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Fax cover sheet

To: **Ed Steffani** At: 209.948.0423

From: Barry Hecht and Ed Ballman

Date 6-21-99

Time

File 8924.11

Pages 14+enclosures
(including cover page)

Attachments

Erosion of Hoods Creek Ltr.
Table1
Figures 1 and 2
Attachments

Remarks:
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June 21, 1999

Mr. Ed Steffani
General Manager
Stockton East Water District
6767 E. Main Street
Stockton, California 95205-0157

Subject: Erosion of Hoods Creek - Whittle and Hertlein Properties

Dear Ed:

You had asked that I assess the causes of erosion along the banks of Hoods Creek within the Whittle and Hertlein properties. I visited the site on July 17, 1997 accompanied by Jeannette Thomas (SEWD), on May 13, 1998 accompanied by Andres Lozano (SEWD), and on other occasions. We have subsequently had a number of discussions with the Hertleins and Whittles, attempting to gather useful and usable data pertinent to sites of concern. Since our last meeting, I have worked closely with my colleague Ed Ballman to:

- locate, inspect, enlarge and analyze additional aerial photography, extending back to 1937, and
- collect and review additional information describing the Dec. 16, 1997, early January 1997, and February 1998 storms.

This letter summarizes my interpretations of the bank conditions, and presents several recommendations.

Technical Background

Some brief technical background will likely help readers of this letter. First, in 1989, Balance Hydrologics assessed the stability of Hoods Creek and adjoining streams, and their ability to convey flows of up to 550 cfs. This analysis was completed in 1989 and finalized in a March 1990 report. The '1989 report' considered stability of the bed, banks, and coarse layer covering the bars from several independent lines of reasoning and analysis. It includes a large number of tests and measurements from Hoods Creek. Portions of this letter draw upon the observations and calculations in that report.

We have attached hydrographs for recent storms from the USACE stream gage on Duck Creek, located a few miles northwest of the study sites, to help readers understand the sequence of storms and their relative magnitudes on a typical local stream. A schematic cross section from the 1989 report showing the hard Red Terrace and erodible Black Terrace is also attached.

Recent Conditions

Although the Stockton East Water District planned and constructed the Farmington instream conveyance facilities during the late 1980's, the initial significant deliveries of water began in April 1996. They continued into the summer of 1997 at rates of approximately 130 to 170 cubic feet per second (cfs). Major storms occurred during the New Years Day weekend of 1997 causing flooding throughout the Central Valley; storms later in January 1997 were considered serious further threats to the low-lying areas of Stanislaus and San Joaquin Counties. Storms of local significance occurred in mid-December 1996 as well as in February 1998. The latter storm filled the Farmington Reservoir flood control pool for the first time. Both local storms produced greater peaks in local streams than the regional event of Jan 1-2, 1997.

At the request of the USBR, SEWD allowed its conveyance facilities to be used to minimize high flows along the Stanislaus and San Joaquin Rivers during the late-January 1997 flooding threat. Known flows conveyed through SEWD's diversion and the channels from Goodwin Dam are shown in Table 1, attached. The data you have provided show that SEWD did not convey flood-relief flows during the early January floods, but did so during the latter portions of the late-January 1997 event.

During the winter of 1996/7, Hoods Creek experienced at least one flood crest which resulted in overbank flows commonly one to three feet deep along the Hertlein property, and to comparable but more variable depths along the Whittle holdings. Solely to establish a general context for evaluating the effects of the 1996/7 storm(s), we developed a reconnaissance estimate of peak flows at a location with suitable hydraulic conditions a short distance upstream from the Smith Creek confluence, near SEWD's cross-section 78. This estimate of approximately 4040 cubic feet per second (cfs) suggests that the flood crests of the 199/7 winter likely corresponded to an event with an expected recurrence of about 50 years or somewhat more, based on the analysis of the Duck Creek and Bear Creek flood records presented in our 1989 report.[1] Although only one high-water mark was seen in the field, it is possible that separate overbank flows occurred on December 16 and January 2, based on the Duck Creek flow record (attached). High flows also occurred in February 1998 (see below).

Role of Corps and SEWD Flow Releases

Flood-relief flows conveyed through SEWD's facilities at the request of the Corps of Engineers were made during late January and early February (Table 1). SEWD continued to convey flows through Hoods Creek through the summer of 1997. The flows requested by the Corps or the subsequent SEWD flows were about 10 percent of the peak storm flows of 1996-7, which almost certainly occurred in late December 1996 or early January 1997, before the diversions commenced. The released flows probably did not have a significant role in bank erosion or retreat during the past winter, since much greater peak flows were generated from within the watershed by storm runoff.

[1] The recurrence tables for peak flows in this part of Stanislaus County are expected to be revised downward, because the 1996-7 events and the February 2, 1998 event all appear to have exceeded the 1986 storm crest, probably the highest flows for this area since the early 1930s, when regular record-keeping commenced.

Review of Specific Sites

I examined seven sites (figure 1), within reaches 12, 13 and 14. These reaches were identified in the 1989 report as being among the most stable in the Shirley/Hood/Rock Creek system, and those least likely affected by SEWD's instream conveyance program.

Site 1. Red terrace bank, at east side of Hertlein orchard, near SEWD cross section 88

The most critical site visited was in the vicinity of a 90-degree bend in the channel on the east side of the Hertlein property near the Oliver residence and barn. On the high, steep bank just downstream of the bend, a wedge of soil collapsed, eroding away approximately 20 lineal feet of upper bank material from beneath the barbed-wire fence, which is now suspended across this gap. This erosion most likely occurred during a period of extremely high water, such as the flood flows experienced this past winter. One of the fenceposts has been washed away. The top of the bank seems to have retreated approximately 8 feet during this one event, to a position 31.4 feet from the base of the trunk of the nearest walnut tree, and about 21 feet from the top of the collapsed bank to its drip line. The intervening distance is occupied by the unimproved service road essential to the operation of any orchard.

Geologic conditions: The Red Terrace deposits at this site visible above summer low water are composed of about 8 feet of massively-bedded, partly-cemented, rounded cobbles in a sandy-clay matrix, overlain by a variable thickness (usually several feet) of partly-cemented gravels and sands, and capped by about 8 feet of non-cemented sandy silty clay and silty clay. Soils with shrink-swell cracks approximately 1/2-inch wide are visible in the hard-packed dirt of the service road, defining peds (soil blocks) typically about 12 inches across. No signs of seepage are visible in the massive, smoothed face of the bluff.

Ongoing processes and suggest actions -- bank-failure scale: We believe that the bank at this location simply collapsed along a pre-existing localized fracture or zone of weakness. The collapse plane is arcuate and concave upward in both the east-west and north-south directions, intersecting the bank approximately 3 to 4 feet above the summer water level when flows are being released at approximately 500 cfs from the SEWD facilities. It appeared in from examining the bank in July 1997 that:

(a) the collapse was in fact caused by the peak flows of the previous winter, in combination with the hard rains which caused other slope and swale failures on the opposite bank of the stream (see Site 2).

(b) the upper portion of the collapse may propagate a short distance further into the bank, probably less than 5 to 10 feet, with the primary mechanism being upper bank collapse (rather than undercutting by the stream) during rare, very wet periods in stormy winters of the next few decades; I believe that the slope will then have reached a stable inclination for the non-cemented upper soils, with little or any further bank retreat expected.

(c) it will prove extremely costly to repair this feature *at present.* Most approaches to repair will require driving supports into the adjoining bank of cemented cobbles, possibly weakening the bank; with further bank retreat, a low retaining wall anchored in the cohesive silty clays of the upper bank may prove feasible.

(d) a preferred approach at this site would include a tiered set of actions:
- move the fence back several feet from the existing top of bank, such that use of the service road around the periphery of the orchard is safer,
- plan for additional bank retreat of up to 5 to 10 feet during the next few decades,
- consider repair of the bank with a shallow retaining wall anchored in the upper 8 to 10 feet of the red terrace deposits if retreat beyond 10 feet occurs, threatening long-term use of the orchard service road.

Ongoing processes and suggested actions -- whole-bluff scale: Conditions at this site suggest that it may be useful and helpful to focus on the processes affecting the whole bluff, rather than focusing on the localized failure. Therefore, since last meeting with the SEWD Board and the owners, our staff has tried to obtain any and all additional information pertinent to this complex site. The Hertleins have also attempted to learn more about the evolving position of the bank through discussions with neighbors and review of property records. Neither search has yielded much in the way of tangible data either identifying the location of the bank or any major changes in stream location or conditions. Our staff then took the next step of using high-resolution analysis of enlarged aerial photographs to estimate the rate and pattern of bank retreat at this site between 1937 and 1997. We purchased additional aerial photography from 1937 centered over this site to minimize photographic distortion. Custom enlargements were made of both the 1937 and 1997 aerials, so that position of the banktops could be analyzed at various scales, including some as detailed as 50 feet to the inch. Results, depicted in Figure 2, indicate that (a) as much as 13 feet of retreat may have occurred during the past 60 years at the localized failure, inclusive of the estimated 8 feet reported in 1997, (b) retreat elsewhere along this bluff has generally been two feet or less, comparable to the discrimination errors inherent in interpretation of hyper-enlarged aerial photography. It is likely that (c) a prior bank retreat event occurred at the localized failure, an inference consistent with evidence of an older fenceline the presence of an older north-south fenceline a few feet east of the existing barbed wire; and (d) no evidence can be found for similar collapses elsewhere along the bluff.

Rates of bank retreat, averaged over 60 years, range from about 0.4 inches per year for most of the bluff to a maximum of about 2.6 inches per year at the localized failure.

Site 2. Erosion of bluff face, Mehrten formation bluffs, near SEWD cross section 83

Two fresh slippages are visible at the upstream end of the bluffs across the river from the southeastern corner of the Hertlein orchard. The bluffs are composed primarily of Mehrten formation volcanic ash and sediments of varying types. The slippages appear to be failures of the swale fills on the bluff face, caused by rainfall, and are not attributable to flows in the stream, as the slippages do not extend down to the 1997 high-water mark.

It may be helpful to note that we have observed many failures of this type during the 1995 and 1997 storms -- more so than during the 1982, 1983, and 1986 events, which were somewhat more intense in most areas in which we work. Our staff infers that many of the slides of the past three years result from death of shrubby vegetation during the 1987-1991 drought, and the loss of strength which the roots of these plants imparted to swale fills, colluvium or other slope deposits. We suspect that similar processes have been occurring at this site.

Site 3. Straight reach, south side of mature orchard, Hertlein property, between SEWD cross sections78 through 82

Downstream from the Mehrten bluffs, the stream flows westward through a straight reach in which the banks are slightly to moderately unstable, with some widening of the channel evident. Both banks are formed of 'Black Terrace' deposits, or more recent stream deposits. A fence paralleling the top of the north bank and set back a number of feet from it excludes cattle from the orchard, and provides a dry stockway when the stream is flowing. The channel and range land extending southward from the fence is presently leased for grazing. The downstream end of the reach coincides approximately with the western end of the mature portion of the Hertlein orchard.

My principal concern at this location is the potential for significant future bank erosion if appreciable amounts of cobble enter the channel from site 1 or other banks upstream. The stream would be expected to widen and perhaps braid at this location if more cobble than is transportable by high flows enters this reach.

If coarse debris does not enter the stream in large volume, the channel is expected to retain its overall stability, with perhaps very gradual bank retreat balanced by bar and bank formation on the insides of bends. There may be a tendency for the southern banks to erode more than those on the north. I understand that the Hertleins are re-evaluating grazing of the channel and south bank; diminished use will probably increase the stability of both banks as the channel is presently configured and vegetated. I do not believe that the orchard or its peripheral service road is appreciably at risk at this location, unless the stream's present regime is disturbed by erosion of upstream banks. From a channel stability standpoint, the northern bank would be an excellent candidate site to allow establishment of suitable woody vegetation because:

- the lower banks are composed of suitable alluvial materials,
- a range of pool/riffle and velocity conditions can be found here applicable to most conditions encountered along Hoods and Shirley Creeks
- the riparian vegetation would supplement the incipient tulle and cattails patches, which are beginning to establish themselves in this reach.

The Hertleins note that willows and certain other woody streamside vegetation are known to host pests which will affect their trees and/or crop. Management to minimize these species seems compatible with channel-stability needs.

Site 4. Bend area, downstream end of Hertlein holdings, between SEWD cross sections 75 - 78

This site includes banks on the north and west sides of the stream, adjoining the Hertlein orchard extension. It is a complex reach with distinct Black and Red Terrace bank segments.

Conditions and Processes: Most of this site is the interior of a looping former meander of the channel, which extends northward well into the orchard, to the base of the slope extending up to the larger part of the newly-planted orchard, on the Red Terrace. The former course of the channel is the least-resistant portion of this area. Consequently, active erosion is occurring where the former course of the channel is exposed in the banks, both at the upstream end of this reach, and (most noticeably) at the bend, where this winter the channel eroded a small pocket extending perhaps 25 feet along the bank. The active erosion is caused by several factors, including (1) over irrigation, (2) natural erosion, (3) concentrated use by cattle, and (4) very high winter flows (exceeding 2000 cfs) which are greater than the SEWD flows of 150 to 550 cfs. The downstream boundary of this pocket is clear and abrupt, where the former channel is bounded by resistant Red Terrace deposits. The upstream boundary is transitional, with some small patches of bare bank visible for about 70 feet upstream of the pocket.

The lower third of this site, downstream from the bend, is a thinly vegetated sloping bank of Red Terrace deposits. It deflects the flow southward, and has been doing so for many decades with little sign of change. I consider this segment to be stable, with no treatment currently needed.

I also considered the possibility of re-routing the main thread of the channel to the south, eliminating the bend. Plainly, much of the peak flow did follow an overflow channel along this course. At this site, however, it seems preferable to allow the vegetation to re-establish following the likely removal of grazing pressures; if this passive approach proves ineffective, channel realignment can be further evaluated if monitoring at site 5 (below) demonstrates stability of downstream bank segments.

Site 5. Whittle holdings, upstream of Smith Creek, between SEWD cross sections 66- 72

At several locations, the channel has eroded, principally into the southern bank. The banks are composed of Black Terrace deposits, except at two bends where the more-resistant Mehrten volcanics are exposed. One new fresh cutbank distinctly longer than the others, and which the Whittles have identified as of concern, has formed in the relatively erodible Black Terrace deposits. No improvements were observed to be at risk.

In this reach, the channel appears to be in dynamic equilibrium. Cutbanks seem to be in approximate balance with formation of bars and new banks. Because it is formed in Black Terrace, potentially erodible during SEWD flows, the District could potentially be contributing to erosion at this site; however, effects, if any, are masked by the influence of the recent flood flows. As noted below, we suggest it be monitored. The question at this site is whether bank retreat will affect use of the land. Since erosion one side is matched by deposition on the other, there may be no difference in the value of the rangeland lost to erosion and the value of newly formed bars and low banks. The need for specific action beyond monitoring by SEWD is unclear at this time. This opinion might be re-evaluated if you believe that there is a difference in agricultural value.

The longest of the cutbanks could be included in the problem sites to be monitored, should SEWD choose to embark on a monitoring program. It may serve as a useful 'worst-case' index site for meander migration rates and overall channel stability for reaches just upstream and downstream from the Hoods Creek confluence. This site would also be the first on the Whittle parcels to be affected by channel widening if appreciable volumes of coarse cobbles enter the channel from upstream (see Site 2 discussion), and could enable proactive steps to be taken at other bends further downstream.

Site 6. Confluence of Hoods and Smith Creeks, between SEWD cross sections 60 - 63

Both erosion and braiding are evident at the confluence of Hoods and Smith Creeks. Erosion consists of an undercut bank on inside of the meander opposite the Hoods Creek mouth. The channel has also braided at and just upstream from the confluence and as a result is wider. It is not clear whether the braiding is a result of deposition of coarse bed material transported this winter by Smith Creek, by Hoods Creek, or by both.

These changes are typical of those, which occur at the confluences of channels of similar sizes; especially those located at the outside of a large meander bend. They are generally attributable to differences in the timing of peak flows (and peak sediment movement) from the two channels; the larger flow tends to backwater the smaller, resulting in rapid deposition of unstable bars followed by rapid incision and erosion of portions of the bars when the relative amounts of flow change from one channel to the other. Remains of several previous episodes of bar-formation and braiding are, in fact, evident in the field just downstream from the present confluence. Also supporting this view is Nancy Whipple's observation that this bank was eroding prior to the 1996/7 storms. At these types of sites, channels often repair themselves during the first few years after a major sediment-transporting event.

I suggest that the channel at this site be left alone to develop a stable profile until changed by the next major storm crests. Engineered or structural solutions are not appropriate for confluence bars.

Meander cutoff alternative: An alternative which the owner has been considering, I understand, is straightening the channel such that the entire northward bend to the Hoods Creek confluence is eliminated, and the channel is directed northwestwardly from site 5. The feasibility and benefits of this alternative can be further discussed. We note that steepening the channel may result in additional braiding downstream.

Site 7. Corral area, Whittle holdings, between SEWD cross sections 54 - 57

Minor widening of the channel appears to have occurred at this site during the past winter's storms. A former overflow channel on the point bar on the inside of the main meander was temporarily re-occupied; the channel pattern retained its prior and generally stable form during and following this year's floods. The cutbank into the white ashy Mehrten deposits just downstream of the main meander has expanded slightly, but remains fully stable. The most active erosion appears to be in the lowermost reaches of a tributary entering from the northeast, suggesting that local rainfall intensities or other effects beyond SEWD's control are also significant at this location.

No specific action is recommended at this site, because the channel retained its shape and pattern throughout the appreciable flow events of the past winter. As for site 5, it appears that erosion and deposition are roughly in balance within a stable channel regime. Once again, our assessment rests on the assumption that the value of the land formed and eroded is comparable, which SEWD and its agricultural committee are better equipped to evaluate.

1998 Observations

I visited sites 1 through 6 on May 13, 1998. Little change was evident at most sites, despite record storm crests on February 3 throughout most of the region. Peak flows at the Duck Creek gage were greater than during the prior season, but high-water marks on Hoods Creek appeared to be lower than during the 1996/7 events. No signs of fresh failures were observed at sites 1 and 2.

Monitoring Program

Questions similar to those raised by this past year's events will continue to affect SEWD instream conveyance program and the operations of the cooperating landowners along Shirley, Hoods, and Rock Creeks. SEWD might wish to consider implementing a focused monitoring program involving aerial photography of the three streams, combined with specific tracking of selected problem spots. Pending further discussion with SEWD, the following program is proposed for consideration:

(a) sequential aerial photography: At intervals averaging about 3 years, photography of the three streams would be flown at a scale of 1:12,000 (1 inch = 1000 feet). Prints would be received by SEWD, and held by the District following quick review for changes at pre-selected locations where (a) bank retreat had been observed in the recent past, (b) bank erosion was anticipated as a potential future issues in our 1989 report, or (c) concern over improvements or environmental values warrants monitoring. The photos would be held on file until and if a question or issue arose for more comprehensive review extending the full length of one of the

stream reaches defined in the 1989 study. The record of channel behavior and bank changes would then be available for quick analysis. Note those photographic enlargements to scales as detailed as 1 inch = 250 feet are feasible from a program of this type, if implemented by one of the more reputable aerial photography contractors. It should be noted that since photogrammetry is not part of this program, surveyed controls would not be needed, appreciably reducing cost and complexity.

(b) specific tracking of problem spots: Local trouble spots would be monitored by a combination of surveys and photographs. For example, the localized failure at the Hertlein orchard could be closely traced using one of several straightforward survey methods. At this location, I suggest that a surveyed baseline be established parallel to the bank and about 20 to 50 feet west (landward) of the top of the bank, along an alignment acceptable to the owners. Ends of the baseline should be marked with survey humbs or other re-locatable monuments, positioned where they will not interfere with orchard operations. The distance from the surveyed baseline[2] to the top of the bluff would also be measured at specific stations by either SEWD or the owners, whenever there is a cause for concern, or a desire by either party to measure the rate of retreat. This bank would also be photographed from standard photo points to be established at each problem site warranting this level of attention. If agreeable, we will be happy to set up the baseline, worksheets, and files to make this monitoring approach usable to SEWD and others.

Based on Balance's experience with other programs of this general type, we can roughly estimate costs averaging about $2000 per year (or $6000 every third year) for the aerial photography, and similar or perhaps slightly greater costs for monitoring the specific problem sites, depending upon their number, extent, and the degree to which SEWD staff conduct the work, rather than outside consultants. We will be happy to refine these costs once the scope of this program has been further defined.

Summary of Findings and Recommendations

1. Major peak flows on Hoods Creek in December 1996, January 1997, and February 1998 tested the stability of the channel. It appears that peak flows during the winter of 1996/7 were the highest or among the highest since inception of local record-keeping in the early 1930s. With some specific exceptions, the banks and beds exhibited a high level of stability under major-flood conditions.

2. Flood-relief flours conveyed through SEWD's facilities at the request of the USBR were made during late January through early March 1997. The flows were about 10 percent of the peak flows which occurred presumably in early January, before the diversions commenced, and there is no evidence that they played a major role in bank erosion or retreat during the winters of 1996/7.

[2] Once surveyed and monumented, the baseline can be re-established at any time by stringing a tape measure between the two monuments demarking its endpoints; no special measures or training are needed.

3. I observed the three very different patterns of erosion developing in the three rock types -- Mehrten formation, Red Terrace and Black Terrace -- anticipated in our 1989 report; no need to change or update our descriptions of these patterns was evident.

4. The bank collapse at the east end of the Hertlein orchard is a localized failure in a bluff, which has proven to be quite stable during the past 60 years. Specific recommendations for this problem area are discussed in the text. We also recommend that a detailed monitoring plan for this site be developed.

5. Guidelines and suggestions for other sites are presented: No measures requiring structures or permitting are proposed.

6. Our 1989 report identifies the segment of Hoods Creek between Milton Road and the Rock Creek confluence as one of the most stable, both during and between periods when SEWD is conveying water through the stream system. Following at least 3 major storm events, this same finding prevails. We have seen no evidence of general instability or channel distress.

7. Questions similar to those raised by recent events will continue to affect SEWD's instream conveyance program and the operations of the cooperating landowners along Shirley, Hoods, and Rock Creeks. SEWD might wish to consider implementing a monitoring program involving aerial photography of the three streams, combined with specific tracking of selected problem spots. Costs and complexity of such a program are likely to prove reasonable.

Closing

I understand that we will meet soon with your Board to discuss these suggestions and recommendations with your Agricultural Committee and the affected owners. Please let me know if additional information would prove helpful.

Sincerely,

BALANCE HYDROLOGICS, INC.

Barry Hecht
Principal

Attachments:

Table 1:	Flows diverted through Shirley/Hoods/Rock Creeks, 1997
Figure 1:	Locations of sites along Hoods Creek
Figure 2:	High-resolution comparison of the position of top of bank at the Hertlein orchard, 1937 and 1997.
Attachments:	1996/7-storm hydrograph for the Duck Creek gage
	1997/8 storm hydrograph for the Duck Creek gage
	Typical low-bank configuration (Figure 6 from the 1989 report)

Table 1
Flows Diverted Through Shirley/Hoods/Rock Creeks, Jan., Mar., and Feb. 1997

Date (1997)	*Flow (cfs)*	*Duration*	*Volume (ac-ft)*
24 Jan	179	4:45-5:45	8.26
25 Jan	252	12:00 am-9:30 am	157.02
26 Jan	350	12am-1pm	0
27 Jan	350	24hrs	705
28 Jan	409	12am-9am	260.33
29 Jan	450	24hrs	900
30 Jan	477	12am-9am	334.7
31 Jan	460	12am-3:30pm	640.5
1 Feb	400		800
2 Feb	400		800
3 Feb	400		800
4 Feb	400		800
5 Feb	400		800
6 Feb	400		800
7 Feb	400		800
8 Feb	400		800
9 Feb	400		800
11 Feb	194	12am-11am	363
12 Feb	0		0
13 Feb	0		0
14 Feb	0		0
15 Feb	0		0
16 Feb	0		0
17 Feb	0		0
18 Feb	250	4hrs	82.64
19 Feb	250		500
20 Feb	250		500
21 Feb	250		500
22 Feb	250		500
23 Feb	250		500
24 Feb	250	12am-9am	185.9
25 Feb	0		500
26 Feb	0		500
27 Feb	0		500
28 Feb	0		500
1 Mar	108	13 hours	215
2 Mar	200		400
3 Mar	200		400
4 Mar	200		400
Date (1997)	*Flow (cfs)*	*Duration*	*Volume (ac-ft)*
5 Mar	200		400
6 Mar	200		400
7 Mar	200		400
8 Mar	137	16.5 hours	273

Notes:

Flow data supplied to Balance Hydrologics by Stockton East Water District on 08 August 1997. No data were available for days prior to 24 Jan 1997. Flows were variable in March, ranging from 200 cfs for several days early in the month to a minimum of 25 cfs on March 25.

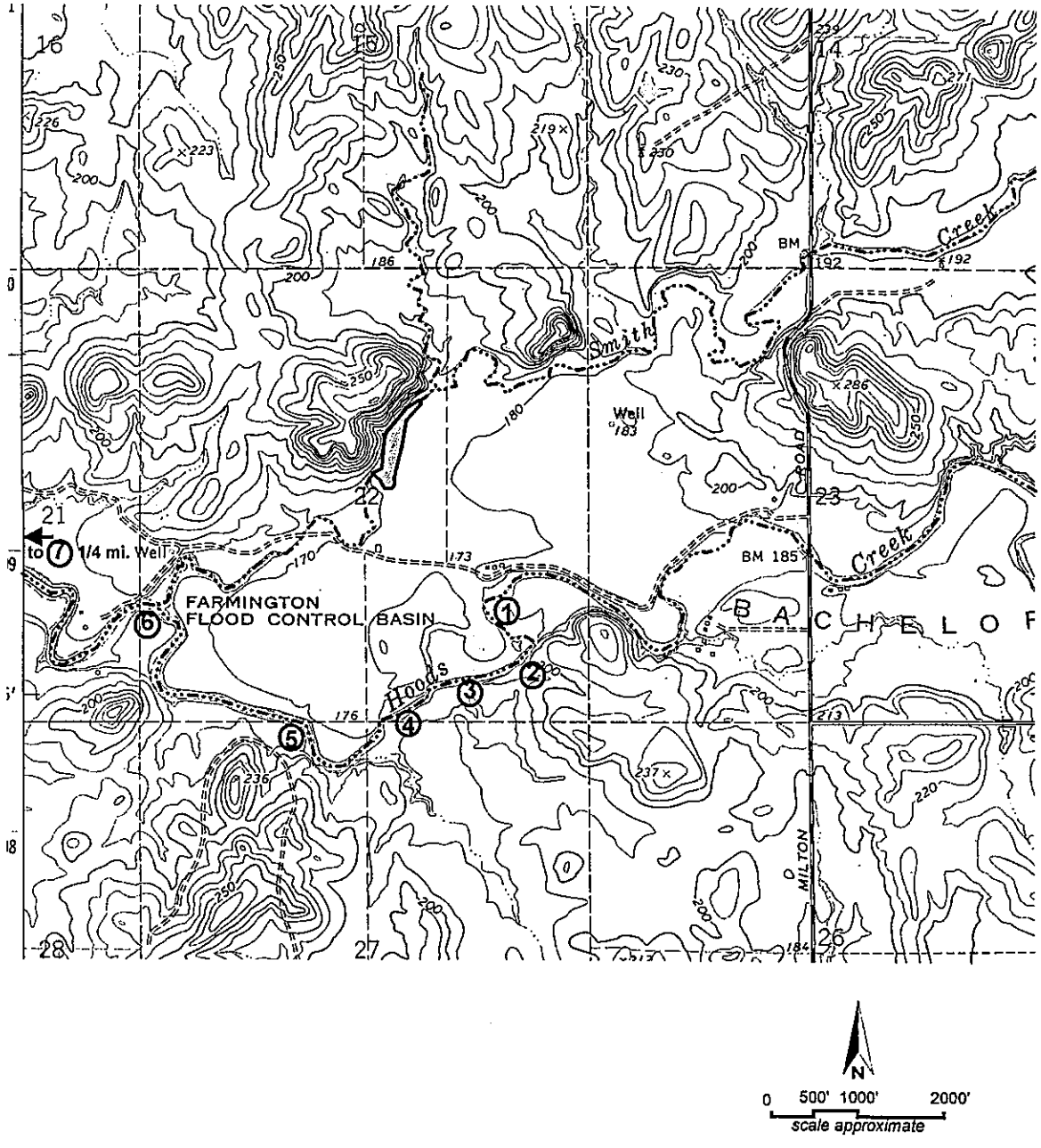

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Figure 1. Locations of sites along Hoods Creek.

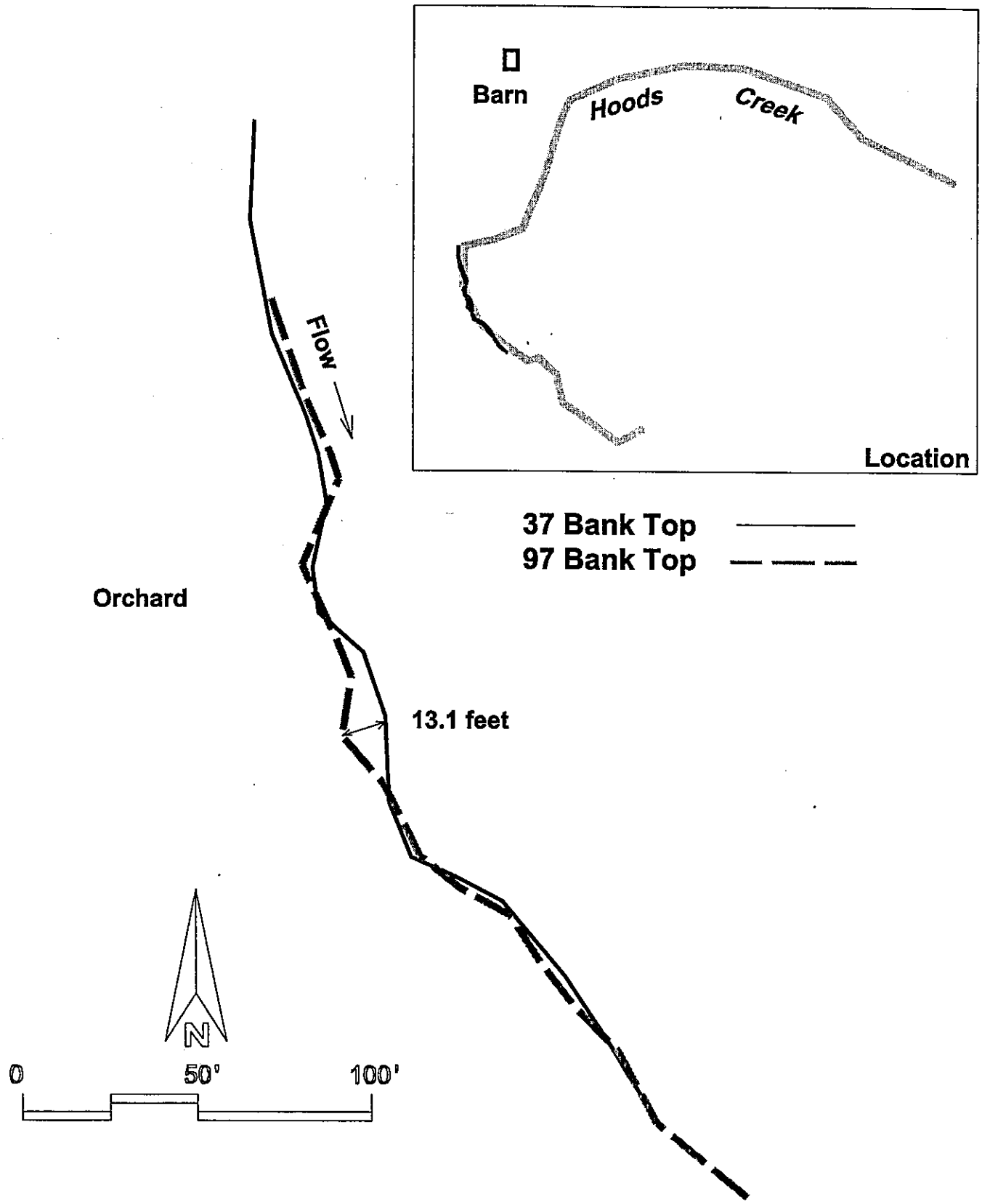

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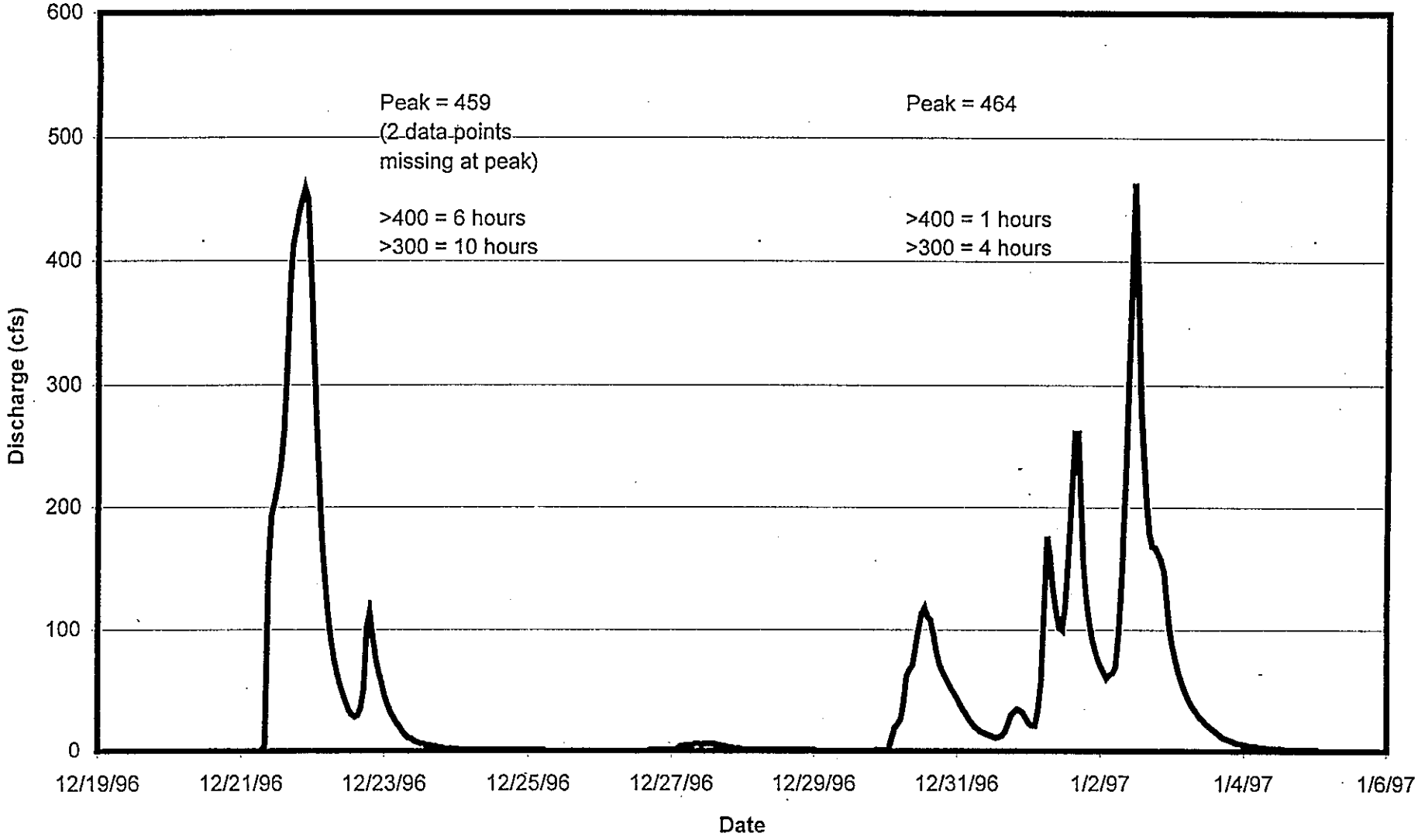
Figure 2. High-resolution comparative map of top of bank at Hertlein's orchard, 1937 and 1997. Maximum retreat of approximately 13 feet is associated with a bank collapse reported during the winter of 1996-97. Other areas show change on the order of 2 feet or less, or about 0.4 inches or less per year.

Discharge at USACE Gage on Duck Creek near Farmington
December 19, 1996 to January 6, 1997



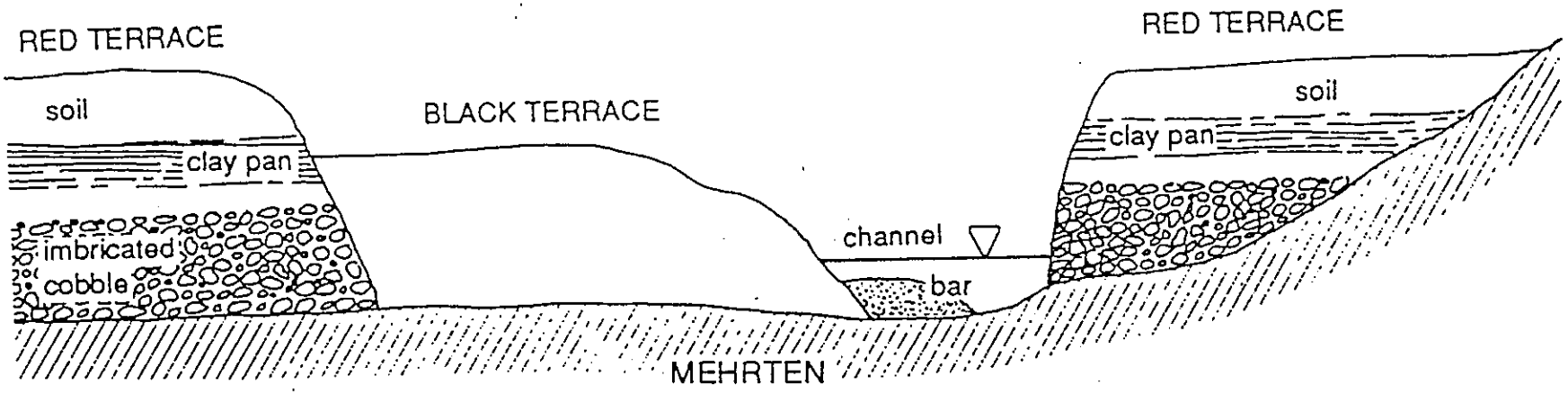


Figure 6. Typical Low-Bank Mehrten Occurrence