of an expanded qualitative and quantitative evaluation of the relative impact of those mitigation measures that were identified, during the Phase I study, as being the most appropriate and cost-effective to address the drainage problems inherent to the study area (i.e., the South Branch, Upper Carmack drainage basin from the Carmack Wash upstream to the Forest Service boundary, Figures 1 and 2). In addition, preliminary cost estimates are provided for each mitigation measure, and a recommendation is made as to which mitigation measures should be implemented.

1.1 Phase I Summary

Phase I represented an existing-conditions analysis of the study area. As part of that study, a hydrologic analysis and a flood plain analysis were first conducted to identify potential flood-prone homes within the area. Finished-floor elevations were then obtained for each of the identified homes and a damage-assessment analysis was performed on selected homes to estimate the impact from a monetary standpoint. The homes were grouped into problem areas and concept mitigation measures were developed for each problem area. A preliminary evaluation, both qualitative and quantitative in nature, was then conducted relative to each problem area to estimate the cost-effectiveness and impact of each mitigation measure. Recommendations regarding Phase II were then presented.

More specifically, the hydrologic analysis included watersheds or drainage areas that were capable of generating greater than 100 cfs during the 5-year event. As a result fifteen runoff concentration points were established and a peak discharge was determined at each concentration point for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year events.

The flood plain analysis was performed on seven different watercourses or watercourse segments. These watercourses and their HEC-2 (Reference 1) file names are: (1) the South Branch Wash from its confluence with the Carmack Wash upstream to Oracle Road (SBW.DAT); (2) the South Branch Wash from Oracle Road upstream to the Forest Service Boundary (SBW-US1.DAT); (3) the Northern Tributary to the South Branch Wash from Rancho Catalina Avenue upstream to the Forest Service Boundary (SBW-US2.DAT); (4) the Glenhurst Wash in the immediate vicinity of Glenhurst Drive (401-409.DAT); (5) an historic channel braid along the South Branch Wash located immediately upstream of Northern Avenue (300-305.DAT); (6) the Southern Tributary to the Shadow Mountain Wash from Calle Buena Vista upstream to Shadow Mountain Drive; and, (7) the Shadow Mountain Wash from its confluence with the Carmack Wash upstream to Oracle Road. Each watercourse or segment was analyzed to define the flood plain associated with the 5-year, 25-year and 100-year flood events.

Of the twenty-six homes located in or near the 100-year flood plains (see Figure 3), only fourteen were included in the damage-assessment analysis. Those homes that possessed greater than one-foot of freeboard during all three of the flood events analyzed were excluded from the analysis. Based on the location of each home within the study area, its proximity to other flood-prone homes, and the primary flooding source, six problem areas were identified (A through F). The flood-prone homes were then grouped by problem area and their damage estimates, relative to each return interval, were combined in order to evaluate the cost effectiveness of the proposed mitigation measures relative to each area.

Since the study area is almost totally developed and the upstream portion of the impacting watersheds are located on Forest Service property, only structural flood-control measures seemed appropriate to resolve the drainage problems attributed to each problem (i.e., residential flooding with minor erosion and sedimentation damage). Three structural mitigation measures were considered for each problem area, channelization, flood-control levees, and floodwalls.

With the exception of Problem Area A, channelization and/or channel reshaping was rejected as the least cost-effective and the least desirable mitigation measure. With the exception of one home in Problem Area B and one in Problem Area F, continuous floodwalls with closures or floodwalls segments, both designed to provide protection up to and including the 100-year flood event, seemed to be the most appropriate and cost-effective mitigation measure compared to flood-control levees. Although flood-control levees are generally less expensive than floodwalls, the relative height of the wall; the need to protect the levees from erosion; the amount of area required to accommodate a levee; and the general appearance of a levee contributed to the conclusion that a floodwall would be the best solution.

Within Problem Area B, home #11 did not exhibit a potential for flooding, however, it did lack adequate freeboard, which suggests some minimal damage to the lot, pad, or structure may occur. Considering the minor damage potential associated with this home, structural improvements, other than the maintenance program already initiated by the Town of Oro Valley, did not seem justified.

Within Problem Area F, the most appropriate means of dealing with the hazard associated with home #23 was to purchase the home; remove it; and restore the lot to its predeveloped condition. This was considered the most logical approach since the actual damage potential, which might exceed the value of the home by a substantial amount, was difficult to estimate.

Overall, the results of the mitigation analysis seemed to indicate that cost-effective measures could be provided within most of the problem areas especially if protection were geared toward the 100-year event. Consequently, it was recommended that Phase II proceed with a more detailed evaluation of the floodwall concept for all problem areas with the exception of Problem Area A and home #23 in Problem Area F. Within Problem Area A, channelization and/or channel reshaping should also be evaluated and compared to the approximate cost of a floodwall to determine which appears to be the most cost effective. Within Problem Area F, a quantitative analysis should be performed in an attempt to evaluate both the positive and negative impacts of removing home #23.

1.2 Phase II Objectives

Based on the results, which were both qualitative and quantitative in nature, and the recommendations of the Phase I study, Pima County and the Town of Oro Valley agreed that the Phase II study should be performed as originally conceived. The main objectives of Phase II are to: (1) provide preliminary designs for the selected mitigation measures; (2) perform an evaluation of the impacts of each measure from hydraulic standpoint; and (3) establish preliminary cost estimates that can be compared to the benefits derived.

With these main objectives in mind, the Phase II study was conducted to determine the impact and cost effectiveness of: (1) an improved channel section versus a floodwall within Problem Area A; (2) a continuous floodwall along a portion of the northern bank of the South Branch Wash within Problem Area B; (3) a floodwall and/or levee with closures along either a portion of the south bank of the South Branch Wash within Problem Area C or around the combined area occupied by home #14 and #14A; (4) a continuous floodwall around home #17 within Problem Area D; (5) a continuous floodwall along a portion of the northern bank of the SBW Northern Tributary within Problem Area E; and (6) individual floodwalls around homes #24 through #26 coupled with a quantitative evaluation of the removal of home #23 within Problem Area F.

II. PRELIMINARY DESIGNS

2.1 Floodwalls

Figure 4 provides a conceptual design of a typical, concrete-reinforced, retaining wall that can be used as a floodwall. This section was taken from a manual prepared by the Concrete Reinforcing Steel Institute (Reference 2, Page 14-8). Figure 5 provides a similar design for a masonry floodwall. This section was taken from Reference 3 (Appendix G, Page 243).

The latter design (Figure 5) was based on specific design conditions relative to a particular site. It was presented in that reference as part of a case study. Consequently, the design is applicable only when similar site conditions are encountered since variations in the depth of flow will affect the height of the wall. This coupled with varying soil conditions will affect the structural design of the wall. Therefore, the design as presented can not be used for cost-estimation purposes.

However, since Reference 3 was intended to be used as a design manual, it provides a table of physical dimensions and quantities for walls of varying heights (although it does not address varying soil conditions). Since the height of the proposed floodwall will vary from one problem area to another, Figure 4 will be used to provide the quantities necessary to estimate the approximate cost of each floodwall. Locally, a cost of $275.00 per cubic yard is commonly used to estimate the cost of installing a structural concrete feature similar to the retaining represented in Figure 4. The linear-foot cost estimate for the various wall heights represented in this figure are provided in the following table.

Table 2.2.1
Cost Estimate for Varying Wall Heights

Height (ft)	Concrete (ft^3/lf)	Concrete (cy/lf)	Cost ($/lf)
3.0	4.25	0.1574	43.29
4.0	5.50	0.2037	56.02
5.0	6.84	0.2533	69.67
6.0	8.25	0.3056	84.03
7.0	9.66	0.3578	98.39
8.0	10.92	0.4044	111.22

Since floodwalls must be designed with consideration for the hydrodynamic and hydrostatic forces that impact the wall and the soil conditions that exist at the site, they should only be designed by a qualified structural engineer with input from a soils engineer. Consequently, these preliminary designs are for cost estimation purposes only and are not intended for construction.

2.2 Flood-Control Levee

Figure 6 provides a typical design for a flood-control levee. Again this design was taken from a case study presented in Reference 3. However, some exceptions must be noted. Within Pima County and the city of Tucson, the minimum top width for a levee ranges between 10 feet and 16 feet (typically 16 feet for Pima County and 10 feet for the city of Tucson). In addition to constructing the levee using impermeable material, the surface on the floodside must be protected against erosion, and the protection must be buried deep enough below the bed of the channel to account for scour.

For cost-estimation purposes, the side slopes of the levee will be the same as those shown in Figure 6; however, the top width will be 10 feet. The bottom width and height will vary depending on site conditions. In addition, since this conceptual design applies primarily to Problem Area C, where it will be used to form a portion of the south bank of the main channel, the levee will include bank protection in the form of gabions and a filter fabric will be used beneath the structure to prevent the leaching of fine material from the levee. The estimated cost of constructing the levee will be $4.00 per cubic yard. The estimated cost for a 1.5 foot-thick gabion lining will be $50.00 per cubic yard with an additional $1.00 per square foot for the filter fabric.

Since levees must be designed using impermeable materials and/or properly compacted to prevent seepage, and the foundation soil must be capable of supporting the anticipated loads, a soils engineer should be consulted during the design of the levee and should be present to test the levee while the lifts are being constructed. Consequently, these preliminary designs are for cost estimation purposes only and are not intended for construction.

2.3 Improved Channel Section

Figures 7 and 8 represent two cross sections of the Shadow Mountain Drainageway within Problem Area A. These cross sections, which were taken from HEC-2 model 101-120.DAT, as presented in the Phase I report, are identified as Sections 113 and 114 (see Figure 9). Section 113 is located immediately downstream of the only home located in this problem area (i.e., home #1). Section 114 is located immediately upstream of the home. These figures also show the geometry of the improved channel section that could be provided within the existing drainage easement in an attempt to reduce the water surface elevation along this portion of the drainageway.

The improved section has a 25-foot bottom width with 3:1 side slopes (horizontal to vertical). No man-made channel lining is shown on these sections and none currently exists. However, reshaping the existing channel will result in the removal of existing vegetation (although removal was not taken into consideration in the hydraulic analysis). If the banks are not capable of withstanding the erosive forces of flow along this reach, bank protection may be required.

Although general guidelines are available to determine the need for bank protection using the basic composition of the soils that make up the channel banks and the velocity of flow, a soils analysis is normally required in addition to a hydraulic analysis. Under most circumstances, if the compressive strength of the soil is sufficient to withstand erosion, bank protection is not needed.

Consequently, it is not intended that an unprotected section be provided unless a soils engineer is consulted or a soils analysis is performed to verify that bank protection is not required. The purpose of providing this section is simply to demonstrate that channel reshaping can improve flow conveyance in the area. By retaining the roughness characteristics associated with the existing vegetation, the incorporation of bank protection will not alter the results of the hydraulic analysis of this improved section.

For comparative purposes, however, three cost estimates will be prepared for Problem Area A. One will cover the estimated cost of a floodwall; the second will assume that channel reshaping can occur without bank protection; and the final estimate will assume bank protection will be required to protect against erosion. Bank protection in the form of a 1.5 foot-thick gabion lining (with filter fabric) will be used to estimate the cost of this improvement.

2.4 Design Parameters

The design parameters for the three types of improvement just described will be determined using the HEC-2 program (Reference 1) and, if necessary, uniform-flow equations (Reference 4) to obtain the appropriate hydraulic parameters. In addition, the guidelines presented in Reference 5 will be used to estimate anticipated scour depths (i.e., general scour, bed-form scour, bend scour, etc.). The scour computation summary sheets will accompany the HEC-2 input/output listings in the referenced appendices.

If the associated procedures and their application criteria are limited by the physical conditions of the site or they do not provide consistent or reasonable results, engineering judgement will be used to select the most appropriate design parameters. However, under no circumstances will the minimum design values or criteria established by Pima County (References 5 and 6) be reduced or compromised.

III. MITIGATION IMPACT AND COST ESTIMATE

3.1 Problem Area A

The existing-conditions HEC-2 model associated with this problem area (101-120.DAT) was manually revised to reflect the improved channel section depicted on Figures 4 and 5 (101I120.DAT) and the placement of a floodwall along the western right-of-way limit (101II120.DAT). Summary input and output listings for these revised models can be found in Appendix A. In addition, the input and output data files are provided on a 5 1/4-inch diskette which can be found inside the back cover of this report.

Figures 7 and 8 show the modifications made to model the effect of channel reshaping. Figure 10 shows the proposed alignment of the wall with respect to home #1. This alignment corresponds to the approximate location of the western limit of the Shadow Mountain Wash drainage easement. Figure 11 shows the ground profile and the associated design water surface profile along the proposed alignment.

The results of the hydraulic analysis of channel reshaping indicate that weir flow is prevented during the 5-year and 25-year events and only one cfs will escape the confines of the drainageway during the 100-year event. Considering the relative accuracy of both the hydraulic model and the hydrologic calculations, the one cfs of calculated outflow can be considered insignificant. Consequently, the effect of reshaping as proposed will, for the most part, eliminate breakout and thus prevent the anticipated damages associated with home #1. Although containment of the breakout flows will result in a slight increase in the downstream water surface elevations, the increase does not exceed one-tenth of a foot at any downstream section. Therefore, channel reshaping will not have an adverse impact on adjacent properties.

The results of the hydraulic analysis of the floodwall measure again indicate that the downstream water surface elevations will be increased a small amount due to flow containment along the breakout reach, but the increase does not exceed one-tenth of a foot at any downstream section. The only location where the increase does exceed one-tenth of a foot is at Section 114. The increase at this section is approximately two-tenths of a foot. However, flow remains confined to the channel section and no further increase in excess of one-tenth of a foot was noted in the upstream sections. Consequently, the presence of a floodwall will not have an adverse impact on adjacent properties.

Approximately 171 cubic yards of material must be removed to accommodate the reshaped channel section. At an approximate cost of $4.00 per cubic yard, the reshaping measure would cost approximately $685.00. If a soils analysis determines that bank protection is required, the estimated cost for 690 linear feet (total length required for both banks) would be approximately $22,232.00. This figure includes $17,871.00 for the gabions and $4,361.00 for the filter fabric. The bank protection design includes a height, relative to the flow line of two feet and a minimum toe-down depth of three feet. The latter value was selected when the results of the scour analysis indicated that the depth of scour would be less than three feet. When the cost of channel reshaping is added to the cost of the bank protection, the total cost of channelization is estimated to be approximately $22,917.00

Using Figure 11 as a guide, the average height of the wall required to just contain the 100-year water surface would be approximately 1.25 feet. When an additional one foot of freeboard is added to the top of the wall and a three foot toe-down is applied relative to the flowline elevation, the total height of wall required would be approximately 5.25 feet. Again, using Figure 11 as a guide, approximately 200 linear feet of wall would be required. Consequently, the cost of the wall at a unit price of $73.26 per linear foot would be approximately $14,652.00.

The costs associated with the three alternatives just discussed are summarized as follows:

Channel Reshaping:	$ 685.00
Channelization:	$ 22,917.00
Floodwall:	$ 14,652.00

The results of the damage-assessment analysis from the Phase I study indicated that the maximum damage potential during the 100-year event would be approximately $10,800.00. Consequently, only channel reshaping is cost effective. The other alternatives will cost far more than the benefits derived.

3.2 Problem Area B

Two of the three, existing-conditions, HEC-2 models associated with this problem area (SBW.DAT, 300-305.DAT, and 200-212.DAT) were revised as needed to reflect the existence of a floodwall along a portion of the ridge that separates the South Branch Wash from the SMW Southern Tributary. The alignment of this wall is shown on Figure 12. Summary input and output listings for the two revised models (SBW-D.DAT and 300D305.DAT) are provided in Appendix B. Complete listings are provided on the 5 1/4-inch diskettes.

The SBW-D.DAT model was created by removing the split-flow routine from the SBW.DAT model. Since the revised model reflects containment of all runoff conveyed into this problem area (i.e., no weir flow occurs over the ridge that separates the two watercourses), it was apparent that the amount of flow diverted along the historic channel braid would be changed. For this reason, the 300-305.DAT model had to be revised accordingly. However, for the purpose of modeling the impact of the floodwall, there was no reason to revise the 200-212 model. If weir flow from the South Branch is prevented, the quantity of runoff conveyed in the SMW South Tributary will be the amount associated with Concentration Point 12, which is less than 100 cfs during the 5-year event. Consequently, a revised flood plain analysis of this tributary was not required for this scenario.

The results of the containment analysis relative to the South Branch Wash (SBW-D.DAT) indicate that the proposed wall will significantly increase the water surface elevations along the majority of the downstream reach and the reach that parallels the wall. The increase will exceed one-tenth of a foot at all sections during all return intervals with the exception of Section 9 where, during the 5-year event, the increase was limited to 0.09 feet. The average increase during the 100-year event is in excess of 0.5 feet for all downstream sections. An increase in the water surface elevation results in a corresponding increase in the width of the associated flood plain. The maximum increase occurs during the 100-year event at Section 4, where the change was determined to be approximately 107 feet. In addition, during the 100-year event, the velocity of flow in the

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main channel will be increased in excess of one foot per second at several sections. Table 3.2A summarizes the changes at all sections during the three return intervals analyzed.

As previously mentioned, the wall will also increase the quantity of flow diverted along the historic channel braid. During the 5-year, 25-year, and 100-year events the increased quantity was determined to be approximately 162 cfs, 438 cfs, and 806 cfs, respectively. However, most of this flow will return to the South Branch Wash before it exits the downstream limit of the study reach (i.e., Section 300). The increased quantity of flow impacting the area immediately downstream of Section 300, during the three respective events, will be approximately 35 cfs, 86 cfs, and 158 cfs.

All of the changes just described, including those associated with the South Branch, are generally unacceptable from a flood plain management standpoint. The presence of the wall constitutes an encroachment into the existing 100-year flood plain with undesirable consequences.

Assuming that the results of flood plain analysis had not created an adverse impact on the area, approximately 1215 linear feet of wall would be required along the alignment shown on Figure 12. The relationship between the 100-year water surface and existing grade along this alignment is shown on Figure 13. The 1215 linear feet assumes that a continuous wall is provided. If several walls were constructed to fill the gaps between the existing patio walls, the total linear footage would be reduced to 585 feet.

The average height of wall required to contain the 100-year water surface was estimated to be 1.5 feet. When an additional one foot is added for freeboard and 4.0 feet is added as a toe-down to guard against the combined effect of scour and migration of the channel thalweg, the total height of wall required would be approximately 6.5 feet. The cost per linear foot for this wall would be approximately $91.21. Consequently, the total cost would be approximately $110,820.00 for a continuous wall and approximately $53,358.00 for a fragmented wall. Since the total estimated damages during the 100-year event was determined to be approximately $64,700, the cost of providing the wall is not justified by the benefits derived unless a fragmented wall is provided. However, the cost of a fragmented wall does not consider the additional cost of reinforcing the existing patio walls if they are determined to be unsuitable to withstand the hydrodynamic and hydrostatic forces of flow along this reach.

Considering the negative impacts of the South Branch floodwall and its cost effectiveness, the problem associated with home #11 was considered separately. For home #11, an individual floodwall could be constructed around its upstream perimeter (see Figure 14). To determine if the construction of this wall would have a negative impact on the area, model 200-212.DAT was modified to reflect the existence of this wall and the in-effective flow areas created in both the upstream and downstream directions. The results of this analysis (200D212.DAT) indicate that the wall will not have an adverse impact (i.e., no significant increase in the water surface elevations or flow velocities). A summarized version of the input and output listing is contained in Appendix C. A complete version is provided on the accompanying 5 1/4-inch diskettes.

To accommodate this measure, approximately 220 linear feet of wall will be required. The home is located on the northern overbank adjacent to the confluence of the Shadow Mountain Wash and the SMW Southern Tributary where the

Relative Impact of Floodwall on the South Branch Floodplain

Cross Section No.	Return Period (yr)	W.S. Change (ft)	Velocity Change (fps)	Width Change (ft)	Discharge Change (cfs)
1	5	0.31	0.63	23.87	165.97
	25	0.49	0.90	37.12	466.86
	100	0.72	1.22	54.66	948.53
2	5	0.18	0.60	8.70	165.97
	25	0.33	0.97	16.65	466.86
	100	0.53	1.43	26.55	948.53
3	5	0.25	0.61	17.06	165.97
	25	0.33	1.02	5.00	466.86
	100	0.62	1.15	9.40	948.53
3.5	5	0.30	0.37	29.15	165.97
	25	0.40	0.78	40.44	466.86
	100	0.53	1.23	54.82	948.53
4	5	0.28	0.43	26.04	165.97
	25	0.47	0.51	90.63	466.86
	100	0.58	0.96	107.14	948.53
5	5	0.20	0.68	16.09	138.97
	25	0.46	0.69	34.19	416.86
	100	0.68	1.09	50.83	873.53
6	5	0.27	0.94	16.01	140.97
	25	0.54	0.61	53.23	405.86
	100	0.73	0.97	71.72	833.53
7	5	0.28	0.24	17.56	91.97
	25	0.35	0.92	24.98	292.86
	100	0.50	1.61	57.00	628.53
8	5	0.16	0.45	11.44	53.97
	25	0.36	0.49	26.04	195.86
	100	0.49	1.21	44.49	458.53
9	5	0.09	0.30	18.28	33.97
	25	0.16	0.58	52.24	112.86
	100	0.31	0.90	17.23	299.53
10	5	0.16	0.32	6.22	195.97
	25	0.35	0.49	10.40	550.86
	100	0.59	1.23	39.52	1105.53

average depth of flow is approximately 0.5 feet. If one foot is added to the average depth of flow to provide freeboard, the height of the wall above existing grade would be 1.5 feet. When the minimum toe-down depth is applied, the design height of the wall will be 4.5 feet. The unit cost for a 4.5-foot wall is approximately $62.85 per linear foot. Consequently the total estimated cost of this wall is approximately $13,827.00.

Since the anticipated damages for this home during the 100-year event was estimated to be approximately $9740.00, the cost of protecting the home with a floodwall is greater than the benefits derived. It should be noted that the design toe-down depth for the wall does not account for the possibility of channel migration or bank erosion. Since the wall will be located less than fifty feet from the bank, it will be located in the erosion-hazard area. If the toe-down depth were increased to account for the possibility of channel migration, the total cost of the wall would be even greater.

3.3 Problem Area C

Within Problem Area C, two mitigation measures were evaluated to determine which would be the most cost effective. One measure involves either the combined use of a levee and a floodwall to protect the two affected homes (#14 and #14A). The second measure involves the construction of a floodwall around the upstream perimeter of the combined area occupied by the two homes. The proposed alignment of the levee and the floodwalls are shown on Figure 15.

The advantage of the first measure is that it not only protects homes #14 and #14A but it also affords some protection to the homes located downstream along a secondary channel that conveys breakout flows from the South Branch. However, since the majority of this secondary channel is outside the limits of the study area, there was not enough topographic information available to include this channel in the Phase I floodplain analysis. Consequently, the damage-assessment analysis did not include any of the homes that may be impacted by flows conveyed in this secondary channel.

The second mitigation measure simply addresses the problems associated with the two identified homes. However, since adjacent property owners may object to the existence of a levee or wall along the mouth of the secondary channel, and it appears that the entire structure can not be built on the lot associated with homes #14 and 14A, this secondary measure was also evaluated to determine its cost effectiveness.

When the existing-conditions, flood plain analysis (SBW-US1.DAT) was conducted for this reach of the South Branch, the possible loss of flow down the secondary channel was disregarded. This was done to ensure conservative results relative to the downstream water surface elevations. In addition, the proposed alignment of the wall and the levee corresponds to the effective flow boundary relative to Sections 29.5 and 30, respectively. Consequently, a revised floodplain analysis is not needed to model the impact of constructing the two proposed mitigation measures.

Figure 16 shows the profile of the 100-year water surface from the SBW-US1.DAT analysis and the ground profile along the proposed alignment of the wall and the levee. Using this profile as a guide, the average height of the wall required to contain the water surface is approximately 1.5 feet. When an additional one foot is added for freeboard, the average height above the ground profile will be 2.5 feet. Again, the minimum toe-down depth of three feet must be applied to the wall since the results of the scour analysis indicates that the computed depth will be less than three feet (see Appendix D). Consequently, the total height of wall required will be 5.5 feet.

Approximately 245 linear feet of wall will be required for the first mitigation measure and approximately 375 feet will be required for the second mitigation measure. Using a unit cost of approximately $76.85 per linear foot, the estimated cost of the floodwall for the first mitigation measure will be approximately $18,828.00. For the second mitigation measure the estimated cost will be $28,819.00. However, the total estimated cost of the first mitigation measure must also include the estimated cost of the levee.

Again using Figure 16 as a guide, the average height of the proposed levee will be approximately 3.5 feet which includes an allowance for freeboard. Consequently, the cross-sectional area will be 79.38 square feet. Since approximately 205 linear feet will be required, the total estimated volume of material will be approximately 600 cubic yards. Using a unit cost of approximately $4.00 per cubic yard, the estimated cost to construct the levee, excluding bank protection will be $2,400.00.

To protect the levee against erosion, approximately 124.0 cubic yards of rock will be required to construct the gabions. At an estimated, in-place, cost of $50.00 per cubic yard, the cost of the bank protection will be approximately $6,200.00. Consequently, the total cost of the bank protected levee will be approximately $8,600.00 or $42.00 per linear foot.

Using the cost estimates just derived, the total estimated cost of the first mitigation measure will be approximately $27,428.00 which is very close to the estimated cost of the second measure ($28,819.00). However, the cost of both mitigation measures far exceed the estimated damages ($17,300) associated with this problem area during the 100-year event. Consequently, it does not appear that either of the proposed alternatives are cost effective.

3.4 Problem Area D

Within this problem area, the only reasonable solution is to construct a floodwall around the upstream perimeter of the only affected home (#17). Figure 17 shows the proposed location of this wall with respect to the home. Since the presence of the wall will constitute an encroachment into the floodplain for the SBW Northern Tributary, the SBW-US2.DAT model from the Phase I study was revised.

In order to model the presence of the wall, one cross section was added to the SBW-US2.DAT model at the most constricted section created by the wall. The location of this section is also shown on Figure 17. The results of the impact analysis (SBWDUSII.DAT) indicate that the wall will not have a significant effect on the SBW Northern Tributary floodplain. In fact, there was no change worth noting in the upstream water surface elevations during any of the return intervals analyzed. A summarized version of the input and output listing is contained in Appendix E. A complete copy of these listings is provided on the 5 1/4-inch diskettes.

In order to protect home #17 from flows conveyed in the SBW Northern Tributary and overflow runoff from the Windy Peak Place drainageway, approximately 320 linear feet of wall will be required. Since a portion of this wall (approximately 160 linear feet) will be located along the northern bank of the SBW Northern Tributary and a portion will be located within the sheet flow area created by overflows from the drainageway, the design requirements will vary along the wall.

The average height of the tributary segment will be approximately 2.5 feet which includes one foot of freeboard. Based on the results of the scour analysis, a four-foot toe-down depth is applicable to this segment of the wall. Consequently, the total height of the tributary segment will be approximately 6.5 feet. The unit cost for this height of floodwall was estimated to be approximately $91.21 per linear foot. Therefore, the total cost of 160 linear feet will be approximately $14,594.00.

The average height of the segment located in the sheet flow area will be 1.5 feet. This assumes the average depth of flow will not exceed 0.5 feet and that one foot of freeboard is applicable. Again, a minimum toe-down depth of three feet should be applied to protect against local scour. Consequently, for cost estimation purposes, the total height of the drainageway segment will be approximately 4.5 feet. The unit cost for this segment of floodwall was estimated to be approximately $62.84 per linear foot. Therefore, the total cost of 160 linear feet will be approximately $10,055.00.

The total estimated damages associated with this home during the 100-year event was determined to be approximately $16,200.00. Since the total estimated cost of 320 linear feet of floodwall is approximately $24,649.00, the proposed improvements will cost approximately $8,500 more than the benefits derived.

3.5 <u>Problem Area E</u>

Figure 15 shows the proposed alignment of the floodwall for this problem area. Although the floodprone limit shown on Figure 9 extends to the north of most of the homes in this problem area, the proposed location of the wall will only constitute a very minor encroachment since most of this floodprone area is located in an ineffective flow-conveyance area. Consequently, this area was not included in the existing-conditions floodplain analysis (SBW-US2.DAT) as an effective conveyance area. The revised floodplain analysis that models the existence of the wall is the same one used for Problem Area D (i.e., SBWDUS2.DAT as contained in Appendix E).

The results of the impact analysis indicate that the presence of the wall will not have a significant effect on adjacent and/or upstream water surface elevations. The maximum increase noted was 0.09 feet at Section 41.

Figure 18 shows the profile of the design water surface with respect to existing grade along the proposed alignment of the wall. Using this profile as a guide, the average height of the wall, including one-foot of freeboard, will be approximately 2.0 feet. Based on the results of the scour analysis, the required toe-down depth will be approximately 5.0 feet. Consequently, the design height of the wall will be approximately 7.0 feet.

Based on the alignment shown of Figure 15, approximately 425 linear feet of wall will be required to protect the affected homes within this problem area. At a unit cost of approximately $98.39 per linear foot for a seven-foot wall, the estimated cost of the wall is approximately $41,816.00. The total anticipated damages in this area during the 100-year event were estimated to be approximately $40,800.00. Therefore, given the proximity of the two estimates, it appears that the proposed floodwall may be a cost effective solution for this problem area.

3.6 Problem Area F

Within this problem area, it was not possible during the Phase I study to quantify, using the HEC-2 model, the anticipated depth of flooding relative to homes #24 through #26. Consequently, the depth was estimated using uniform-flow parameters and the effective-conveyance boundary of flow released from the confined channel section created between home #23 and the adjacent hillside. This depth was determined to be approximately one foot during the 100-year event.

The HEC-2 model, 401-409.DAT, was used in the Phase I study to estimate the depth of inundation associated with home #23. Based on the results of that analysis, the results of the corresponding damage assessment analysis and the results of a qualitative assessment of the negative impacts associated with this home, it was recommended that home #23 be purchased for removal. If the home and its improvements were removed, it was further recommended that the lot be physically returned to its natural or pre-developed condition. It was felt that reclamation of this lot would reduce the severity of flooding and mitigate some of the drainage problems plaguing the downstream properties under existing conditions.

In an effort to quantify the impact that removal would have on the flow characteristics of the Glenhurst Wash in this area, the 401-409.DAT model was revised to approximate pre-developed conditions (i.e., the conditions that existed before home #23 and its retaining wall were constructed). The input listing and a portion of the output listing for the revised model (401D409.DAT) is provided in Appendix F. Table 3.6A summaries the changes noted between the existing-conditions model and the approximated, pre-developed conditions model.

The results of the pre-developed conditions analysis indicate that during both the 100-year event and the more frequent flow events, the anticipated depth of flooding on the downstream properties would not be significantly altered. Although the width of flow is increased in excess of 50 feet at Section 401, a maximum difference of only 0.12 feet was noted with respect to the calculated water surface elevation. However, there is a significant change in the velocity of flow in the main channel during the 100-year event (i.e., a reduction of 1.91 feet per second). A significant reduction is also recognized during both the 5-year and 25-year events.

The most significant reduction in the velocity of flow occurs at Section 402. At this section, flow velocities were reduced between three and five feet per second over the range of events analyzed. This section represents the last confined section created by the improvements on Lot 35C. Homes #24 and #25 are located in the direct path of flow exiting this section. Under existing conditions, there is not enough distance between this section and the downstream homes to allow flow to return to a state that more closely approximates pre-developed conditions. Consequently, these downstream homes are significantly impacted by the effects of high-velocity flows that exit the confines of this section.

Relative Impact of Reclamation on Lot 34C of the Sunnyslope Subdivision

Cross Section No.	Return Period (yr)	W.S. Change (ft)	Depth Change (ft)	V_{ch} Change (fps)	Width Change (ft)	Q_{lob} Change (cfs)	Q_{ch} Change (cfs)	Q_{rob} Change (cfs)
401	5	-0.07	-0.07	-1.33	31	0.0	-67.7	67.7
	25	-0.15	-0.15	-1.08	14	0.0	-145.7	145.7
	100	-0.12	-0.12	-1.91	52	0.0	-218.8	218.8
402	5	-0.09	-0.09	-3.16	54	0.0	-73.0	73.0
	25	-0.15	-0.15	-4.13	57	0.0	-162.0	162.0
	100	-0.22	-0.22	-4.83	60	0.0	-259.0	259.0
403	5	-0.08	-0.08	-0.36	7	0.0	0.0	0.0
	25	-0.17	-0.17	-1.54	110	0.0	-38.4	38.4
	100	-0.40	-0.40	-1.40	105	0.0	-90.3	90.3
404	5	-1.98	-0.98	-2.10	70	0.0	-68.6	68.6
	25	-2.30	-1.30	-2.60	68	0.0	-151.7	151.7
	100	-2.55	-1.55	-2.90	66	0.0	-241.6	241.6
405	5	0.00	0.00	0.00	0	0.0	-0.0	0.0
	25	0.00	0.00	-0.03	0	0.0	-0.1	0.1
	100	-0.01	-0.01	0.03	0	0.0	0.1	-0.1
405.5	5	0.00	0.00	0.03	0	0.0	-0.2	0.2
	25	0.00	0.00	0.00	0	0.0	0.0	0.0
	100	0.00	0.00	-0.01	0	0.0	0.0	0.0
406	5	0.00	0.00	0.00	0	0.0	0.1	-0.1
	25	0.00	0.00	0.00	0	0.0	0.0	0.0
	100	0.00	0.00	0.00	0	0.0	0.0	0.0
407	5	0.00	0.00	0.00	0	0.0	0.0	0.0
	25	0.00	0.00	0.00	0	0.0	0.0	0.0
	100	0.00	0.00	0.00	0	0.0	0.0	0.0
408	5	-0.01	-0.01	0.04	0	0.0	0.5	-0.5
	25	0.00	0.00	0.00	0	0.0	0.0	0.0
	100	0.00	0.00	0.00	0	0.0	0.0	0.0
409	5	0.00	0.00	0.03	0	0.0	0.0	0.0
	25	0.00	0.00	0.00	0	0.0	0.0	0.0
	100	0.00	0.00	0.00	0	0.0	0.0	0.0

The most drastic change in the water surface elevation occurs at Section 404 which, like Sections 402 and 403, models the full impact encroachment (by home #23) imposes on the Glenhurst Wash flood plain. During the 100-year event, in the vicinity of Section 404, reclamation will reduce the water surface elevation by approximately 2.55 feet and the flow velocity by approximately 2.90 feet per second. The depth was only reduced by 1.55 feet because the revised model assumes some of the low-flow area will be filled during reclamation.

Based on the results of the HEC-2 analysis, reclamation does not appear to have any significant effect on upstream properties. However, as noted in the Phase I report, removal of the retaining wall on Lot 35C may result in the formation of a headcut if an incised low-flow channel forms after reclamation. The propagation of this headcut in the upstream direction could damage the access drive for Lot 35B

In general, the quantitative assessment of the impact of removal is limited to the immediate area surrounding Lot 35C. Although the last downstream section used in the revised model reflects a small change in the water surface elevation in relation to the upstream sections, the change is still greater than that normally allowed when encroachment studies are performed to gain approval for the construction of improvements in a floodprone area. However, the change is not significant enough to warrant a revision to the damage-assessment analysis relative to homes #24 through #26. In addition, it is impossible to determine what impact removal of home #23 will have on the quantity of flow that is currently diverted down Glenhurst Drive. Therefore, it is difficult to conclude from strictly a quantitative standpoint that removal of the home will significantly reduce the flooding problems attributed to these downstream homes.

Although there is no hard evidence to justify reducing the estimated damages for homes #24 through #26 (even if home #23 were removed), the results of the quantitative analysis, with respect to the velocity of flow, does warrant an addendum to the qualitative discussion presented in the Phase I report regarding the impact that concentrated flow has on these downstream homes. The adverse effect improvements on Lot 35C have had on the velocity of flow in this area is very apparent. Within the confines of the constricted channel (i.e., Sections 402 through 404, under existing conditions), high flow velocities, similar to those defined by the existing-conditions analysis, erode material from the confined section. This material is then transported out of the section and deposited immediately downstream. Since flow leaving Section 402 can not expand fast enough to reduce its kinetic energy and downstream improvements force it to reconcentrate, the erosion potential relative to homes #24 and #25 is greater than the potential that existed prior to the development of Lot 35C. Again, this situation could be mitigated by removing the home and its improvements.

Although adjacent downstream property owners have created problems for themselves and their neighbors by performing improvements that divert and concentrate runoff, the associated impacts are not nearly as significant as those created by the improvements on Lot 35C. This is especially true for homes #24 and #25. To some extent, some of the problems related to home #25 and most of those related to home #26 may be the result of localized improvements, as opposed to the improvements associated with Lot 35C. However, it seems obvious that the severity of some of the problems associated with home #24 and those associated with the upstream portion of home #25 could be reduced by removal of home #23 and its associated improvements. Again, removal would prevent the concentration

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of flow which will significantly reduce the velocity of flow and in turn the erosion and sedimentation potential.

Since the damage potential associated with home #24 through #26 remains unchanged from that reported in the Phase I study, preliminary floodwall designs and cost estimates were prepared for each home. Figure 17 shows the location of each floodwall with respect to the home it will serve. Using an approximate depth of flow of one foot, the height of the proposed wall above existing grade would be two feet when freeboard is considered in the design. Assuming the minimum toe-down depth is applied, the overall height of the wall would be five feet. The linear footage required for home #24, #25 and #26 was estimated to be approximately 220 feet, 300 feet, and 300 feet, respectively. At an estimated unit cost of $69.67 per linear foot, the estimated cost of the three walls would be $15,327.00, $20,901.00, and $20,901.00, respectively.

The individual damage estimates prepared as part of the Phase I assessment for these three homes were $14,119.09, $16,375.76, and $11,378.35 respectively. Consequently, the benefits derived by the proposed improvements do not appear to justify the anticipated costs. However, if the owners of these homes are willing to place the upstream limit of the wall closer to the house itself, the overall length as depicted on Figure 17 could be reduced. To be cost-effective, the length of each wall must be limited to 200 feet, 235 feet, and 160 feet, respectively. However, a site-specific investigation would be required to ensure that these reduced lengths provide adequate protection.

At the present time, there does not appear to be any justifiable improvements that can be used to protect home #23. The only reasonable alternative for the owner of this home is to purchase flood insurance to offset the estimated losses that are, for the most part, definable.

IV. RECOMMENDATIONS REGARDING IMPLEMENTATION

Table 4.1 summaries the damages and estimated costs of the proposed mitigation measures associated with each problem area.

Table 4A
Damages versus Mitigation Cost of Proposed Improvements

Problem Area	Affected Residences	Combined Damages ($)	Proposed Improvement	Mitigation Cost ($)
A	1	10,800.00	Reshaping	685.00
			Channelization	22,917.00
			Floodwall	14,652.00
B	3, 4, 7-10	54,900.00	Floodwall	110,820.00
			Wall Segments	53,358.00
	11	9,800.00	Floodwall	13,827.00
C	14, 14A	17,300.00	Levee/Floodwall	27,428.00
			Floodwall Only	28,819.00
D	17	16,200.00	Floodwall	24,649.00
E	18-20	40,800.00	Floodwall	41,816.00
F	23	44,300.00	None	N/A
	24	14,200.00	Floodwall	15,379.00
	25	16,400.00	Floodwall	20,901.00
	26	11,400.00	Floodwall	20,901.00

Based on the results of the Phase II study, the floodwall is still the preferred (but not necessarily recommended) mitigation measure for all problem areas with the exception of home #23 within Problem Area F. Although channel reshaping within Problem Area A is cost effective, it can not be considered a preferred measure unless a soils analysis confirms that the existing banks are erosion resistent. Within Problem Area B, the preferred measure would be a continuous floodwall since it is unlikely that the existing patio walls are properly designed to withstand flood waters; however, a floodwall is not recommended to protect the South Branch homes (#3, #4, and #7 through #10) since it will have an adverse impact on adjacent properties. Within Problem Area C, the levee/floodwall alternative is less expensive than the floodwall alternative; however, the levee will occupy more area, require a more intensive construction effort, and may be less desirable from an aesthetic standpoint. Consequently, it is not the preferred mitigation measure for this problem area.

With the possible exception of Problem Area E, the preferred mitigation measure is not cost effective in the sense that the estimated cost of improvement exceeds the benefit derived. It may be possible to reduce the estimated improvement costs presented in this study by establishing alternative design methods (i.e., masonry walls versus concrete walls, levees as opposed to floodwalls, reducing the length of wall required by utilizing existing walls, reducing the size of the protected area, etc.). However, the ability to analyze the costs associated with these alternatives is beyond the scope of this project since site-specific information must be obtained and the services of a structural engineer and perhaps a soils engineer may be required. In addition to selecting alternative design methods, the criteria used in this study to establish the design parameters for the floodwall (i.e, toe-down and freeboard requirements) could be adjusted downwards; however, site-specific information must be compiled to justify these reductions.

Nevertheless, it should be noted that the estimated costs presented in this study do not consider any additional engineering that may be required to accommodate the proposed improvements; nor do they consider the need for floodwall closures or contingency costs. If engineering costs and contingency costs, which are usually estimated to be approximately 10 or 15 percent of the total costs that can be assessed, are included in the cost of the alternative design methods, the conclusions of this study (i.e., improvements for the most part are not cost effective) would probably be the same.

In addition, the conceptual masonry wall design shown in Figure 5 includes a concrete footing overall and a reinforced-concrete stem wall at all closure openings. However, due to the potential for local scour, the entire below-grade portion of the floodwall should be constructed using reinforced concrete. Consequently, only the above-grade portion of the proposed concrete floodwall could be replaced with grout-filled masonry block. Since the below-grade component of the required wall height exceeds the above-grade component, replacing the above-grade portion with grout-filled masonry block may not change the estimated cost enough to warrant an expanded study of this alternative. However, if an area-wide study were performed that included both a soils analysis and a structural-design analysis for a masonry wall with varying heights, it would be a simple matter to compare the associated unit costs of the masonry wall to those developed as part of this study to determine which wall type is more cost effective.

It may be possible to obtain a cost effective design for three of the four homes located within Problem Area F if the individual length of floodwall required to protect these three homes (#24 through #26) can be reduced. For the purpose of this study, the length of wall required was estimated in a conservative manner using the location of existing improvements as a guide. If a site-specific design were prepared for each home that effectively relocates the upstream limit of the proposed floodwall closer to the house, it may be possible to reduce the overall length of each wall enough to obtain a cost-effective design. Although removal of home #23 would, in a qualitative sense, mitigate some of the hazards associated with these three downstream properties, removal will not eliminate the hazards, nor will it reduce the design height of the associated floodwalls. Consequently, it was concluded that a floodwall was still needed to protect these three homes. However, no acceptable or feasible mitigation measure seems to exist to address the problems associated with home #23.

Assuming the alternative design methods just discussed would not be cost effective either, flood insurance is the best means available to offset the damage potential associated with all affected homes. Although the minimum amount of insurance purchased should match the anticipated damages, it may be more prudent for the homeowner to purchase insurance using the market value of the home as a guide. Since the affected homes do not reside in a federally-mapped or regulated floodprone area, the minimum rates per $100 of coverage would probably apply. Assuming either the pre-FIRM or post-FIRM construction rates associated with Zone A99, B, C, or X are applicable, the annual premium rates per $100 of coverage would be approximately $0.32 for the home and $0.52 for the contents.

Table 4B summaries the approximate cost, for each affected home, of the annual premiums for flood insurance. Two premium rates are presented. One rate assumes only enough insurance is purchased to cover the anticipated damages. The second rate assumes the estimated market value of the home is used to establish the annual premium. Although both rates include the $45.00 per year Expense Constant, the $25.00 per year Federal Policy Fee, and a five percent CRS (Community Rating System) discount, they are only estimates. Actual quotes must be obtained from a licensed insurance agent or broker.

In conclusion, there are four basic recommendations regarding further studies and/or the implementation of the proposed mitigation measures or their alternatives. These recommendations are summarized as follows:

(1) The purchase of flood insurance is recommended for all affected homes within all problem areas, with the possible exception of the single home in Problem Area A (see (2) below).

(2) Within Problem Area A, the results of a soils analysis may support the cost effectiveness of channel reshaping. Consequently, it is recommended that a geotechnical study of the Shadow Mountain Drainageway be performed within this problem area before the feasibility of this alternative is ruled out.

(3) Since the results of this study seem to support the possible cost effectiveness of a floodwall within Problem Area E, it is recommended that this measure be investigated in greater detail including the preparation of preliminary construction drawings. To facilitate this design, a more-detailed survey of the project site may be required. In addition, since a masonry wall may be less expensive and more attractive than a concrete wall, it may be beneficial to explore the possibility of using a masonry floodwall as opposed to a concrete one. However, it should be noted that implementation of the floodwall concept does not preclude the need for flood insurance as an additional safeguard, although it could significantly reduce the annual premium.

(4) It is further recommended that site-specific, concept designs be prepared and evaluated with respect to homes #24 through #26 within Problem Area F to determine if the required length of the floodwall can be reduced enough to make this measure cost effective. Again, the implementation of the floodwall concept does not replace the recommendation that flood insurance be obtained by the respective property owners.

Estimated Flood Insurance Premiums for Affected Homes

Home No.	Legal Description	Estimated Market Value ($)	Estimated Structure Damages ($)	Estimated Content Damages ($)	Insurance Premium Damages ($/yr)	Insurance Premium Home ($/yr)
1	Lot 25 (1)	57000.00	7800.00	3100.00	111.00	274.00
3	Lot 363 (2)	70800.00	11800.00	5200.00	135.00	331.00
4	Lot 362 (2)	65000.00	4800.00	2100.00	96.00	296.00
7	Lot 372 (2)	61600.00	5400.00	2300.00	99.00	286.00
8	Lot 371 (2)	70000.00	3200.00	1500.00	88.00	309.00
9	Lot 370 (2)	70600.00	5600.00	2500.00	100.00	317.00
10	Lot 370 (2)	66200.00	8000.00	3200.00	112.00	305.00
11	Lot 37 (1)	65500.00	7000.00	2800.00	107.00	301.00
14	Lot 118 (3)	87100.00	5200.00	2300.00	98.00	371.00
14A	Lot 118 (3)	27500.00	7100.00	2900.00	107.00	175.00
17	Lot 185 (3)	80600.00	11600.00	4700.00	131.00	361.00
18	Lot 142 (3)	54800.00	4600.00	2000.00	95.00	262.00
19	Lot 143 (3)	51100.00	9000.00	4000.00	119.00	260.00
20	Lot 144 (3)	88700.00	14900.00	6500.00	151.00	397.00
23	Lot 35C (4)	90800.00	32600.00	11800.00	236.00	430.00
24	Lot 176 (3)	76600.00	10300.00	4000.00	123.00	344.00
25	Lot 175 (3)	88800.00	11900.00	4600.00	132.00	387.00
26	Lot 174 (3)	61700.00	8300.00	3200.00	113.00	291.00

(1) Shadow Mountain Estates; (2) Rancho Felix; (3) Rancho Catalina; (4)Sunnyslope

V. REFERENCES

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6. Pima County Department of Transportation and Flood Control District, "Drainage and Channel Design Standards for Local Drainage for Flood Plain Management Within Pima County, Arizona," Adopted on May 15, 1984, Effective on June 1, 1984.

7. Pima County, Arizona, "Floodplain and Erosion Hazard Management Ordinance No. 1988-FC2 for Pima County, Arizona," Passed and Adopted by the Board of Supervisors sitting as the Board of Directors of the Pima County Flood Control District, December 6, 1988.

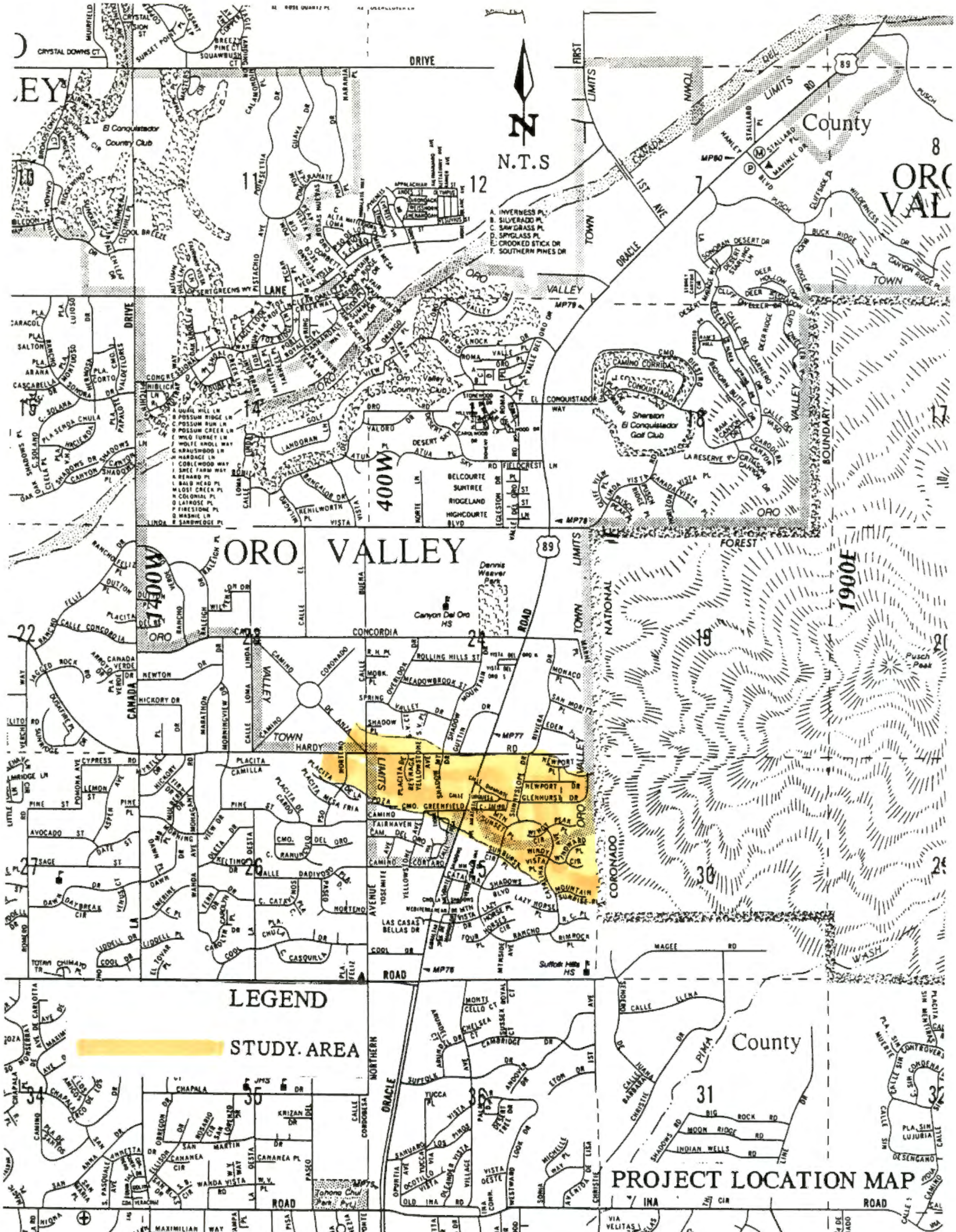
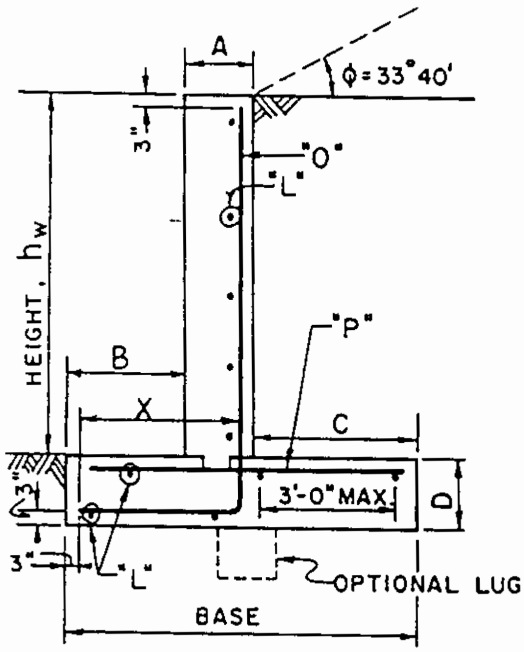

N
N.T.S
ORO VALLEY
County
LEGEND
STUDY AREA
PROJECT LOCATION MAP
El Conquistador Country Club
Oro Valley Country Club
Sheraton El Conquistador Golf Club
Canyon Del Oro HS
Dennis Weaver Park
Suffolk Hills HS
Pusch Peak
ORACLE
ROAD
CONCORDIA
HARDY
MAGEE
INA
FIRST
CORONADO
NATIONAL
FOREST
400W
1400W
1900E
89

FIGURE 1

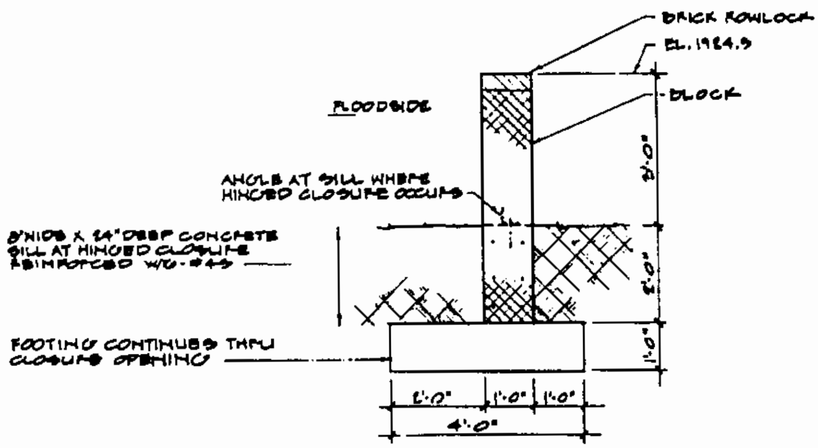
095



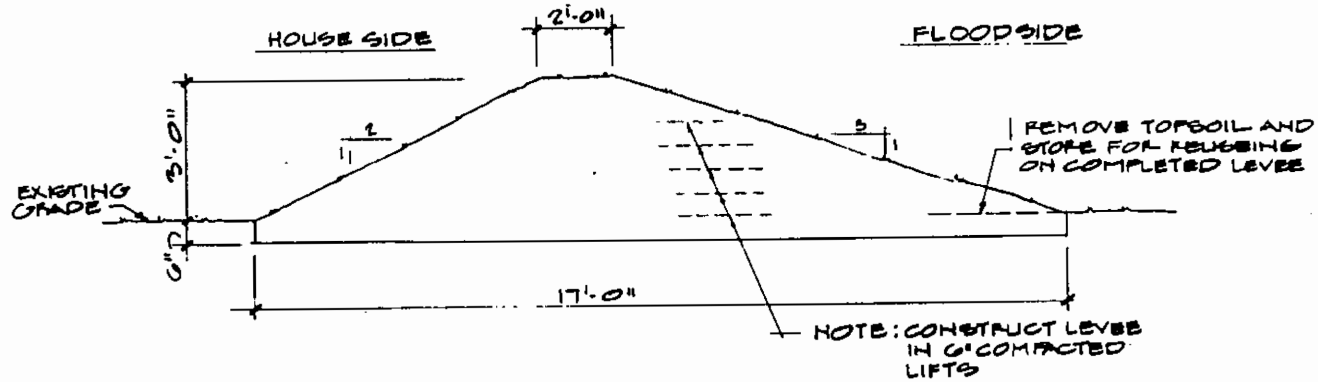
CANTILEVER RETAINING WALLS—Backfill Level—No Surcharge

CONCRETE DIMENSIONS D = A (D ≥ 12")

Height h_w (ft.)	Base (ft.)	B (ft.)	A (ft.)	C (ft.)	Base Pressure at Toe (psf)	Base Pressure at Heel (psf)	Resist. Moment M_r (ft.-kips)	Overturn. Moment M_o (ft.-kips)	S.F. $\frac{M_r}{M_o}$	Concrete (cu. ft. per lin. ft.)
LOW WALLS										
3	1'-9"	0'-4"	0'-10"	0'-7"	860	19	0.728	0.269	2.707	4.25
4	2'-2"	0'-5"	0'-10"	0'-9"	1077	0	1.340	0.539	2.487	5.50
5	2'-8"	0'-5"	0'-10"	1'-5"	1310	0	2.358	0.948	2.489	6.84
6	3'-3"	0'-8"	0'-10"	1'-9"	1325	31	3.966	1.523	2.604	8.25
7	3'-10"	1'-0"	0'-10"	2'-0"	1311	126	6.114	2.294	2.665	9.66
8	4'-3"	1'-1"	0'-10"	2'-4"	1508	93	8.386	3.290	2.549	10.92
9	4'-9"	1'-1"	0'-10"	2'-10"	1720	79	11.600	4.539	2.556	12.25
10	5'-4"	1'-4"	0'-10"	3'-2"	1754	153	15.823	6.069	2.607	13.66



MASONRY FLOODWALL



SECTION THRU EARTHERN LEVEE

FIGURE 6

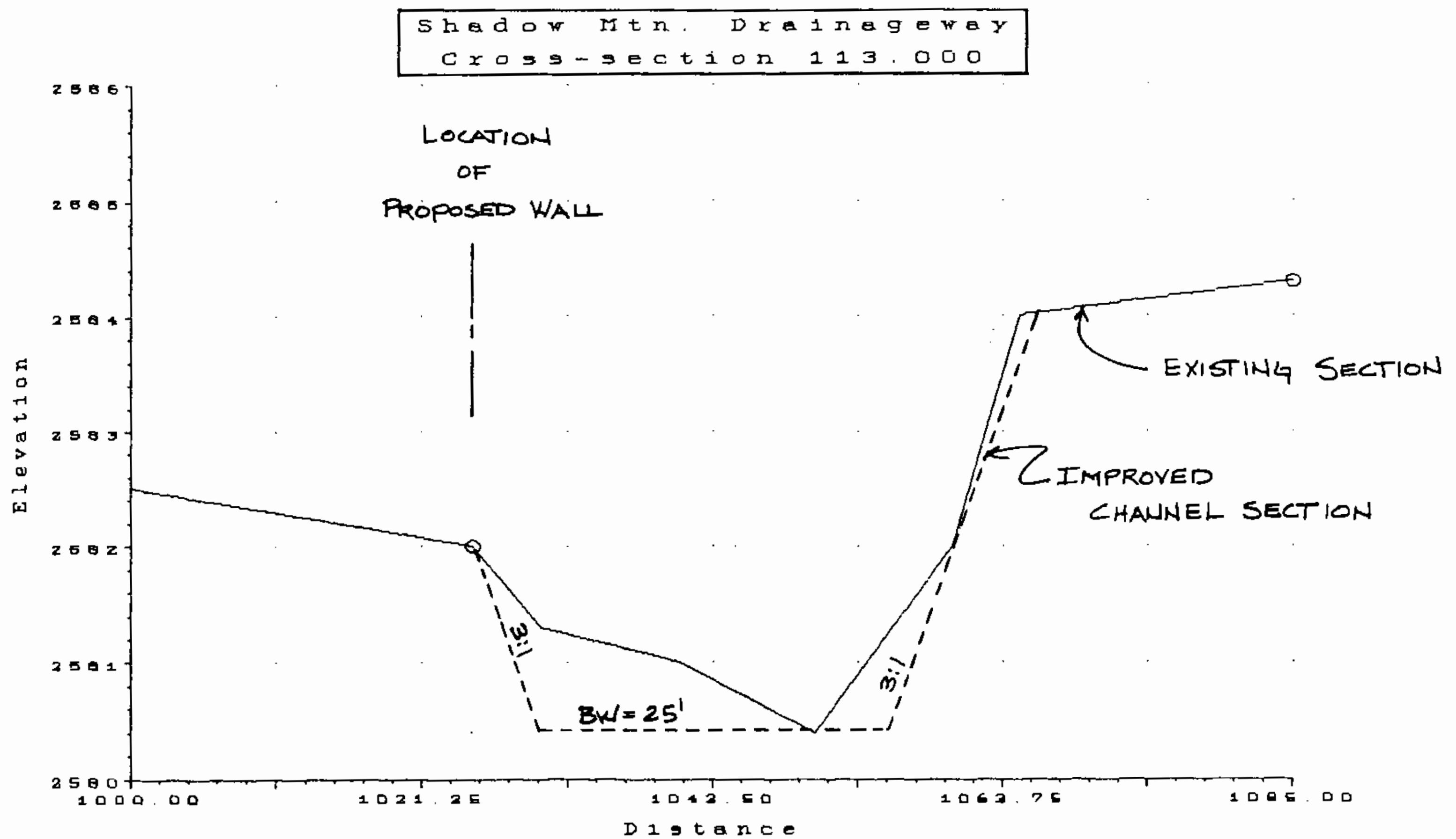
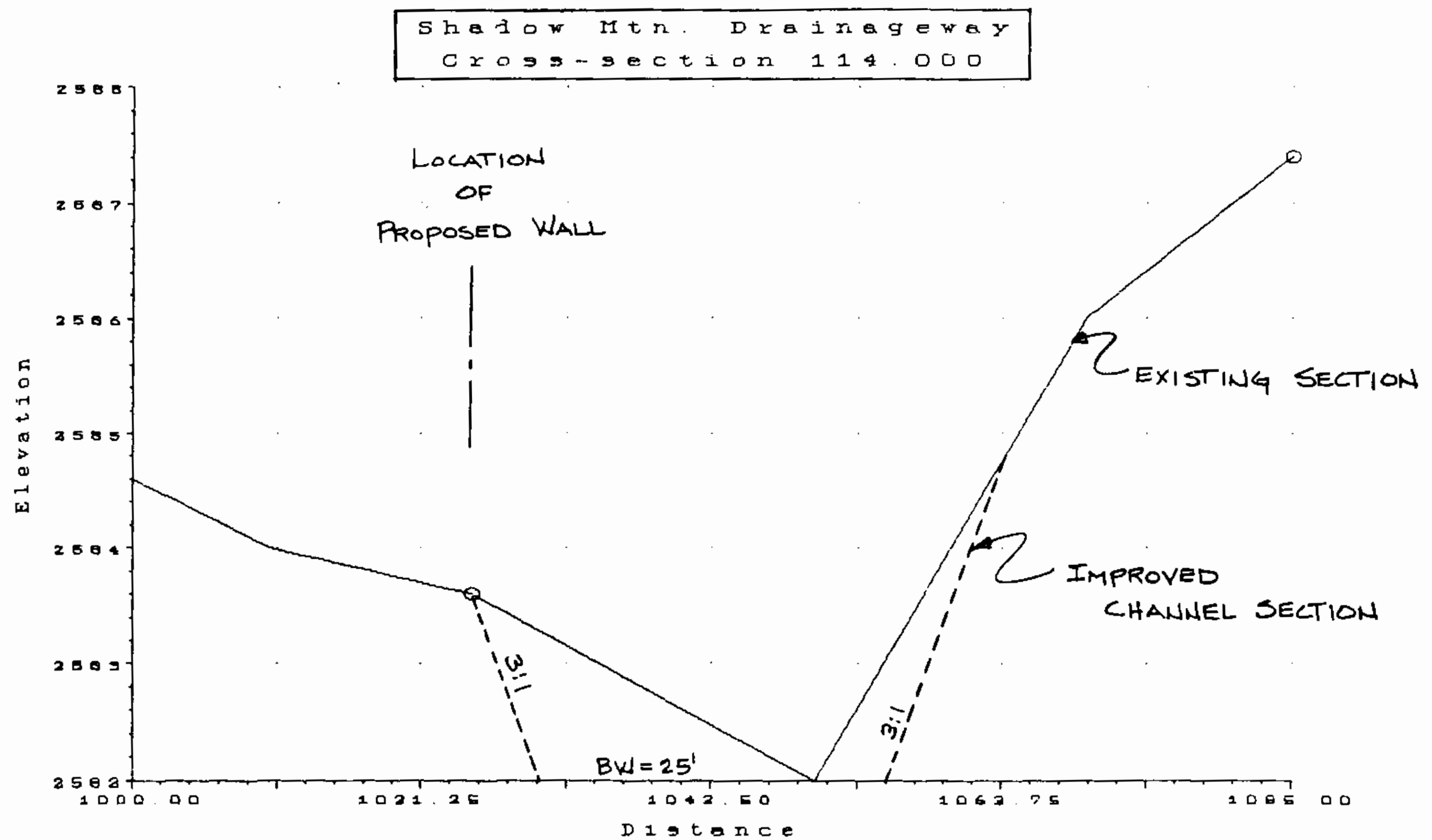


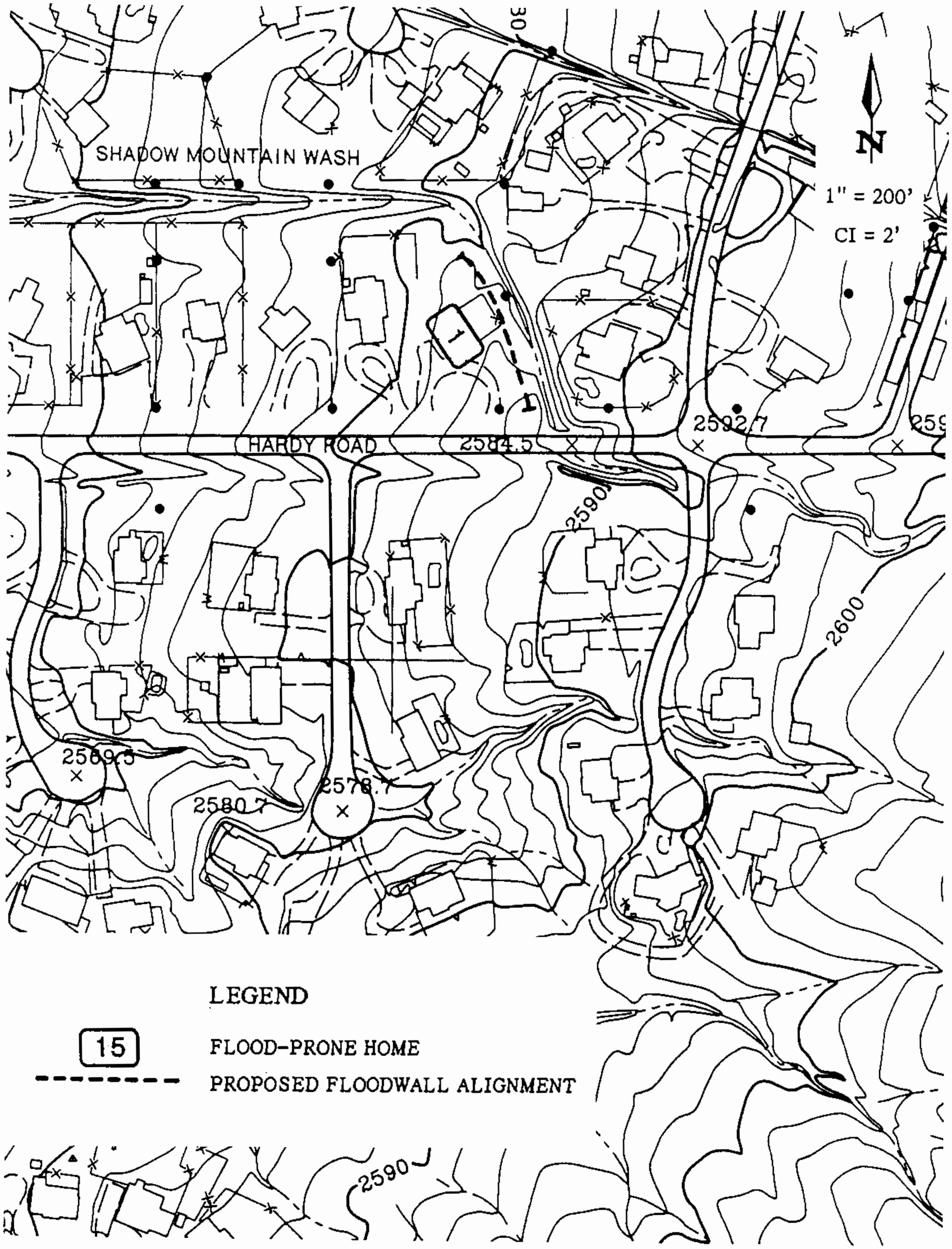
FIGURE 7

CHANNEL IMPROVEMENTS, SECTION 113
PROBLEM AREA A

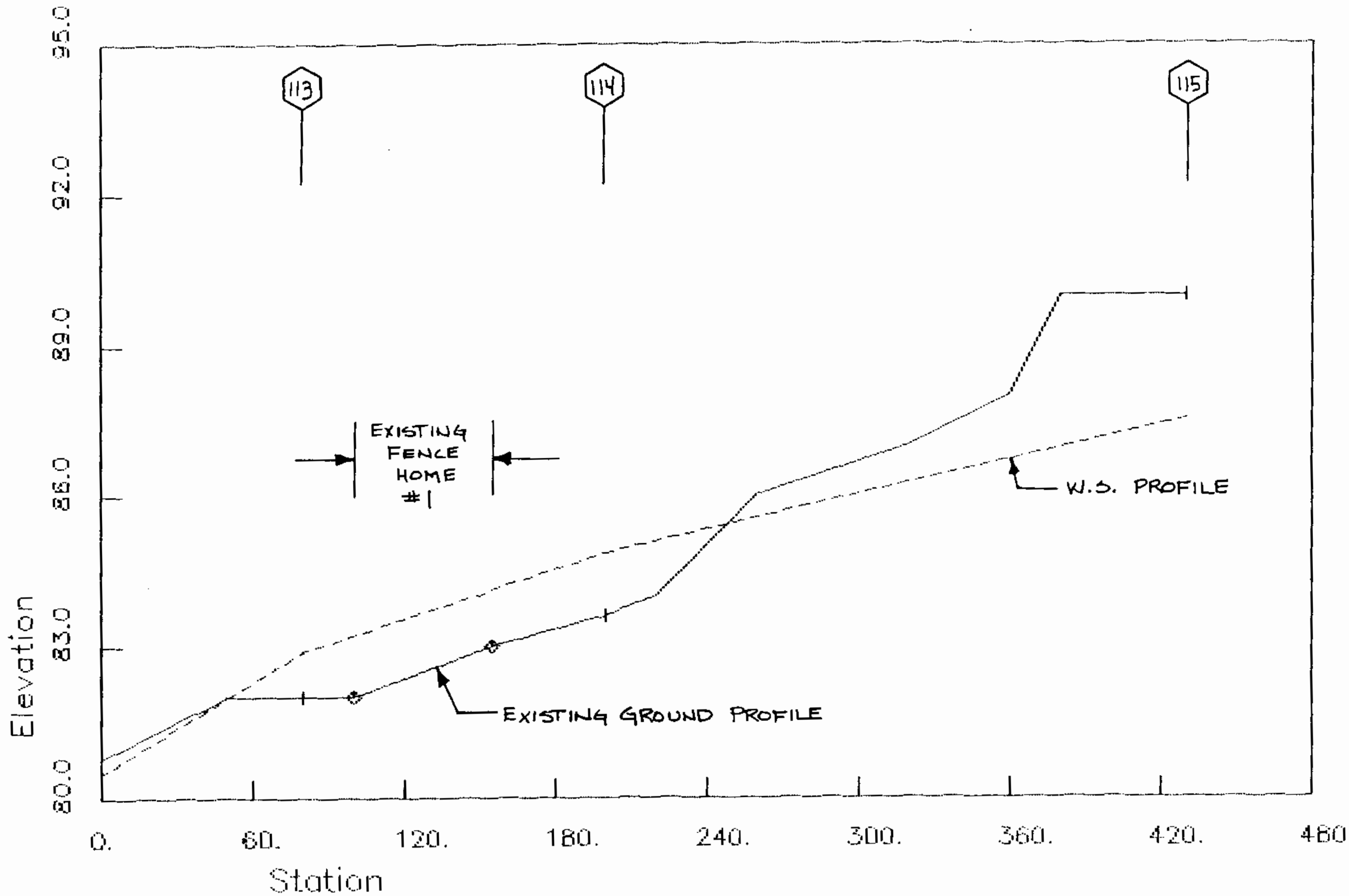


CHANNEL IMPROVEMENTS, SECTION 114
PROBLEM AREA A

FIGURE 8

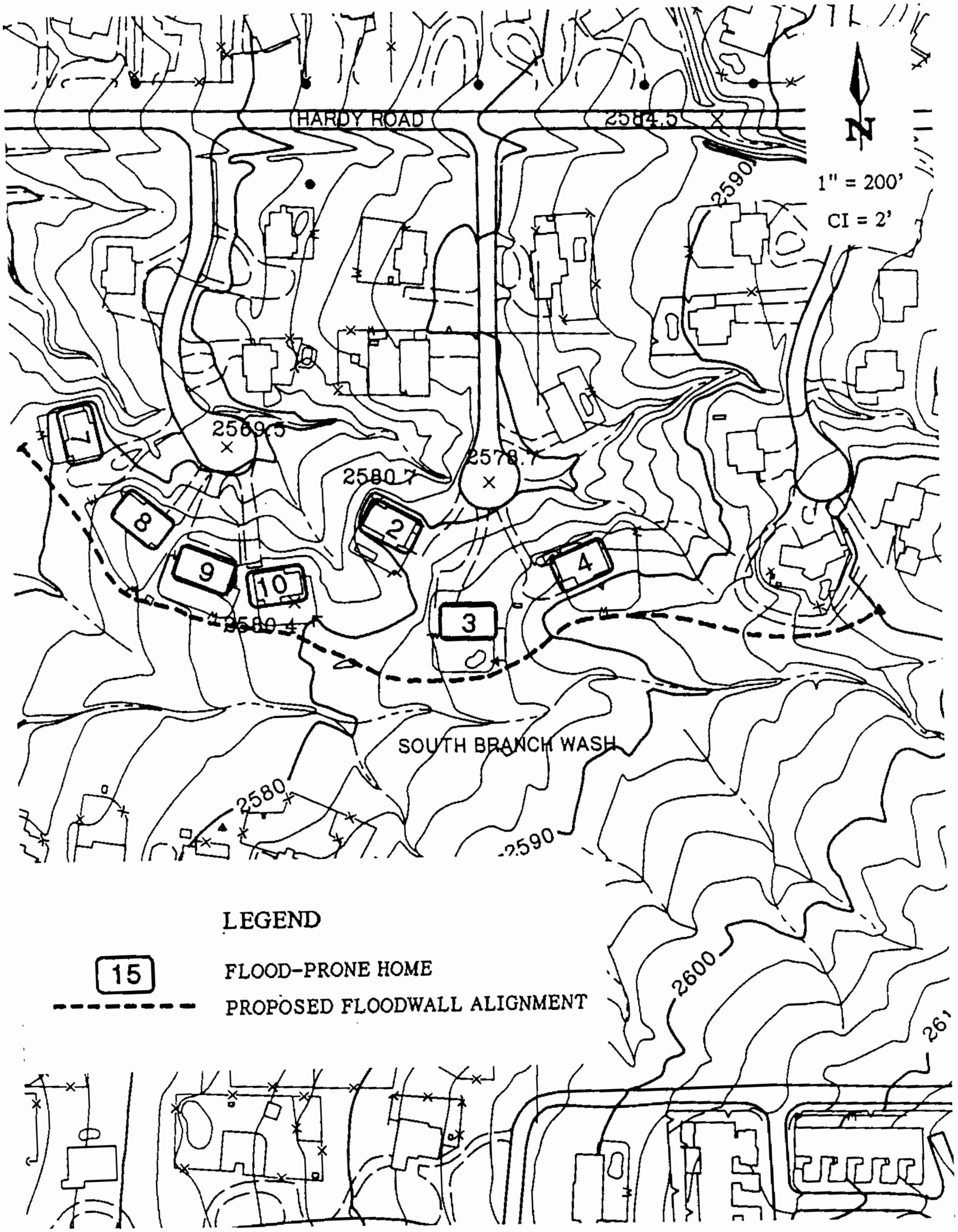


PROPOSED ALIGNMENT OF FLOODWALL
PROBLEM AREA A



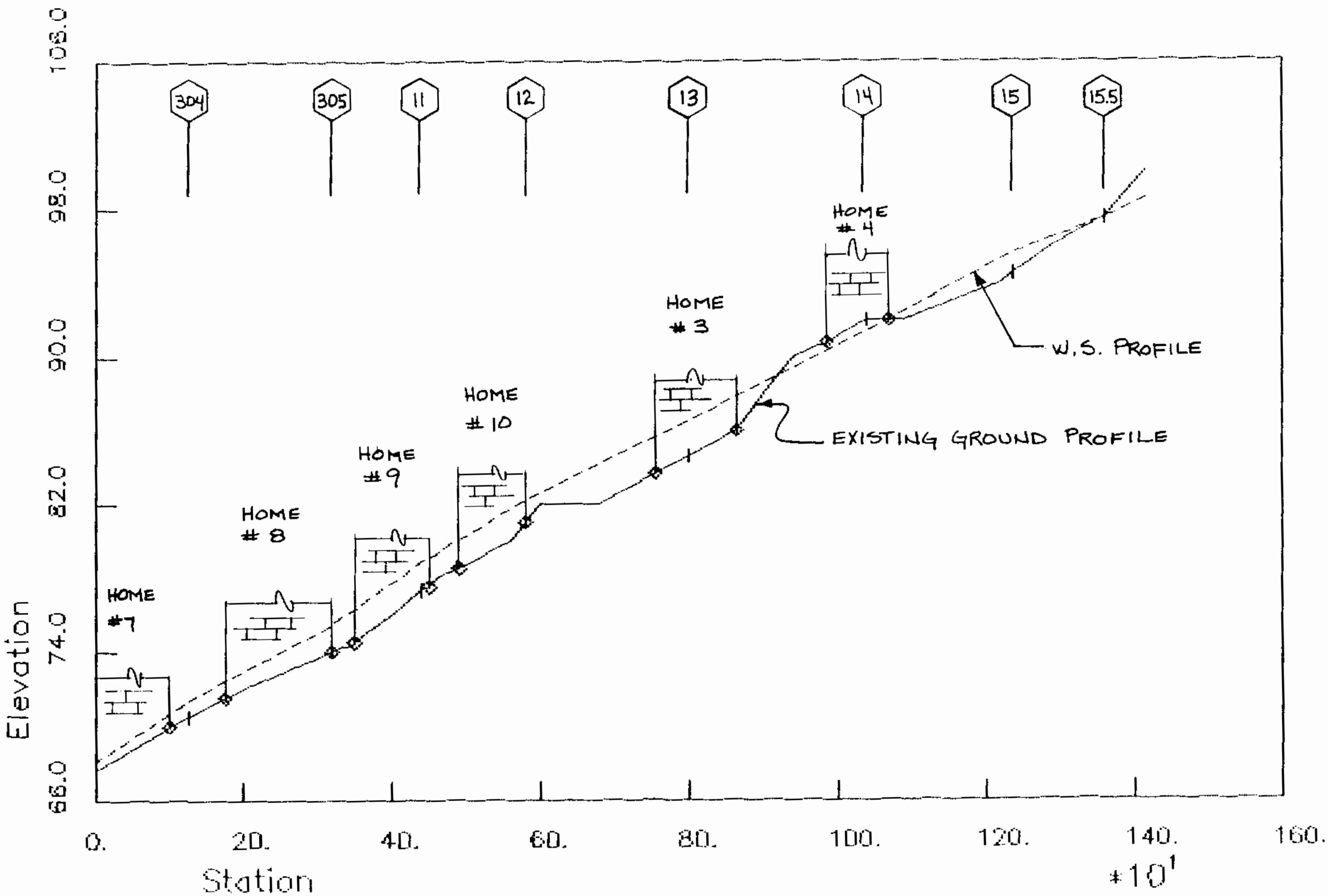
WATER SURFACE/GROUND PROFILE
PROBLEM AREA A

FIGURE 11



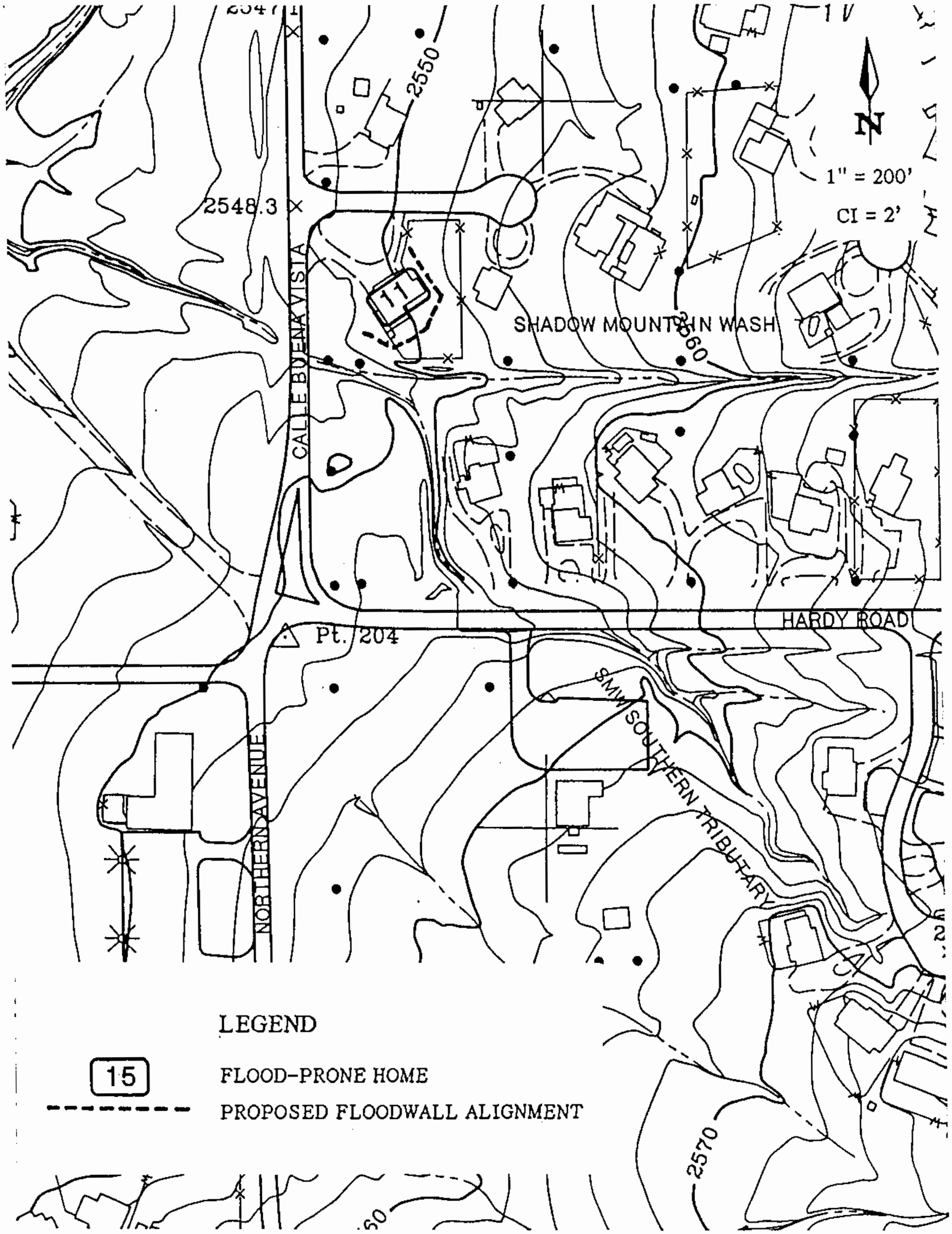
PROPOSED ALIGNMENT OF FLOODWALL
PROBLEM AREA B

FIGURE 12

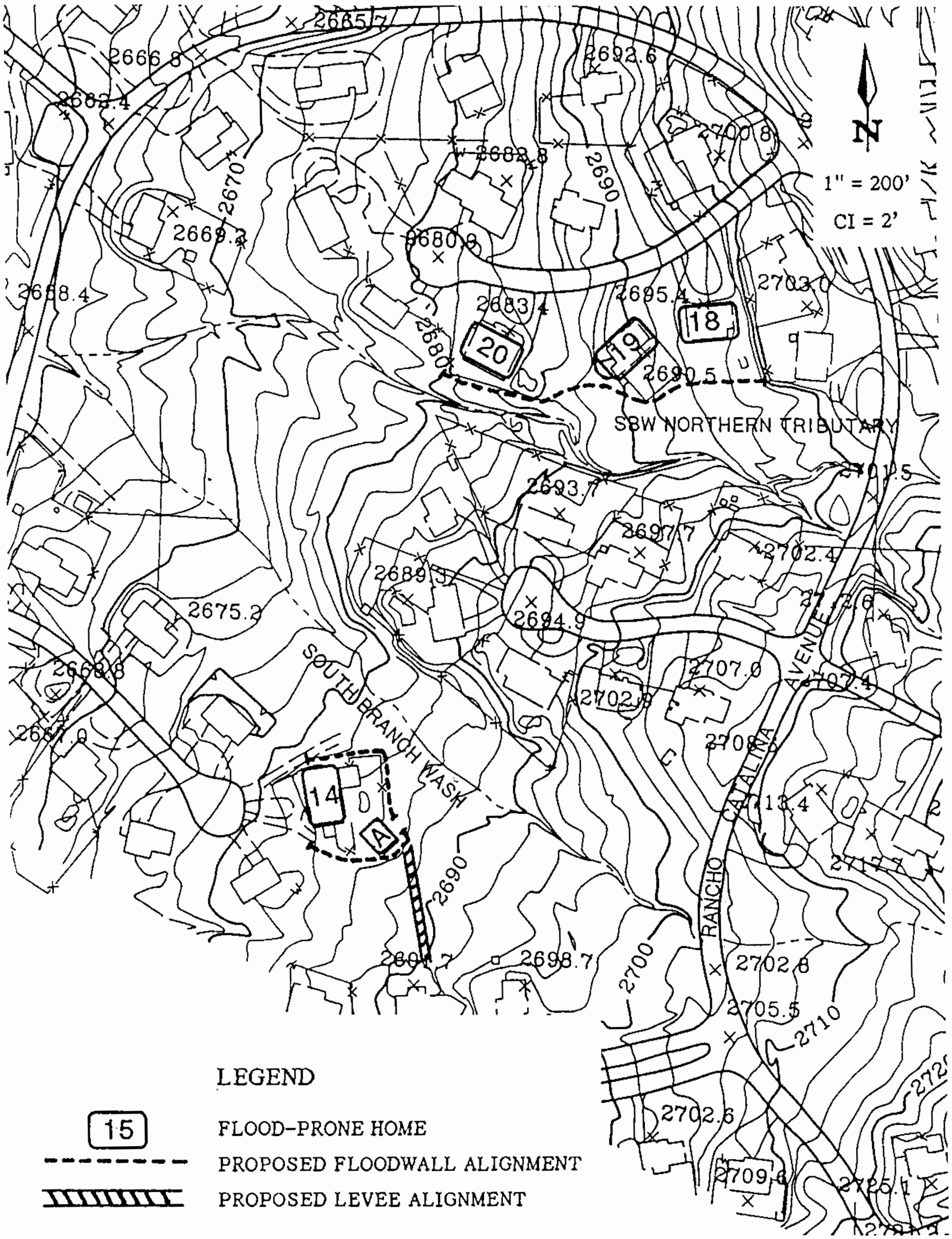


WATER SURFACE/GROUND PROFILE
PROBLEM AREA B

FIGURE 13



PROPOSED ALIGNMENT OF FLOODWALL
HOME #11



PROPOSED ALIGNMENT OF LEVEE/FLOODWALL
PROBLEM AREAS C AND E

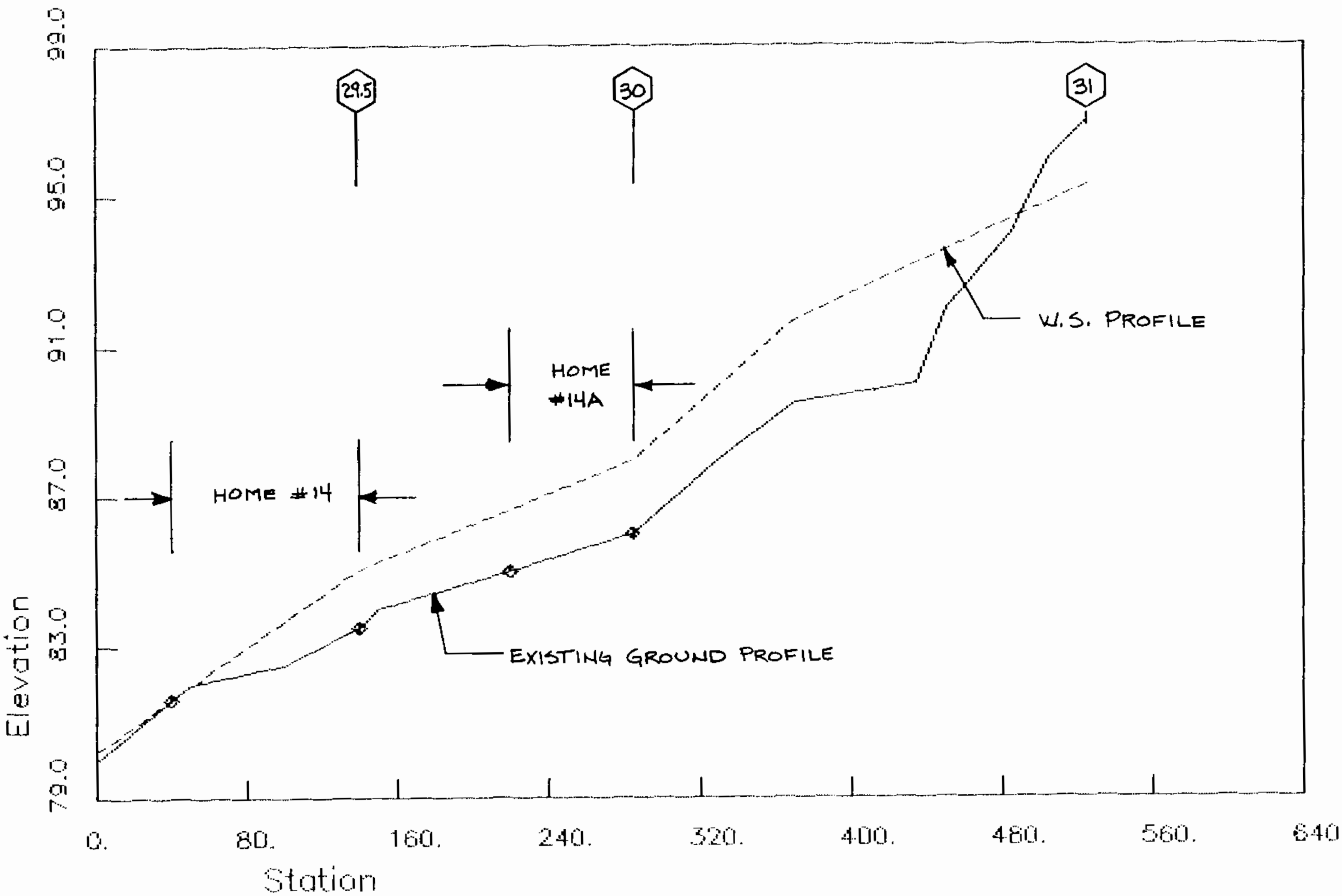
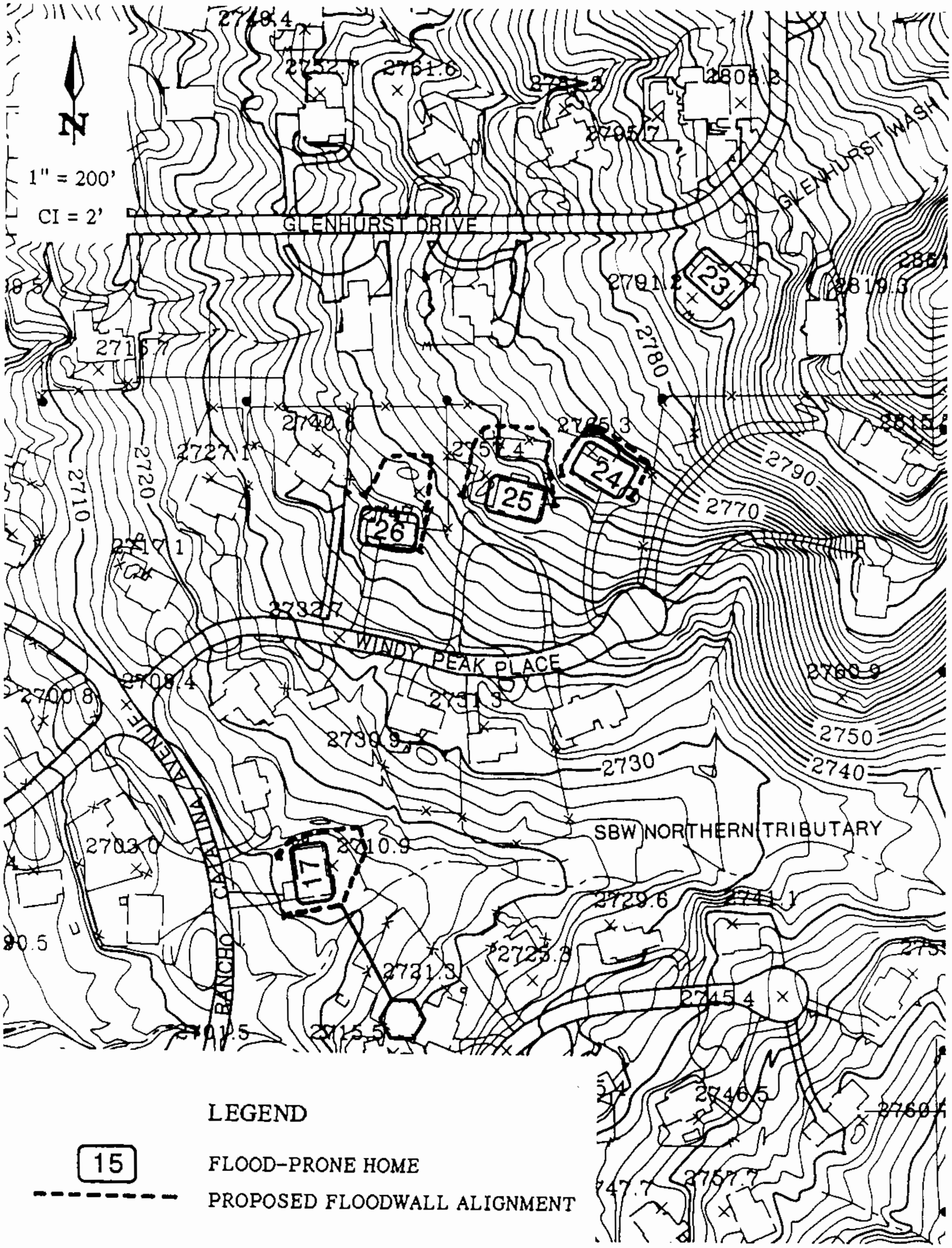


FIGURE 16

WATER SURFACE/GROUND PROFILE
PROBLEM AREA C



PROPOSED ALIGNMENT OF FLOODWALL
PROBLEM AREAS D AND F

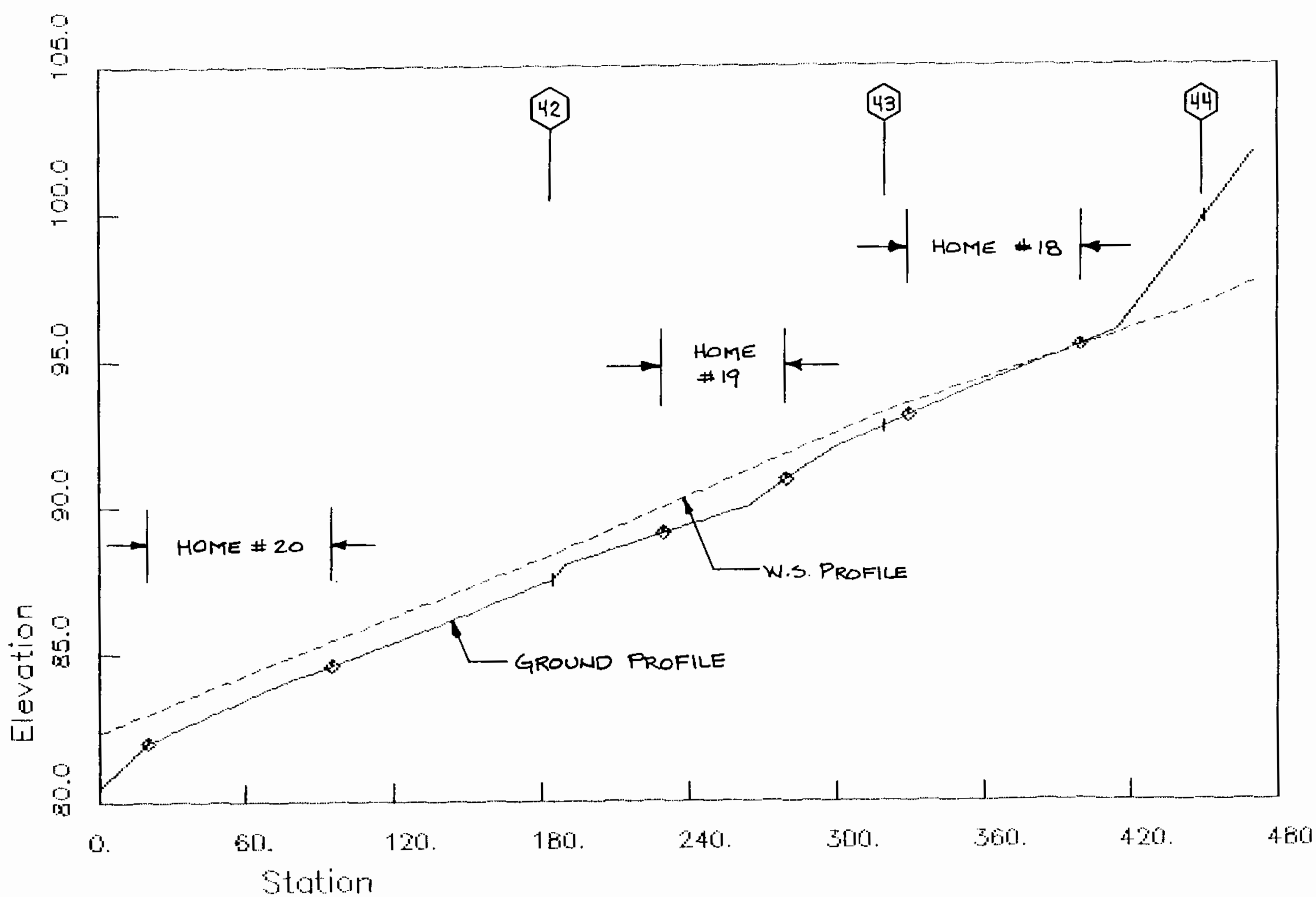


FIGURE 18

WATER SURFACE/GROUND PROFILE
PROBLEM AREA E

FIGURE 2

PHOTOGRAPHIC BASE MAP OF STUDY AREA

P.C.D.O.T. "SOUTH BRANCH UPPER CARMACK SUB-BASIN MGMT. STUDY" 1"=200' C.I.2' 6/20/91 C.A.S. 910618

FIGURE 9 (PHASE I) FIGURE 3 (PHASE II)

FLOOD-PRONE STRUCTURES MAP

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