Stability of Alhambra Creek at the John Muir Gravesite

John Muir National Historic Site

Technical Report NPS/NRWRD/NRTR-2002/297

Richard Inglis
Hydrologist

April 2002

National Park Service
Water Resources Division
Fort Collins, Colorado

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EXECUTIVE SUMMARY

The gravesite of John Muir is potentially threatened by bank erosion of nearby Alhambra Creek. The watershed has been heavily affected by urbanization and other land use changes. This assessment of the stream bank stability near the gravesite uses a combination of hydrologic and geomorphic methods. It is also based on field observations of channel morphology and of riparian vegetation and measurements of channel geometry at three cross sections, longitudinal bed profile, and stream bank stability features.

Riparian vegetation appears to be a major factor holding the banks in place, while stream flow from an urbanizing watershed is probably one of the major causes of instability of the channel. While moderate amounts of organic debris and/or "natural" channel blockage are beneficial, human influence of added concrete rubble has caused artificial blockage and bank instability. Stream bank "erosion potential" for Alhambra Creek was rated "moderate" due to the high root density, explaining why the channel is not in a more serious condition. The channel "stability rating" determined that, even for a gully stream type, the condition was "poor."

The most important step needed to protect the gravesite is to stop the vertical incision of the channel. Constructing a gradient check structure in the proposed Strenzel Lane storm water project would arrest the incision. Channel blockage from the artificial rubble and the bank protection on the opposite (private) side are likely causing undercutting of the bank near the gravesite. The rubble and blockage on the opposite side should be removed and replaced with a properly designed toe protection structure on both sides of the channel. This may require negotiations with the private property owner to allow the NPS to help manage the stability of their side of Alhambra Creek.

The trees on the over bank area provide a lot of support to the streambank. Therefore, it is suggested that trees of various age groups be planted to assure that significant root mass is present well into the future. This action may be an appropriate start, but more stabilization may be necessary in the future. If "tougher" bank protection is needed, major problems must be overcome. The bank near the gravesite is too steep for most types of revetment, and there is no room on the NPS side to "lay back" the bank. There is little room on the other side either. Whatever is done on the NPS side of the channel to protect the gravesite should also be done on the private side without adversely affecting the homeowners.

A monitoring program is highly recommended and should start immediately. If change is detected through monitoring, more severe measures will be needed to protect the gravesite. The amount of buffer space between the gravesite fence and the creek bank is minimal (35' at present), allowing little adaptive management. Response time may be short if certain changes are detected (such as the formation of tension cracks). NPS management would need to take quick and decisive action to prevent damage to the gravesite. In the long run, relocation of the gravesite a short distance away from the creek would allow more permanent stabilization of the area.

INTRODUCTION

John Muir National Historic Site was established in 1964 in Martinez, CA, a rapidly growing community in the Bay Area of San Francisco. Additions to the historic site include Mount Wanda in 1992 and John Muir's and his wife's family gravesite in 1999 (Figure 1). The recently acquired gravesite has been identified as potentially threatened by bank erosion of Alhambra Creek. Alhambra Creek has been heavily affected by urbanization and other land use changes in its watershed (Alhambra Creek Watershed Planning Group, 2001). The gravesite is in an unincorporated part of Contra Costa County adjacent to Martinez. The Water Resources Division of the National Park Service (WRD) was asked by the park to provide information needed to protect and preserve cultural and natural resources of John Muir NHS – specifically the gravesite and Alhambra Creek that flows along the site. The objective of this report is to provide an initial assessment of the stability of the gravesite from erosion and flooding threats from the nearby Alhambra Creek.

John Muir wrote many of his famous works while living in Martinez, which was already a well-established town during the late 1800's. The early land use of the Martinez area provided food and supplies for the early development of California. Railroads, grazing, farms, and orchards have impacted the area for well over 150 years. In Muir's viewpoint the area must have provided a major contrast to such pristine places as Yosemite and Alaska, giving a modern day insight as to why he wrote so passionately for the preservation of wilderness. Ironically, the continuation of development has come back to threaten the earthly remains of John Muir and his family. The impacts of development higher in the watershed have affected the stability of Alhambra Creek – as seen in this analysis.

The gravesite is located in a 1.27-acre relic orchard, surrounded by private homes on one-acre lots (Figures 2 and 3). The southeast line between NPS property and adjacent private property is understood to be in the middle of Alhambra Creek. There are private buildings on the opposite side of the creek a few feet from the edge of the bank. There is a 20 by 30-foot iron picket fence around the graves and a dirt path outside the fence. At its closest point, the southeast corner of the fence is 35 feet north of the edge of the stream channel. The ground surface at this corner post is 16 feet above the deepest part of the creek. The ground around the gravesite will be managed by the NPS as a part of the historic pear orchard. A few large trees grow immediately south of the gravesite, while younger sycamore and California buckeye trees (6 to 9 inches diameter) grow between the fence and the edge of the ravine formed by Alhambra Creek (Figures 4 and 5).

In 2001, the Contra Costa County Flood Control District received a grant form the State of California to alleviate flooding and improve water quality in the Strenzel Lane neighborhood, just west of the gravesite. The proposed project involves building an underground storm drain through the NPS property about 100 feet away from the gravesite. A 5-foot diameter pipe will be buried under the NPS parcel with the outlet to Alhambra Creek about 130 feet downstream from the gravesite.

Contra Costa County Floodplain Management Program has guidelines for the unincorporated parts of the watershed for construction within the floodplain (Alhambra Creek Watershed Planning Group, 2001). They have become aware of a construction project involving dumping

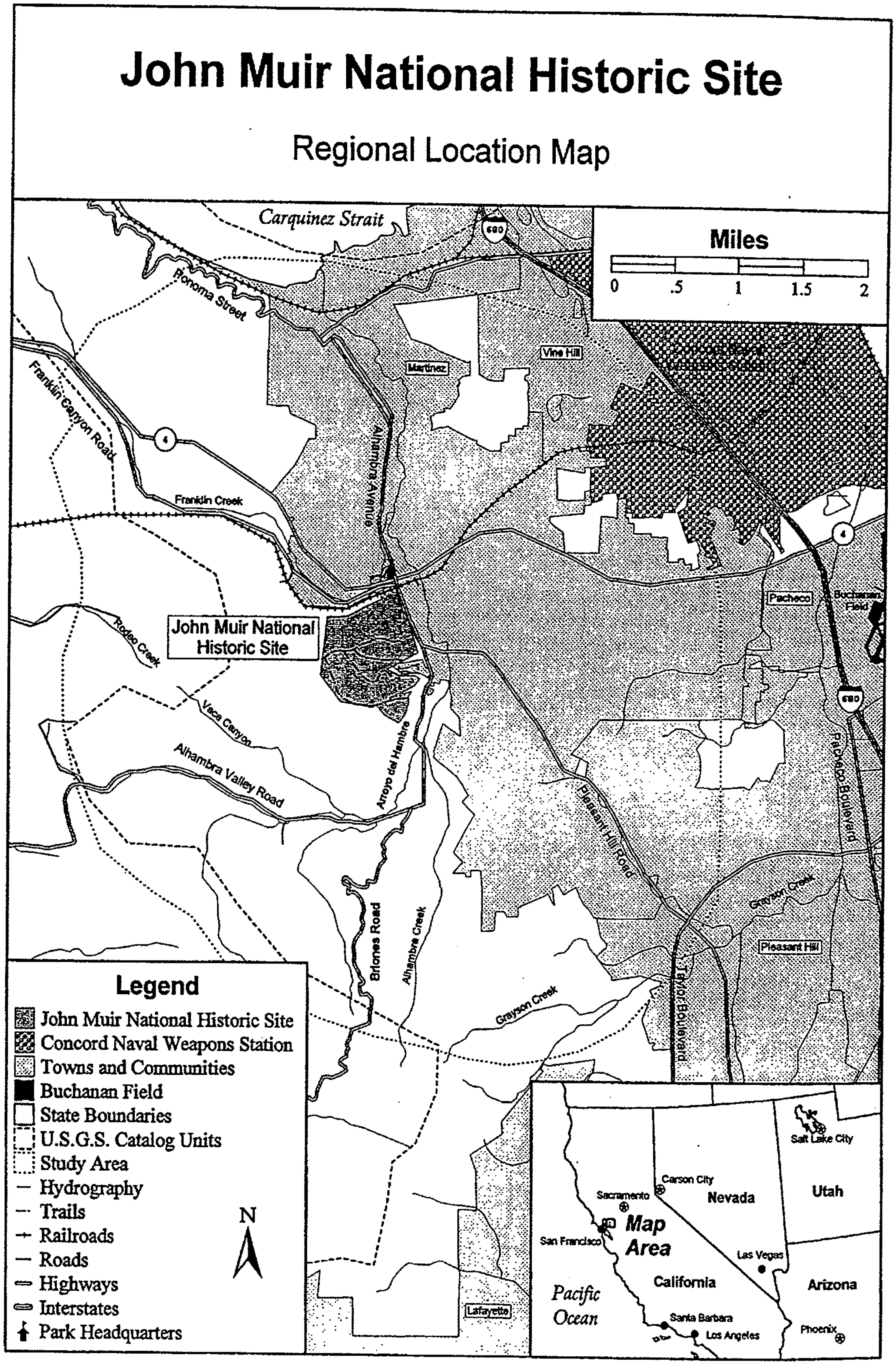


Figure 1. Regional location map (NPS, 1998)

Figure 2. John Muir Family Gravesite in the relic pear orchard (NPS, March 1998)

Figure 3. Alhambra Creek, looking upstream at bridge abutments and concrete rubble (NPS, February 2002)

Figure 4. Alhambra Creek, looking downstream (northeast) from below the gravesite (NPS, February 2002)

Figure 5. Looking east at Alhambra Creek from the southeast corner of the gravesite (NPS, March 2000)

concrete rubble in Alhambra Creek opposite of the gravesite on private property. It is a violation of County ordinances, as well and State and Federal laws, to build in the channel without a permit. The presence of this rubble blocking and/or diverting flows in the channel has serious consequences for the stability of the gravesite.

METHODS

This initial assessment of the bank stability of Alhambra Creek uses a combination of hydrologic and geomorphic methods as described in published references. It is based on information from field observations of 1) the morphology of the channel, 2) riparian vegetation and 3) measurements including channel geometry at three cross sections, 4) longitudinal bed profile, and 5) stream bank stability features.

The field data was supplemented with available information and publications from the Natural Resource Conservation Service (NRCS), previous WRD studies, and the 2001 Alhambra Creek Watershed Management Plan. Fieldwork along Alhambra Creek was conducted for this study August 13-15, 2001, and February 25-27, 2002. Guidance on stability assessments is from 1) Stream Corridor Restoration: Principals, Processes and Practices (Federal Interagency Stream Restoration Working Group, 1998), 2) Applied River Morphology (Rosgen, 1996), and 3) Streambank Stabilization Handbook (Army Engineer Waterways Experiment Station, 1998). A more detailed evaluation using geotechnical and hydraulic modeling was not conducted due to the intensive data requirements and the expertise required.

Factors that affect channel stability can be conceptualized in terms of the resistance of the channel to erosion and the erosive forces acting on the channel. The channel is considered to be "in equilibrium" if these opposing tendencies (resistance and erosion) are balanced and no net erosion or deposition will occur with time. The result of a disruption to the equilibrium (balance) between available stream power (the discharge-gradient product) and the discharge of bed-material sediment can be considered to cause vertical instability to the channel (Lane, 1955).

RESULTS

Observations in the field – (Using Section 3.1.2.3 in the Streambank Stabilization Handbook)

Bed Controls – In Alhambra Creek bedrock is not visible in the bed of the channel. The depth of soil in the area of the gravesite is very deep, reported by the SCS Soil Surveys to be greater than 5 feet (NRCS, 1997). Large amounts of concrete rubble and large cobbles of different origins are scattered in the channel, providing some resistance to downcutting. It appears that the boulder, rubble, and cobble bed is just a veneer. There is no evidence in the banks for course material, and they do not appear to be lag deposits (relic geologic material). They are locally derived from numerous stabilization projects. A reach with more step/pools exists downstream about ¼ mile, indicating an over-steepened zone, which could migrate upstream and cause headcutting. Undercutting of cement walls and exposure of tree roots indicate continual downcutting.

Berms and Terraces – The gravesite is believed to be on the old, pre-settlement floodplain, which is now a "high terrace." There are discontinuous terraces, believed to be the bed of the pre-settlement channel, along the creek about halfway between the current streambed and the high terrace. An alternative explanation for the bench in the bank is a post settlement floodplain feature. The latter implies a second period of incision within the last few decades, although the field evidence is thin. A few, small, isolated berms (deposits at the base of channel walls) are forming – mostly from rubble dumped into the creek to protect the banks – with one or two possibly from bank failure.

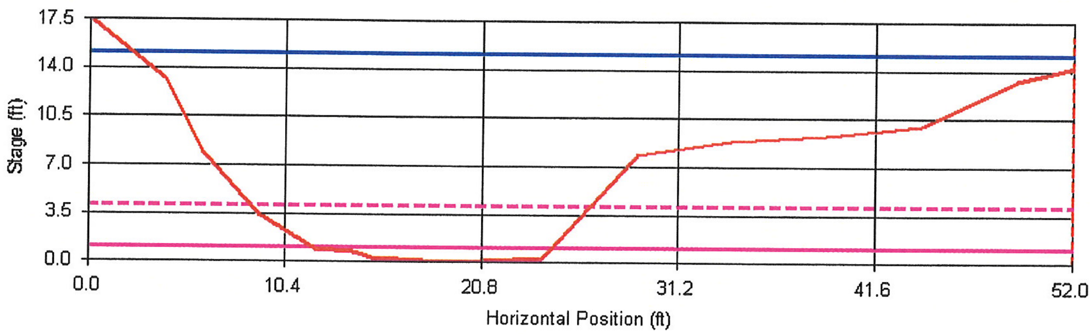
Channel Geometry – Three cross-sections (one upstream of the gravesite, one opposite and one downstream) and the stream gradient were measured using a 100-foot tape, a pocket rod, and a hand level. Very few bankfull indicators were visible. High water marks were about halfway up the channel walls. The marks appear as a faint line or zone of exposed roots with little leaf fall and loose material. The age of this indicator could be as old as five years, possibly due to the El Nino floods of 1997. The width/depth ratio of the channel is very low at 10.6 measured at bankfull height determined by the projected depth of water for a 2-year recurrence interval flood (Figures 6, 6a, 7, and 8). At Cross-section #1 two plots are included, showing the extent of illegal bank protection works. WinXSPRO, a program using Manning's Equation, was used to develop stage discharge relationships. These provide a graphic view of how deep the flows will be in the creek at different flood levels. Using a 100-year flood discharge the depth of flow in the channel would be up to 14.0 feet and would not flow out onto the high terrace where the gravesite is located. The results of the program and the cross-section field data are included in the Appendix.

Bank Stability – Bank angle ranges from 45 to 90 degrees based on visual estimates and measured cross-section data. Some over-hanging banks exist in the channel. Mode of bank failure is probably a combination of dry ravel, small slabs, and fluvial scour during high flows. It is probably safe to say that saturation of bank soil plays an important role in bank failures. Dry ravel occurs during very dry periods, with slab and other mass failures occurring during super-saturated conditions. The failure of the bank could be quick and result from an episodic event, most likely a slab bank failure caused by a rapid drop in water level in the creek after a 50-year, or larger, event in the early Spring, when the soils are already saturated.

Vegetation - A deciduous forest (sycamores and California buckeye) with many exotic trees (eucalyptus and Ponderosa Pine) dominates the riparian zone. See Figure 9 and Table 1 for an inventory of the trees conducted by park staff. The under story is composed of a few shrubs and exotic vines. Many roots from woody species are exposed on the surface of the bank (most of them still alive). A few herbaceous plants grow in the channel.

Sediment – The Alhambra watershed is prone to landslides. It is becoming urbanized with roads, housing construction, and agriculture – all potential sources of sediment. Channel banks, channel bed, and tributary input appear to be the largest sources of sediment because

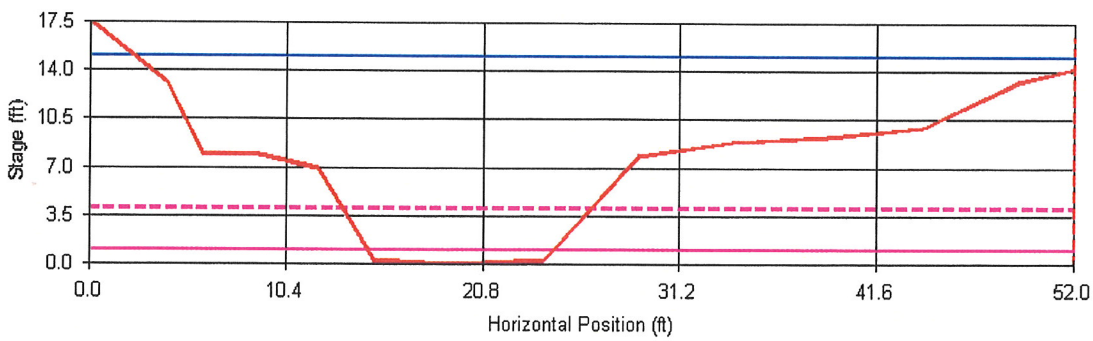
Alhambra Creek Cross-section #1



Clear Channel

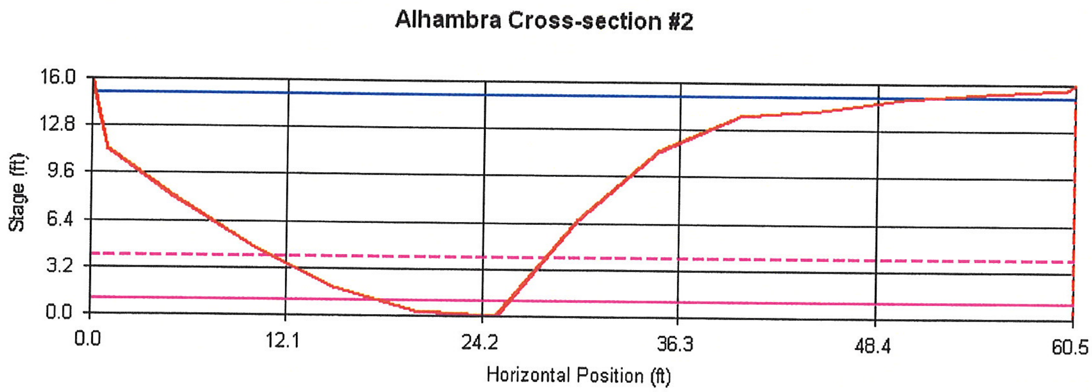
Figure 6. Upstream cross-section plot with a clear channel (WinXSPRO)

Alhambra Creek Cross-section #1a



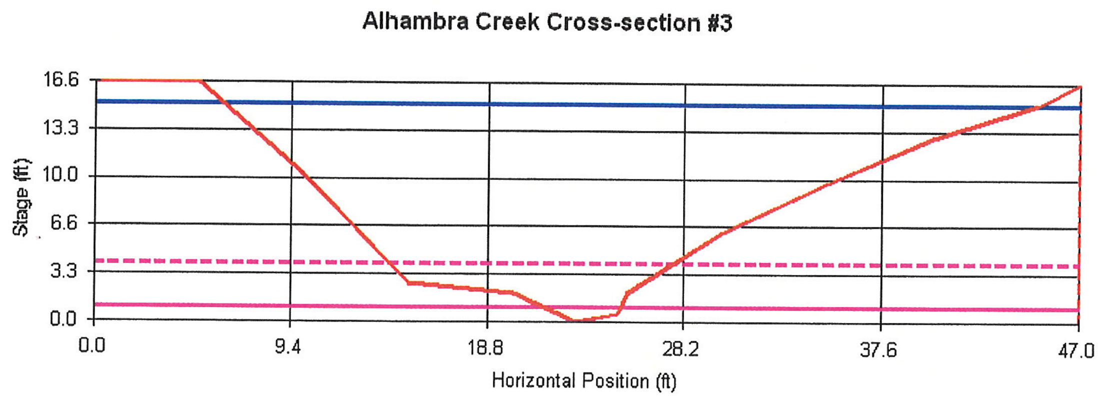
Includes rubble bank protection

Figure 6a. Upstream cross-section plot with rubble bank protection (WinXSPRO)



Adjacent to gravesite

Figure 7. Plot of cross-section opposite the gravesite (WinXSPRO)



Near Strenzel Lane Outfall

Figure 8. Downstream cross-section plot (WinXSPRO)

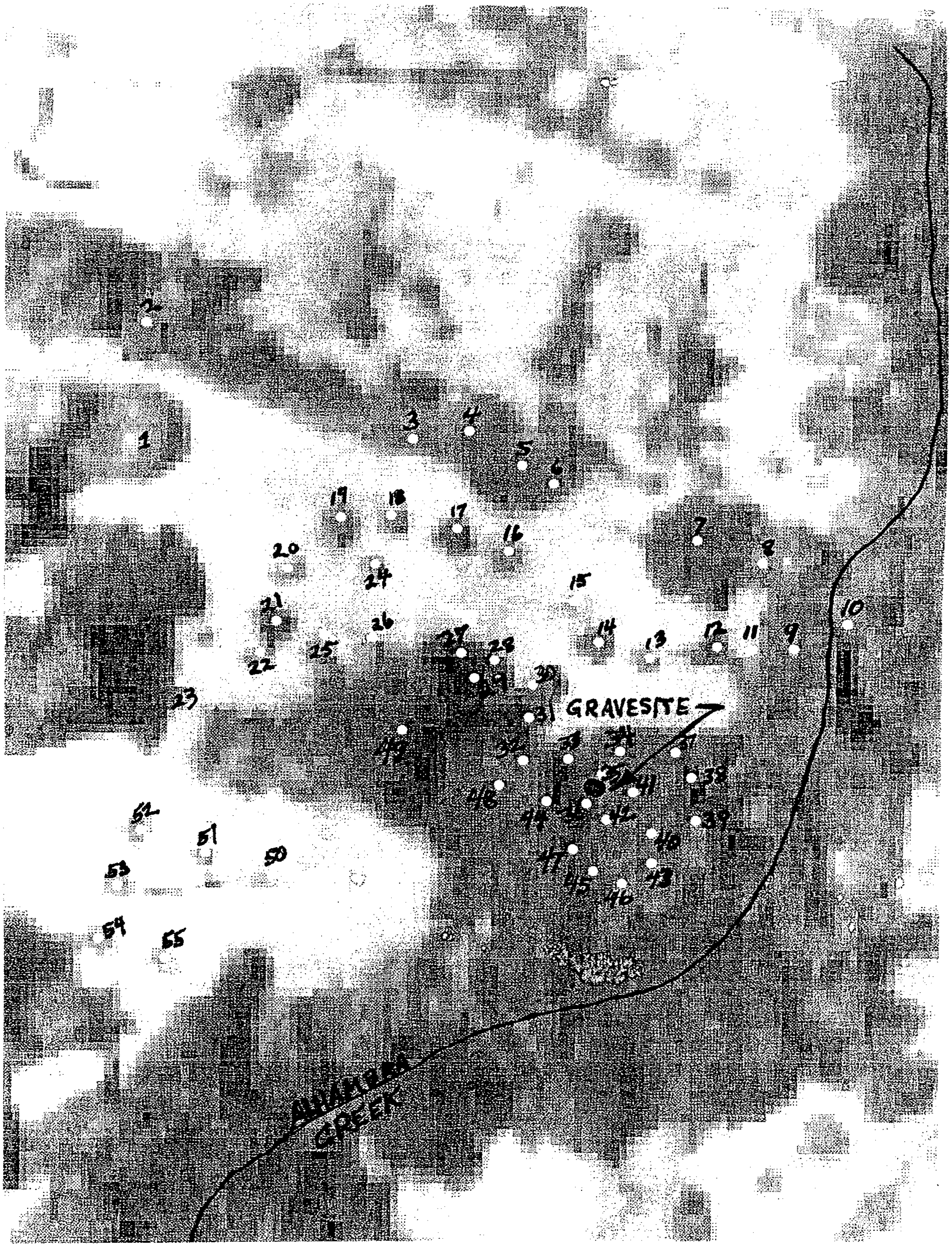


Figure 9. Inventory of tree species near gravesite (NPS, 2002)

Trees in the John Muir Gravesite

Shape		Tree_name
Point	1	Sitka Spruce, Black Walnut, California Bay Laural, Coast
Point	2	Beginning of Oleander Hedge
Point	3	Pear, Algerian Ivy
Point	4	Pear
Point	5	Coast Redwood, Neighbor's new fence.
Point	6	Oleander Hedge.
Point	7	Coast Live Oak, Utility Pole
Point	8	Coast Redwoods, ten trees.
Point	9	Black Walnut, Vinca Major, Poison Oak.
Point	10	Bridge abutment
Point	11	Pear rotten. termites
Point	12	Pear
Point	13	Pear
Point	14	Pear
Point	15	Pear
Point	16	Pear
Point	17	Dead Pear, Valley Oak, Blackberry, Calif. Bay Laurel, Co
Point	18	Pear
Point	19	Pear
Point	20	Pear
Point	21	Pear
Point	22	Dead
Point	23	Pear
Point	24	Pear
Point	25	Pear. California Bay Laurel
Point	26	Coast Live Oak
Point	27	Pear
Point	28	Pear
Point	29	Pear
Point	30	Pear
Point	31	Pear
Point	32	Port Orford Cedar (?), California Bay Laurel
Point	33	Coast Redwood
Point	34	Incense Cedar
Point	35	Coast Live Oak
Point	36	California Bay Laurel
Point	37	Dead Pear
Point	38	California Bay Laurel (2)trees)
Point	39	California Bay Laurel. 3 trees
Point	40	Hawthorn, multiple trunks Largest: 12" dia.
Point	41	Incense Cedar in graveplot. Two 3" limbs off dead stump.
Point	42	Ponderosa Pine. 2 ft. dia
Point	43	Big Leaf Maple (six trees)
Point	44	Ponderosa Pine 30" dia
Point	45	California Bay Laurel
Point	46	Black Walnut, (3 trees)
Point	47	Big Leaf Maple
Point	48	Incense Cedar, 4 ft. dia
Point	49	Manna Gum Eucalyptus, Pomegranate, (2 trees)
Point	50	Pear
Point	51	Pear
Point	52	Pear

Table 1. Detailed list of the trees in the gravesite (NPS, 2002)

Shape	[illegible]	Tree_name
Point	53	Pear
Point	54	Pear
Point	55	Pear

Table 1. Continued

the creek is entrenched for its entire length. Channel banks are composed of soil and clay. The channel bed appears to be bimodal with fine sand and small gravel plus the cobble size rubble.

Hydrologic Factors – Channel roughness was estimated using Barnes (1967). Manning's n is rough (estimated to be in the range of 0.035 to 0.057) with anchored vegetation and a large amount of concrete rubble. There is no functioning floodplain to relieve the erosive energy during high flow events. Evidence of high water is about half way up the banks – believed to be from the 1997 El Nino event.

Existing Structures – Abandoned bridge abutments exist about 150' downstream from the gravesite. Bank protection works are scattered throughout the reach. The channel is completely lined by concrete about 500' upstream from the gravesite along the entire length of an upstream property. The recently constructed, concrete rubble wall across from the gravesite obstructs flow in the channel by about 25%. See Figures 6 and 6a for the difference in the area of the cross-section. The proposed storm drain is to be built downstream, possibly replacing the abandoned bridge abutments. See Figure 10 for the configuration of the storm drain.

Flow Analysis (Using Stream Corridor Restoration: Principles, Processes and Practices)

Alhambra Creek is mainly intermittent flow with a small perennial component due to urban sources (lawn irrigation, leaks from water or septic systems, etc.). While moisture is available to riparian plants year around, significant flow for aquatic resources is from December through May. February is typically when the peak of winter flows occur.

Comparative Surveys and Mapping – Historic channel surveys or cross-sections were not available for this assessment. See Figures 10 and 11 for property maps and enlargements of the Strenzel Lane neighborhood. If better property boundary maps and surveys such as road crossings exist, it might be possible to determine the evolutionary trend of the channel meanders.

Qualitative Assessment of Bank Stability – The streambank is composed of fairly uniform, cohesive, fine-grained soil – with a few discontinuous gravel or sand lenses less than an inch thick. Layering is evident with indistinct bedding planes. An infrequent mass-wasting mechanism appears to be slab failures. This is due to the lack of evidence of tension cracks at the top of the bank generally parallel to the stream alignment. Rotational failure features are also present a short distance downstream. Most gravity failure processes seem to occur when the banks have been saturated from extended periods of precipitation. It appears that previous bank failure deposits have been scoured away and redeposited further downstream.

Soil and Water (Using Alhambra Creek Watershed Resources Inventory)

The soil at the site has been mapped and identified as Botella-Zamora-Cropley by the NRCS (1997). These soils in this map unit are well to moderately well drained. They are reported as very deep soils on alluvial fans or floodplains with slopes from 0 to 9 percent.

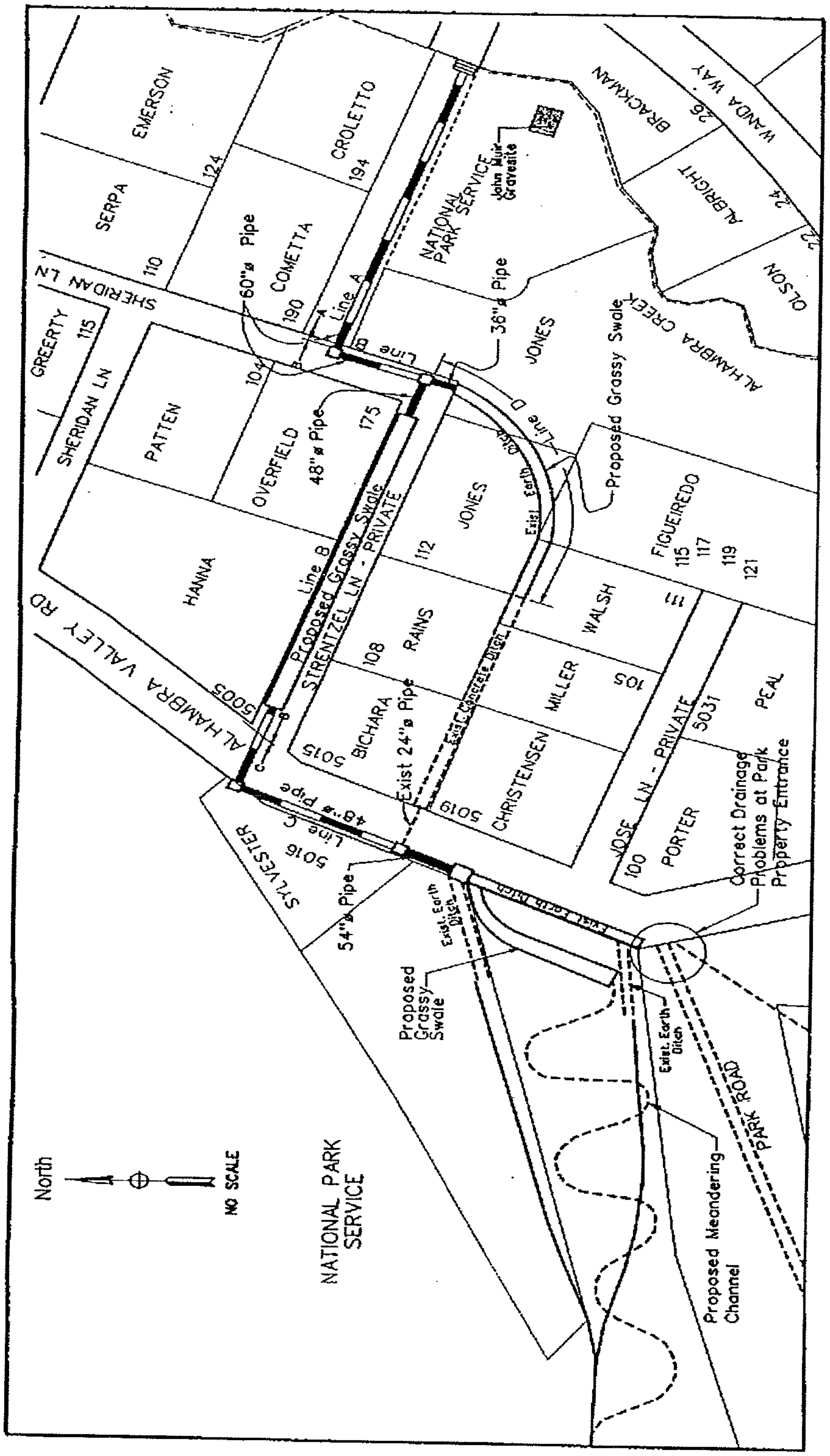


Figure 10. Property map and proposed storm drain (Contra Costa County Flood Control District, 1999)

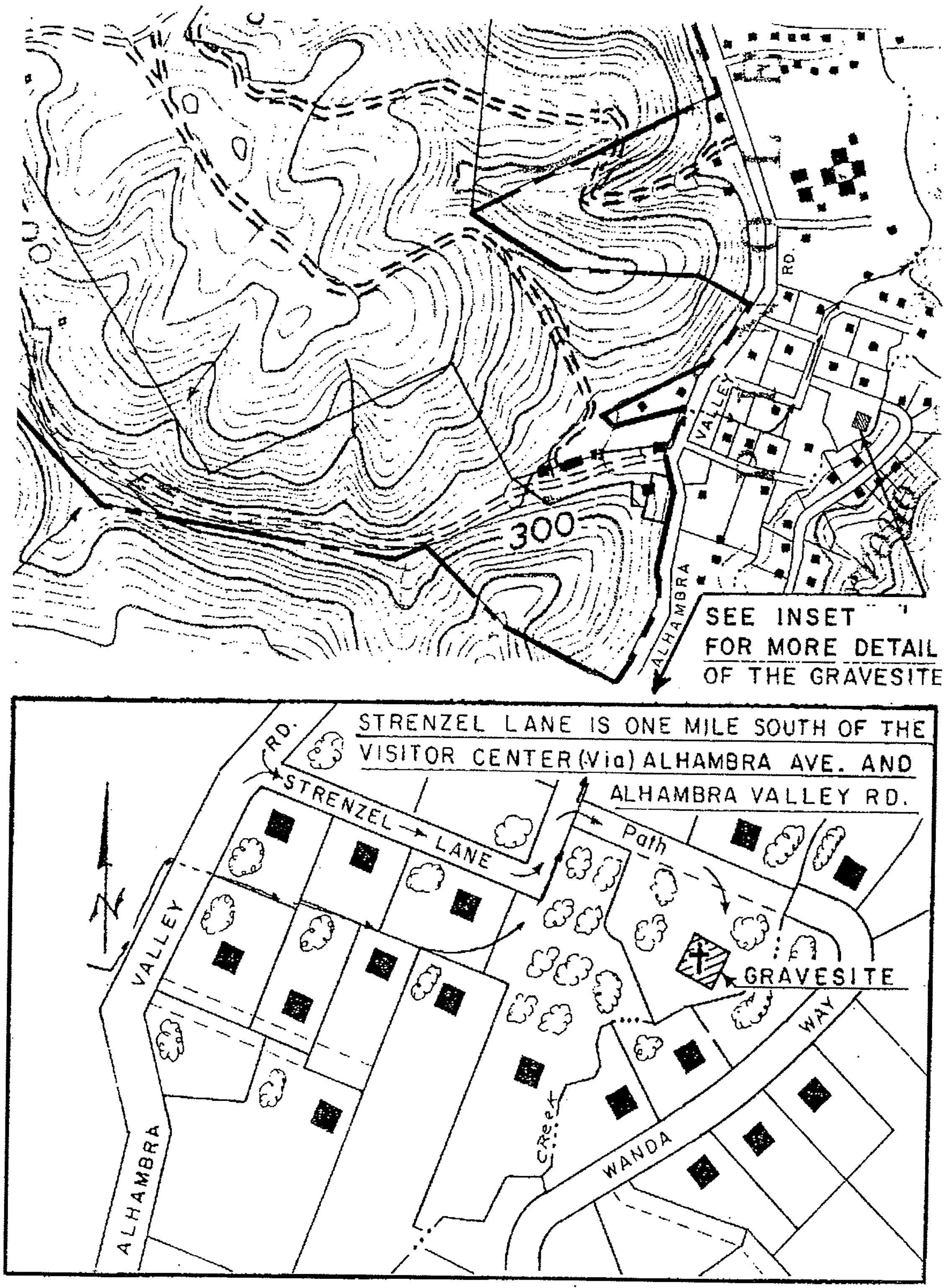


Figure 11. Property map and enlargement of Strenzel Lane neighborhood (Contra Costa County Flood Control District, 1999)

Soil property interpretations were developed by the NRCS to predict soil behavior for specified soil uses and under specified soil management practices. These interpretations are based on soil properties or qualities that directly influence a specified use or management of the soil. The interpretations given in the inventory are 1) soil properties and qualities, 2) soil limitations – suitabilities, and 3) soil potential or capability. Table 2 shows selected properties related to erosion and permeability. The Cropley soil has more clay than the other two soils, which decreases permeability and erodability.

Table 2. Selected Soil Properties Related to Erosion and Permeability (NRCS, 1997)

Property	Value	Botella	Cropley	Zamora
K – erosion factor	Range – 0.05–0.9	0.37–0.32	0.24	0.37
Percent Clay	%	27-35	35-60	20-60
Permeability	Inches/hour	0.20-0.60	0.06-0.20	0.20-0.60
Hydrologic Soil Group		B	D	B
Grassy waterways		Erodes easy	Percolates slowly	Erodes easy

Hydrology – The Alhambra Creek watershed covers an area of about 16.3 square miles at its confluence with the Carquinez Straights. Elevations range from sea level to 1500 feet above sea level. The longest watercourse is a little over 8 miles long. NRCS used the U.S. Geological Survey (USGS) regional regression equations for estimating recurrence interval flood flows for the entire watershed (Table 3).

Table 3. Flood hydrology calculations using USGS regressions (NRCS, 1997)

Recurrence Interval	Entire Watershed	At Gravesite
2 years	386 cfs	271 cfs
10	1469	1096
25	2241	1405
50	2958	1819
100	3672	2265

The NRCS also calculated flood flows from 5 individual subwatersheds of Alhambra Creek. The subwatersheds are Alhambra Creek, Arroyo del Hambre, Franklin Creek, Middle Arroyo del Hambre, and Lower Arroyo del Hambre (Figure 12).

The gravesite is downstream of Alhambra Creek, Arroyo del Hambre, and Middle Arroyo del Hambre sub-watersheds, a total of 7.85 square miles. Flood calculations shown in Table 3 for the gravesite are the sum of flood flows of these three subwatersheds. Digitizing the watershed divide from a 7.5-minute contour map in ArcView software determined that 7.08 square miles of catchment area exists above the gravesite.

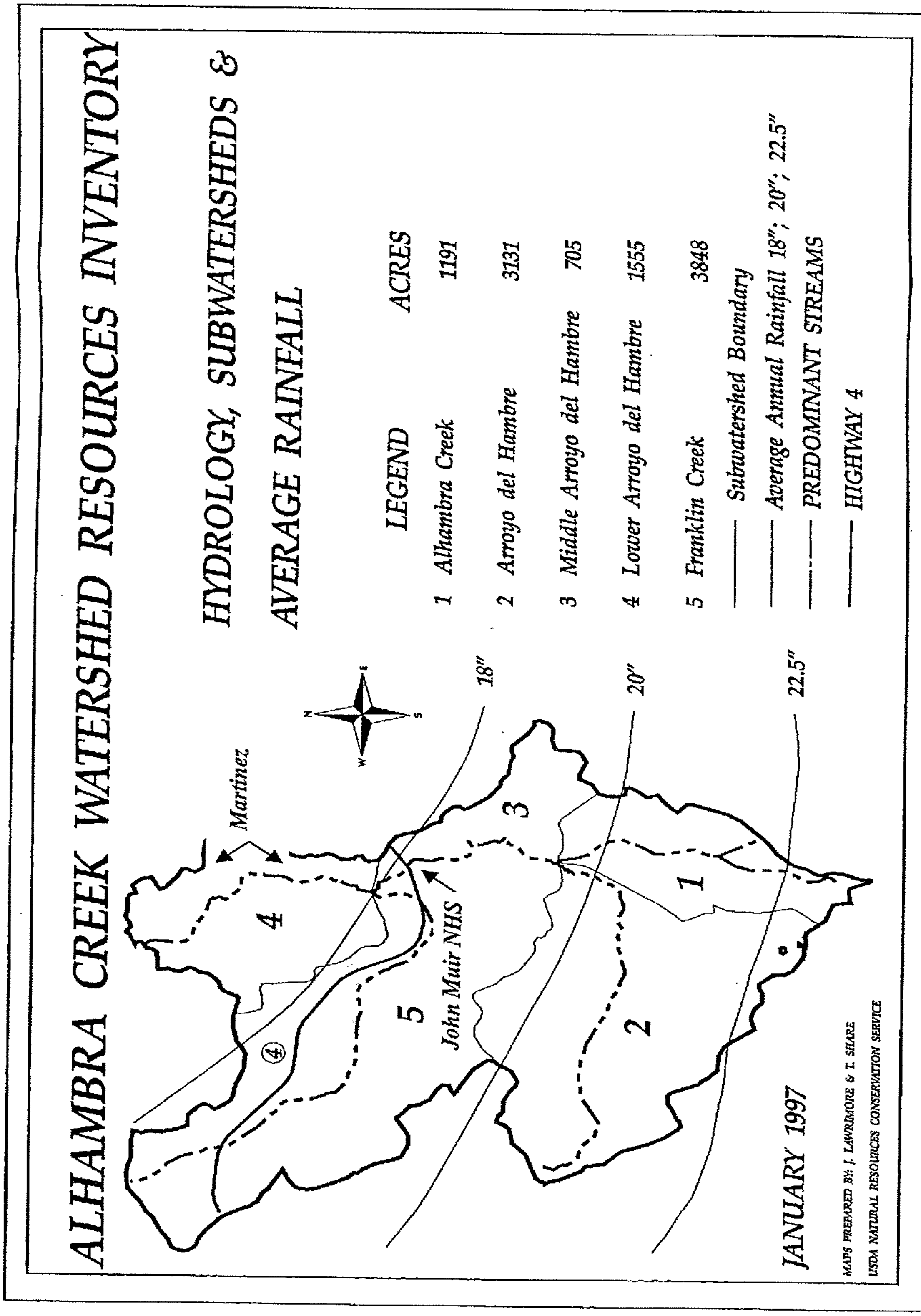


Figure 12. Alhambra Creek subwatersheds (NRCS, 1997)

USGS operated a gaging Station at lower Arroyo del Hambre at Martinez near the D Street Bridge for 18 years from 1965 to 1982. The size of the watershed above this gage is 15.1 square miles. See Figure 13 for a graphic depiction of the complete record. The representative mean annual hydrograph for seasonal analysis is shown in Figure 14. See Figure 15 for a listing of peak storm flows. The highest flow during this time period was 2,200 cfs, recorded January 4, 1982.

Assessment of Level II and III Stream Condition (Using Applied River Morphology)

Examining the factors identified in Rosgen's (1996) Level III assessment allows the investigator to 1) focus on individual components of the fluvial system, 2) identify those factors that are out of acceptable range for a stable system, and 3) assemble a more in-depth understanding of the significance of each part in a functioning stream system as a whole.

The Level II stream channel classification for Alhambra Creek would be a "G6c" which means that it is an entrenched, single thread channel with a low width/ratio and moderate sinuosity; or in laymen terms a "gully." The "6c" indicates that it has a low stream profile slope (less than 2 percent) and the native channel material is silt and clay. If the Alhambra channel existed on the discontinuous terraces (as it might have in the past) with only a moderate entrenchment, the stream type would be a B6c. The B6 stream types are found in narrow valleys containing cohesive residual soils and on well-vegetated alluvial fans (Rosgen, 1996). The evolutionary stages of channel adjustment commonly proceed from a gully to an entrenched, wide, shallow channel (F6) by cutting away at the banks and then to a B6 or C6 by building an inner floodplain and narrower channel at a lower base level. This information is used to determine the departure of existing conditions from previous conditions and to determine the channel dimensions that need to be restored.

In describing stream conditions (Level III), 10 parameters which exert a strong influence on the morphologic template are used: 1) riparian vegetation, 2) flow regime, 3) stream size and order, 4) sediment depositional patterns, 5) meander pattern, 6) woody debris and/or channel blockage, 7) channel stability rating, 8) stream bank erosion potential, 9) aggradation/ degradation potential, and 10) altered channel materials and dimensions.

1) Riparian vegetation – Composition is considered a mixed urban forest. Density and vigor is estimated to be about 50% crown closure and about 80% ground cover, both of which appear thick and vigorous. There is some potential for the riparian vegetation to increase in density and a lot of potential for increases in native composition, diversity, and distribution. The composition estimate is shown in Table 4. The Level III Summary Category would be RV 9b, moderate density deciduous overstory.

2) Flow regime – The general category is intermittent stream flow, which means Alhambra Creek flows seasonally even though it has a small perennial urban leakage component. The USGS gaging station recorded zero flows during most years. Other streams of this size in the region carry a trickle of flow through most dry seasons. It is believed that Alhambra Creek was naturally perennial in the past. The specific category is "Altered" due to development and the urbanized watershed.

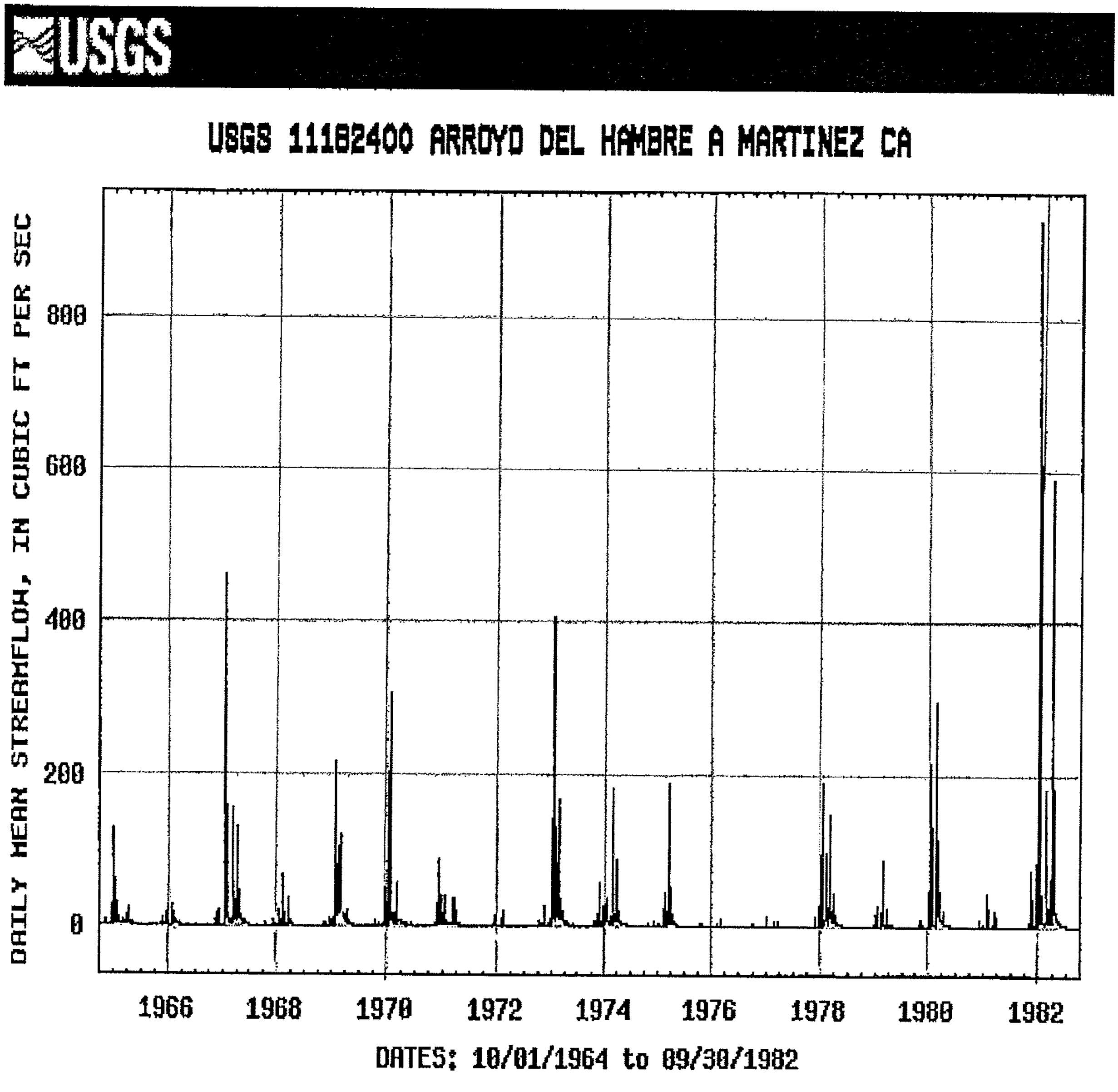
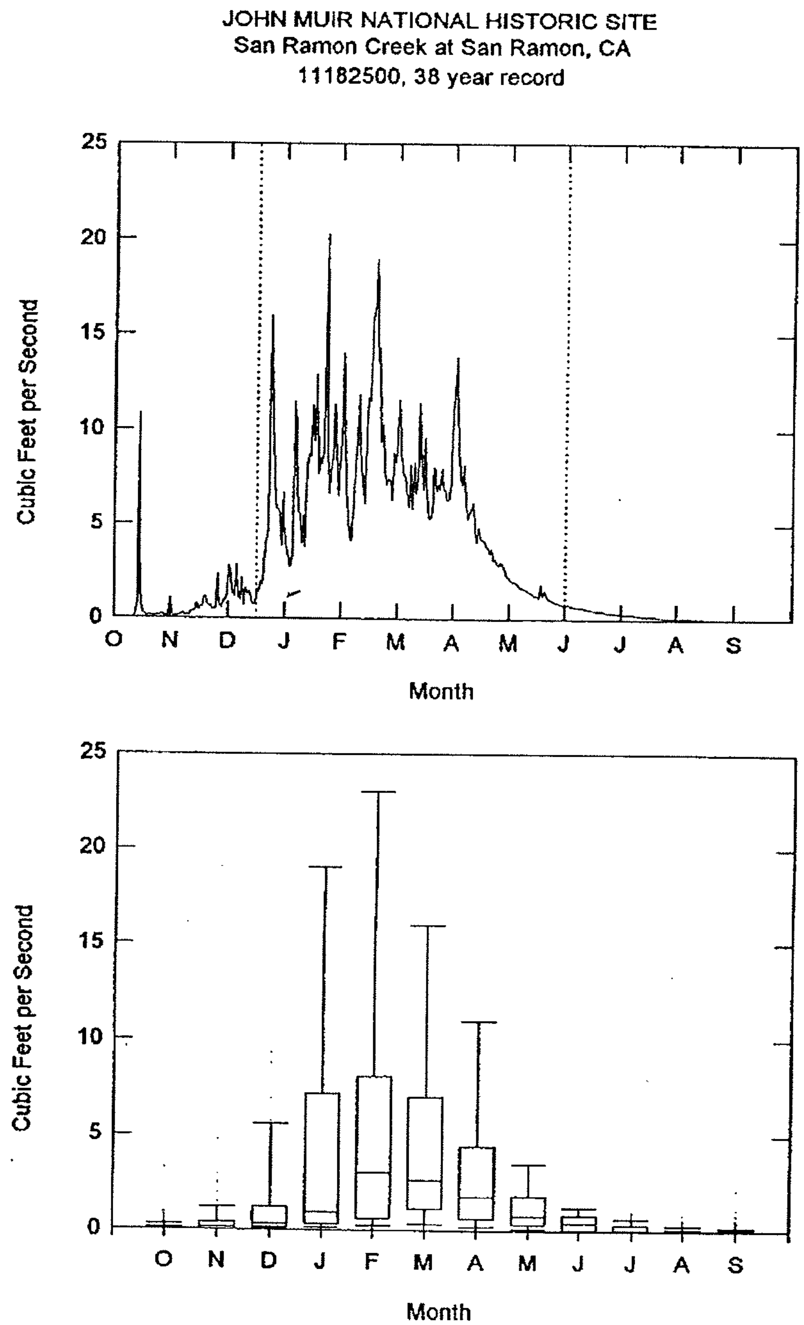


Figure 13. Complete flow record for Alhambra Creek (USGS, 2002)

REPRESENTATIVE MEAN ANNUAL HYDROGRAPH FOR SEASONAL ANALYSIS



Representative mean annual hydrograph (top) and distribution of daily flows by month (bottom) for hydrologic season determination. Box and whiskers represent a five number summary; bottom whisker cap is 10th percentile, bottom of box is 25th percentile, internal line is median, top of box is 75th percentile, and top whisker is 90th percentile. Hydrologic seasons for John Muir National Historic Site are: Jun. 1 to Dec. 14, and Dec. 15 to May 31.

Figure 14. Representative mean annual hydrograph for Alhambra Creek (NPS, 1998)

Peak Streamflow for California
USGS 11182400 ARROYO DEL HAMBRE A MARTINEZ CA

Contra Costa County, California
Hydrologic Unit Code 18050001
Latitude 38°00'12", Longitude 122°07'44" NAD27
Drainage area 15.10 square miles
Gage datum 48.33 feet above sea level NGVD29

Output formats

- Table
- Graph
- Tab-separated file
- WATSTORE formatted file
- Reselect output format

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1965	Jan. 5, 1965	6.63	780
1966	Feb. 1, 1966	3.20	105
1967	Jan. 21, 1967	9.00	1,480
1968	Jan. 30, 1968	3.51	201
1969	Jan. 26, 1969	9.62	1,640
1970	Jan. 14, 1970	8.71	1,400
1971	Dec. 20, 1970	4.01	287
1972	Jan. 27, 1972	2.71	41.0
1973	Jan. 18, 1973	10.93	1,960
1974	Nov. 30, 1973	4.27	342
1975	Mar. 21, 1975	10.20	1,770
1976	Feb. 29, 1976	2.73	47.0
1977	Jan. 2, 1977	3.13	111
1978	Jan. 16, 1978	6.58	876
1979	Feb. 22, 1979	5.97	729
1980	Feb. 19, 1980	10.75	1,920 D
1981	Jan. 27, 1981	3.01	88.0
1982	Jan. 4, 1982	12.65	2,200

Peak Streamflow Qualification Codes.

- D -- Base Discharge changed during this year

Figure 15. List of peak storm flows for Alhambra Creek (USGS, 2002)

Table 4. Estimated percent composition of vegetative categories (NPS, 2002)

Categories	Percent	Categories	Percent
Bare soil	10 %	High Brush	2 %
Forbs only	2 %	Combination grass/brush	0 %
Annual grasses	2 %	Deciduous overstory	50 %
Perennial grasses	2 %	Deciduous with brush understory	5 %
Rhizomatous grasses	2 %	Perennial overstory	5 %
Low Brush	20 %	Wetlands	0 %

3) Stream size and order is a category S-3 (3) which means bankfull width between 5–15 feet and a stream order of 3 measured from USGS 7.5' Quadrangles.

4) Sediment depositional patterns are helpful for interpreting stream condition. The patterns can indicate effects of past land management on sediment supply and sediment storage. The very few depositional features observed were sidebars along the margins (Type B-4) of Alhambra Creek. This would indicate that the channel bed is degrading, adding to the problem of entrenchment.

5) The meander pattern appears to be a mix of Irregular Meanders (M-3) with Confined Meander (M-6). Comparison to examples in Rosgen (1997) indicates a strong similarity to the confined meandering stream types except that Alhambra Creek appears to have a lower sinuosity.

6) The presence of woody debris and channel blockage would be considered Moderate (D3). Naturally occurring blockage consists of small and medium branches, twigs, leaves and infrequent small logs. Human Influences (D10) exist in the form of revetments, bridge abutments, and concrete rubble.

7) Pfankuch's channel stability rating was conducted on this reach of Alhambra Creek. The stability rating score was converted to reach condition by stream type. The score for Alhambra Creek (type G6) is 129, a "poor" reach condition (Figure 16).

8) Stream bank erosion potential was evaluated using the hazard rating procedures that characterize various stream bank conditions into numerical indices of bank erosion potential. The result of this rating was "moderate," largely due to high surface protection and root density (Figure 17).

9) The aggradation/degradation potential for this reach of Alhambra Creek is largely degradational. This is due to the lowered base level of the drainage network and the lack of bedrock, which would prevent down cutting. Additionally, the urban flow regime is capable of transporting more sediment out of the system than the amount being supplied to the creek from upland areas of the watershed.

10) Altered or natural state – The width, depth, bed features, and entrenchment ratio are measurable parameters that have been altered on Alhambra Creek since pre-settlement (Figure 18).

CHANNEL STABILITY (PFANKUCH) EVALUATION AND STREAM CLASSIFICATION SUMMARY (LEVEL III)

Reach Location Alhambra Creek near Gravesite Date 2/26/02 Observers R. Inglis

Stream Type G 6c - Low gradient "Gully" with Silt or Clay bed material

		Category	EXCELLENT	
UPPER BANKS	1	Landform Slope	Bank Slope Gradient <30%	2
	2	Mass Wasting	No evidence of past or future mass wasting.	3
	3	Debris Jam Potential	Essentially absent from immediate channel area.	2
	4	Vegetative Bank Protection	90%+ plant density. Vigor and variety suggest a deep dense soil binding root mass.	3
LOWER BANKS	5	Channel Capacity	Ample for present plus some increases. Peak flows contained. W/D ratio <7.	1
	6	Bank Rock Content	65%+ with large angular boulders. 12"+ common.	2
	7	Obstructions to Flow	Rocks and logs firmly imbedded. Flow pattern without cutting or deposition. Stable bed.	2
	8	Cutting	Little or none. Infreq. raw banks less than 6".	4
	9	Deposition	Little or no enlargement of channel or pt. bars.	4
BOTTOM	10	Rock Angularity	Sharp edges and corners. Plane surfaces rough.	1
	11	Brightness	Surfaces dull, dark or stained. Gen. not bright.	1
	12	Consolidation of Particles	Assorted sizes tightly packed or overlapping.	2
	13	Bottom Size Distribution	No size change evident. Stable mater. 80-100%	4
	14	Scouring and Deposition	<5% of bottom affected by scour or deposition.	6
	15	Aquatic Vegetation	Abundant Growth moss-like, dark green perennial. In swift water too.	1
			TOTAL	

		Category	GOOD	
UPPER BANKS	1	Landform Slope	Bank Slope Gradient 30-40%	4
	2	Mass Wasting	Infrequent. Mostly healed over. Low future potential.	6
	3	Debris Jam Potential	Present, but mostly small twigs and limbs.	4
	4	Vegetative Bank Protection	70-90% density. Fewer species or less vigor suggest less dense or deep root mass.	6
LOWER BANKS	5	Channel Capacity	Adequate. Bank overflows rare. W/D ratio 8-15	2
	6	Bank Rock Content	40-65%. Mostly small boulders to cobbles 6-12"	4
	7	Obstructions to Flow	Some present causing erosive cross currents and minor pool. filling. Obstructions newer and less firm.	4
	8	Cutting	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12"	6
	9	Deposition	Some new bar increase, mostly from coarse gravel.	8
BOTTOM	10	Rock Angularity	Rounded corners and edges, surfaces smooth, flat.	2
	11	Brightness	Mostly dull, but may have <35% bright surfaces.	2
	12	Consolidation of Particles	Moderately packed with some overlapping.	4
	13	Bottom Size Distribution	Distribution shift light. Stable material 50-80%.	8
	14	Scouring and Deposition	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12
	15	Aquatic Vegetation	Common. Algae forms in low velocity and pool areas. Moss here too.	2
			TOTAL	8

		Category	FAIR	
UPPER BANKS	1	Landform Slope	Bank slope gradient 40-60%	6
	2	Mass Wasting	Frequent or large, causing sediment nearly year long.	9
	3	Debris Jam Potential	Moderate to heavy amounts, mostly larger sizes.	6
	4	Vegetative Bank Protection	<50-70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9
LOWER BANKS	5	Channel Capacity	Barely contains present peaks. Occasional overbank floods. W/D ratio 15 to 25.	3
	6	Bank Rock Content	20-40% with most in the 3-6" diameter class.	6
	7	Obstructions to Flow	Moder. frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6
	8	Cutting	Significant. Cuts 12-24" high. Root mat overhangs and sloughing evident	12
	9	Deposition	Moder. deposition of new gravel and course sand on old and some new bars.	12
BOTTOM	10	Rock Angularity	Corners and edges well rounded in two dimensions.	3
	11	Brightness	Mixture dull and bright, ie 35-65% mixture range.	3
	12	Consolidation of Particles	Mostly loose assortment with no apparent overlap.	6
	13	Bottom Size Distribution	Moder. change in sizes. Stable materials 20-50%	12
	14	Scouring and Deposition	30-50% affected. Deposits & scour at obstructions, constrictions, and bends. Some filling of pools.	18
	15	Aquatic Vegetation	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3
			TOTAL	45

Figure 16. Channel stability evaluation for Alhambra Creek (Rosgen, 1996)

CHANNEL STABILITY (PFANKUCH) EVALUATION AND STREAM CLASSIFICATION SUMMARY (LEVEL III)

	Category	POOR	
UPPER BANKS	1 Landform Slope 2 Mass Wasting 3 Debris Jam Potential 4 Vegetative Bank Protection	Bank Slope Gradient 60%+ Frequent or large causing sediment nearly year long or imminent danger of same. Moder. to heavy amounts, predom. larger sizes. <50% density, fewer species and less vigor indicate poor, discontinuous and shallow root mass.	8 12 8 12
LOWER BANKS	5 Channel Capacity 6 Bank Rock Content 7 Obstructions to Flow 8 Cutting 9 Deposition	Inadequate. Overbank flows common. W/D ratio >25 <20% rock fragments of gravel sizes, 1-3" or less. Sediment traps full, channel migration occurring. Almost continuous cuts, some over 24" high. Failure of overhangs frequent. Extensive deposits of predom. fine particles. Accelerated bar development.	4 8 16 16
BOTTOM	10 Rock Angularity 11 Brightness 12 Consolidation of Particles 13 Bottom Size Distribution 14 Scouring and Deposition 15 Aquatic Vegetation	Well rounded in all dimensions, surfaces smooth. Native rocks Round 30% Concrete Predom. bright, 65%+ exposed or scoured surfaces. No packing evident. Loose assortment easily moved. Marked distribution change. Stable materials 0-20%. More than 50% of the bottom in a state of flux or change nearly year long. Perennial types scarce or absent. Yellow-green, short term bloom may be present.	4 4 8 16 24 4
		TOTAL	76

3.3 sq ft² Surface 2.3 ft/sec

Stream Width 5.5' x avg. depth .06' x mean velocity 2.0 = Q 6.6 cfs

Gauge Ht No gage Reach Gradient ______ Stream Order 3 Sinuosity Ratio ______

Width w 8' Depth w .75 W/D Ratio ______ Discharge (Qbf) ______

Drainage Area ______ Valley Gradient ______ Stream Length ______ Valley Length ______

Sinuosity ______ Entrenchment Ratio ______ Length Meander (Lm) ______ Belt Width ______

Sediment Supply
Extreme ______
Very High ______
High ______
Moderate ______
Low ______

Stream Bed Stability
Aggrading ______
Degrading ______
Stable ______

Width/Depth Ratio Condition
Normal ______
High ______
Very High ______

Stream Type: G6

TOTAL SCORE for Reach E ___ = G 8 + F 45 + P 76 = Pfankuch Rating: 129

Remarks ______

from table — Reach Condition: Poor

CONVERSION OF STABILITY RATING TO REACH CONDITION BY STREAM TYPE*

Stream Type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6
GOOD	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60
FAIR	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78
POOR	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+

Stream Type	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
GOOD	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
FAIR	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
POOR	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream Type	DA3	DA4	DA5	DA6	E3	E4	E5	E6
GOOD	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63
FAIR	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86
POOR	87+	87+	87+	87+	87+	97+	97+	87+

Stream Type	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
GOOD	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
FAIR	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
POOR	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Generalized relations ... need additional Level IV data to expand data base for validation.

Figure 16. Continued

BANK EROSION POTENTIAL												
CRITERIA	VERY LOW		LOW		MODERATE		HIGH		VERY HIGH		EXTREME	
	VALUE	INDEX	VALUE	INDEX	VALUE	INDEX	VALUE	INDEX	VALUE	INDEX	VALUE	INDEX
Bank Ht/Bkf Ht	1.0-1.1	1.0-1.9	1.1-1.19	2.0-3.9	1.2-1.5	4.0-5.9	1.6-2.0	6.0-7.9	2.1-2.8	8.0-9.0	>2.8	10
Root Depth/Bank Ht	1.0-0.9	1.0-1.9	0.89-0.50	2.0-3.9	0.49-0.30	4.0-5.9	0.29-1.15	6.0-7.9	0.14-.05	8.0-9.0	<.05	10
Root Density (%)	80-100	1.0-1.9	55-79	2.0-3.9	30-54	4.0-5.9	15-29	6.0-7.9	5-14	8.0-9.0	<5.0	10
Bank Angle (Degrees)	0-20	1.0-1.9	21-60	2.0-3.9	61-80	4.0-5.9	81-90	6.0-7.9	91-119	8.0-9.0	>119	10
Surface Prot. (%)	80-100	1.0-1.9	55-79 66	2.0-3.9 3.0	30-54	4.0-5.9	15-29	6.0-7.9	10-15	8.0-9.0	<10	10
TOTALS				3.0		8.0		6.0				10
		5-9.5		10-19.5		20-29.5		30-39.5		40-45		46-50
Numerical Adjustments					Total =	27						

BANK MATERIALS: BEDROCK: BANK EROSION POTENTIAL ALWAYS VERY LOW
BOULDERS: BANK EROSION POTENTIAL LOW
COBBLE: DECREASE BY ONE CATEGORY UNLESS MIXTURE OF GRAVEL/SAND IS OVER 50%, THEN NO ADJUSTMENT
GRAVEL: ADJUST VALUES UP BY 5-10 POINTS DEPENDING ON COMPOSITION OF SAND
SAND: ADJUST VALUES UP BY 10 POINTS
SILT/CLAY: NO ADJUSTMENT
STRATIFICATION: 5-10 POINTS (UPWARD) DEPENDING ON POSITION OF UNSTABLE LAYERS IN RELATION TO BANKFULL STAGE

Stress in the near-bank region, conversion of numerical indices to adjective ratings.

CONVERSION OF NUMERICAL INDICES TO ADJECTIVE RATINGS

Near Bank Stress Rating	Velocity Gradient***	A nb/A**	Near Bank Stress/Mean Shear Stress*
Low	1.0-1.2	.32 or less	.32 or less
Moderate	1.21-1.6	.33-.41	.3-.5
High	1.61-2.0	.42-.45	.6-1.0
Very High	2.1-2.3	.46-.50	1.1-1.3
Extreme	2.4 or more	.51 or more	1.4 or more

* Near bank shear stress/mean shear stress (shear stress = depth*slope*water density)

** A = cross-sectional area: Near-bank cross-sectional area = width*depth* for 1/3 of the channel width in the near bank region.

*** Velocity gradient in ft/sec/ft is the difference in velocity from the core of velocity isovel along the orthogonal length to bank region in feet.

Figure 17. Bank erosion potential for Alhambra Creek (Rosgen, 1996)

VARIABLES ALTERED

Channel dimensions

Width	Previous Unknown	Existing 8'
Depth	Previous Unknown	Existing 0.75'
Width/depth ratio	Previous ______	Existing 10.6

Channel Patterns (* show as a function of Bankfull Width):

Meander Length *	Previous ______	Existing ______
Radius of curvature *	Previous ______	Existing ______
Belt width *	Previous ______	Existing ______
Sinuosity	Previous ______	Existing ______

Longitudinal Profile

Water surface slope	Previous ______	Existing ______
Valley slope	Previous ______	Existing ______
Bed features	Previous: ______	Existing ______
	Riffle/pool X (without Rubble)	Riffle/pool ______
	Step/pool ______	Step/pool ______
	Conver/Diverg ______	Conv./div. ______
	Plane bed ______	Plane bed ______
	Other: ______	Other Rubble mixed riffles+Steps

Spacing of bed features (as function of bankfull width):

______ ______

Describe channel alteration:

Considerable amount of rubble dumped into creek. Concrete blocks piled on opposite side for bank protection. Old bridge abutments exist downstream about 150 ft. Cement lined Channel is about 300ft upstream completely harden both sides and the bed of the channel.

Existing stream type G6c **Potential stream type** B6c

PHOTOGRAPHS
(Looking upstream and downstream)

Figure 18. Altered stream categories for Alhambra Creek (Rosgen, 1996)

DISCUSSION

The Level III factors taken as a whole provide convincing evidence of the condition of Alhambra Creek. Refer to Figure 19 for the summary sheet. The riparian vegetation appears to be a major factor in holding the banks in place. Stream flow regime from an urbanizing watershed appears to be one of the major causes of the instability of the channel. Stream size and low stream order indicate that it should be a small channel in a relatively small watershed. Moderate amounts of organic debris and/or "natural" channel blockage are beneficial for healthy stream channels, whereas the human influence of adding concrete rubble causes artificial blockage and bank instability. The depositional patterns indicate that degradation is occurring, which further adds to the instability of the banks. The irregular meander pattern within the confinement of the valley and urban constraints contradict what would be expected with the valley slope and bed material forming a higher sinuosity, lower gradient stream channel.

Stream bank erosion potential for Alhambra Creek was rated moderate. The high root density explains why the channel is not in more serious condition. The potential for aggradation or degradation is controlled by sediment supply (which is low, based on depositional patterns) and bedrock controls (which are nonexistent), and these factors indicate further downcutting and incision will occur. The channel stability rating conducted in the field determined that, even for a gully stream type, the condition was poor. Stream channels that have been altered (similar to Alhambra Creek) have profound effects on the stability and integrity of natural systems (Rosgen, 1996).

Streams in urban watersheds have a character fundamentally different from that of streams in forested, rural, or even agricultural watersheds. The amount of impervious cover (pavements, rooftops, etc.) in the watershed can be used as an indicator to predict how severe these differences can be. As little as 10 percent watershed impervious cover has been linked to stream degradation, with the degradation becoming more severe as impervious cover increases. Impervious cover directly influences urban streams by dramatically increasing surface runoff during storm events (Federal Interagency Stream Restoration Working Group, October 1998).

The peak discharge associated with the bankfull flow (i.e., the 1.5- to 2-year return storm) increases sharply in magnitude in urban streams. In addition, channels experience more bankfull flood events each year and are exposed to critical erosive velocities for longer intervals.

The hydrologic regime that had defined the geometry of the presettlement stream channel irreversibly changes toward higher flow rates on a more frequent basis. The higher flow events of urban streams are capable of performing more "effective work" in moving sediment than they had done before. The typical response of urban streams is to increase their cross-sectional area to accommodate the higher flows. This is done by channel downcutting or widening, or a combination of both. Urban stream channels often enlarge their cross-sectional areas by a factor of 2 to 5, depending on the degree of impervious cover in the watershed and the age of development. Stream channels react to urbanization not only by adjusting their

SUMMARY OF "CONDITION" CATEGORIES FOR LEVEL III INVENTORY

Stream Name AlhambraCreek
Location Jomu Gravesite
Riparian Vegetation RV 9 B
Stream Size, Stream order S-3 (3)
Meander pattern M3/M6
Channel stability rating (Pfankuch) 129 POOR

Sediment supply (check appropriate category):
- Extreme
- Very high
- High
- Moderate
- Low ✓

Streambed (vertical) stability
- Aggrading
- Degrading ✓
- Stable

Width/depth ratio condition: Very Low
- Normal (stable)
- High
- Very high

Streambank erosion Potential:

Bank erodibility:	Near-bank stress:
Extreme	Extreme
High	High
Moderate ✓	Moderate
Low	Low

Observers R. Inglis
Stream Type G6c Date 2/26/02
Flow regime I 8
Depositional pattern B4
Debris/channel blockages D3
Altered Channel State: Altered

Dimension/shape:
- Width 8'
- Depth 0.75
- Width/depth ratio 10.6

Patterns: (*show as funct. of W_{bkf}):
- Meander length* ~20
- Radius of curve* ~5
- Belt width* ~10
- Sinuosity 1.17

Profile:
- Water surface slope 0.87 %
- Valley slope 0.88 %

Bed features:
- Riffle/pool
- Step/pool
- Conver./divrg.
- Plane bed
- Other x Rubble mixed w/ riffles and steps
- Spacing*

Describe alterations: Rubble, Bank Hardening

General Remarks

Attach photographs taken mid-stream looking up and downstream. Make site map.

Attach vicinity map of reach and/or aerial photo for specific location.

Note any permanent cross-sections for level IV verification of cross-section stability, actual erosion rates, change in pebble counts, deposition studies, sediment sampling, etc.

Attach copy of; stream classification field form, channel Stability rating form, bank erosion rating form, profiles, cross-sections, pebble counts, etc.

Figure 19. Summary of condition categories for Alhambra Creek (Rosgen, 1996)

widths and depths, but also by changing their gradient and meanders. Exacerbating these changes, urban stream channels are also extensively modified in an effort to protect adjacent property from bank erosion or flooding. Headwater streams are frequently enclosed within storm drains, while other are channelized, lined, or armored by heavy stone. Another modification unique to urban streams is the installation of sanitary sewers and other pipelines underneath or parallel to the stream channel (Federal Interagency Stream Restoration Working Group, October 1998).

CONCLUSIONS AND RECOMMENDATIONS

The most important step needed at the gravesite is to stop the vertical incision of the channel. While incision may be approaching a decreasing rate of entrenchment, further degradation must be prevented to assure more stable banks. The deeper the channel gets near the gravesite, the more of a likelihood of bank failure. As a streambank erodes back over time (increased meanders and floodplains) to some angle less than vertical, it becomes more stable. Unfortunately, in this case stability of the streambank means erosion of the gravesite. There is a good opportunity to construct a gradient check structure to be included in the Strenzel Lane storm water project. The outfall structure will need something like a loose rock apron to prevent downcutting from tributary inflow and the potential for a headcut to run upstream. This structure could be designed to anchor the bed of Alhambra Creek and to prevent further incision.

Channel blockage from the artificial rubble and the existing, but poorly designed, bank protection on the opposite side are likely causing undercutting of the bank near the gravesite. The rubble and blockage on the opposite side should be removed and replaced with a properly designed toe protection structure on both sides of the channel. The challenge will be to get the machinery and materials down into the channel without damaging the trees and their root structure, thus inadvertently destabilizing the bank. More natural appearing rock, instead of concrete rubble, will improve the aesthetics of the area. The toe structure should be designed to prevent channel movement to at least bankfull flows, possibly higher to a 5 or 10-year flow without changing the hydraulics or pre-rubble channel capacity. This may require negotiations with the private property owner to allow the NPS to help manage the stability of their side of Alhambra Creek.

The trees on the over bank area are providing a lot of support to the bank. The cohesive soils here are helping, but root structure may be the most important factor in the long run. Therefore, it is suggested that trees of various age groups be planted in order to assure that significant root mass is present well into the future. The streambanks should improve markedly with vegetation. Additionally, "tying" tree root systems together by having two or three rows of vegetation parallel to the bank is another suggestion. One particular strategy is to locate trees at the point where a predicted failure plain intersects the surface of the terrace. This action may be sufficient as an appropriate start, but more stabilization may be necessary in the future. Monitoring will be needed to determine if additional protection is necessary.

If "tougher" revetment (bank protection) is needed, there are big problems to overcome. It can't be overemphasized how tough the channel incision problem is. The bank near the gravesite is too steep for most types of revetment, and there is no room on the NPS side to "lay back" the bank. There is little room on the other side either. There are techniques available for protecting near vertical banks, but a detailed discussion of the feasibility of tougher revetment would be included in an engineering design study. Whatever is done on the NPS side of the channel to protect the gravesite should also be done on the private side to avoid the probability of adversely affecting the homeowners. Many of these solutions can be quite effective but may generate problems downstream. This could lead to "serial engineering" – where each fix leads to a new problem. The only way NPS can decide on this option is if all other "softer" techniques begin to fail and a decision is made to sacrifice natural processes in order to protect the gravesite.

A monitoring program is recommended to alert the NPS to changes in the channel dimension and form near the gravesite. A file or binder should be kept at park headquarters containing this report and all monitoring information. Monitoring should include:

1) Measurements of the cross-sections on an annual basis for approximately 5 years after the construction of the storm drain outfall structure and biennially after that;

2) Visual inspection, annually, of signs of earth movement or weakness such as tension cracks, mass wasting, and seepage from the banks;

3) Annual inventory of the health, distribution and density of deep-rooted vegetation between the gravesite and creek;

4) Annual inspection of the channel for blockage or occurrence of rubble or debris that would reduce the capacity of the channel during flood flows;

5) Establish several photo points to document visual changes in the channel and the bank near the gravesite after major flow events;

6) Measure the distance from the ground level of the southeast corner post of the fence around the gravesite fence to the edge of water in the creek after each large runoff event;

7) Install a staff gage and measure stream discharge during higher flows to establish a rating curve. Recording water levels during higher flow events will indicate when rapid changes in flow could signal when bank failures are possible; and

8) Install two piezometers (shallow wells) on the terrace surface to record water table during the rainy season. Saturated soil conditions could warn when bank stability is weak. These could be placed along the culvert construction zone so no additional NEPA documentation or extra disturbance would be needed.

If change is detected through the monitoring program, more severe measures will be needed to protect the gravesite. The amount of buffer space between the gravesite fence and the creek bank is minimal, allowing little adaptive management. Response time may be short if certain changes are detected (such as the formation of tension cracks). Despite monitoring efforts, the failure of the bank could be quick and result from an episodic event. The physical process would likely be a slab bank failure resulting from a rapid drawdown of the water level in the creek after a 50-year event, or larger, in the Spring, when the soils are saturated. Management would need to take quick and decisive action to prevent damage to the gravesite. In the long run, relocation of the gravesite a short distance away from the creek would allow more permanent stabilization of the area.

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APPENDICES

Results of WinXSPRO calculations

Field data for the cross-sections

*****************************WinXSPRO*********************************
D:\WINXSPRO\JOMU\ALHMBR1.OUT
Input File: D:\WINXSPRO\JOMU\ALHMBRA1.DAT
Run Date: 02/06/02
Analysis Procedure: Hydraulics Clear Channel
Cross Section Number: 1
Survey Date: 01/24/02

Subsections/Dividing stations
A

Resistance Method: Manning's n

SECTION	A
Low Stage n	0.035
High Stage n	0.057

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
1.00	T	8.7	13.1	12.6	0.7	0.7	0.0090	0.028	3.8	33.08	0.4
2.00	T	22.2	15.9	14.5	1.4	1.5	0.0090	0.031	5.8	128.66	0.8
3.00	T	37.6	18.6	16.3	2.0	2.3	0.0090	0.033	6.9	259.06	1.1
4.00	T	54.8	21.2	17.9	2.6	3.1	0.0090	0.035	7.6	416.90	1.5
5.00	T	73.3	23.6	19.2	3.1	3.8	0.0090	0.037	8.1	593.41	1.7
6.00	T	93.2	26.0	20.5	3.6	4.5	0.0090	0.039	8.4	783.18	2.0
7.00	T	114.4	28.4	21.9	4.0	5.2	0.0090	0.042	8.6	984.07	2.3
8.00	T	137.0	31.6	24.0	4.3	5.7	0.0090	0.044	8.6	1176.54	2.4
9.00	T	163.9	39.2	30.9	4.2	5.3	0.0090	0.046	8.0	1306.47	2.3
10.00	T	199.5	48.0	38.9	4.2	5.1	0.0090	0.048	7.6	1511.77	2.3
11.00	T	239.4	50.9	40.8	4.7	5.9	0.0090	0.050	7.9	1884.35	2.6
12.00	T	281.2	53.8	42.7	5.2	6.6	0.0090	0.053	8.1	2275.63	2.9
13.00	T	324.8	56.7	44.6	5.7	7.3	0.0090	0.055	8.3	2683.49	3.2
14.00	T	371.1	60.9	48.1	6.1	7.7	0.0090	0.057	8.3	3070.45	3.4
15.00	T	420.2	63.7	49.7	6.6	8.5	0.0090	0.059	8.4	3530.05*	3.7

STAGE	ALPHA	FROUDE
1.00	1.00	0.80
2.00	1.00	0.82
3.00	1.00	0.80
4.00	1.00	0.77
5.00	1.00	0.73
6.00	1.00	0.70
7.00	1.00	0.66
8.00	1.00	0.63
9.00	1.00	0.61
10.00	1.00	0.59
11.00	1.00	0.57
12.00	1.00	0.56
13.00	1.00	0.54
14.00	1.00	0.53
15.00	1.00	0.51

******************************WinXSPRO**********************************
D:\WINXSPRO\JOMU\ALHMBR1.OUT
Input File: D:\WINXSPRO\JOMU\ALHMBRA1.DAT
Run Date: 02/06/02
Analysis Procedure: Hydraulics Includes rubble bank protection
Cross Section Number: 1
Survey Date: 01/24/02

Subsections/Dividing stations
A

Resistance Method: Manning's n

SECTION	A
Low Stage n	0.035
High Stage n	0.057

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
1.00	T	7.9	10.6	9.8	0.7	0.8	0.0090	0.029	4.0	31.76	0.4
2.00	T	18.3	12.9	10.9	1.4	1.7	0.0090	0.031	5.7	104.90	0.8
3.00	T	29.7	15.2	12.0	2.0	2.5	0.0090	0.033	6.7	198.97	1.1
4.00	T	42.3	17.5	13.1	2.4	3.2	0.0090	0.035	7.3	307.62	1.4
5.00	T	56.0	19.8	14.3	2.8	3.9	0.0090	0.037	7.6	427.84	1.6
6.00	T	70.9	22.1	15.4	3.2	4.6	0.0090	0.039	7.9	557.96	1.8
7.00	T	86.8	24.6	16.8	3.5	5.2	0.0090	0.041	8.0	693.24	2.0
8.00	T	105.8	32.6	24.0	3.2	4.4	0.0090	0.043	7.2	762.82	1.8
9.00	T	132.7	40.2	30.9	3.3	4.3	0.0090	0.045	7.0	923.43	1.9
10.00	T	168.3	49.0	38.9	3.4	4.3	0.0090	0.047	6.8	1151.58	1.9
11.00	T	208.2	51.9	40.8	4.0	5.1	0.0090	0.049	7.3	1515.72	2.3
12.00	T	250.0	54.8	42.7	4.6	5.8	0.0090	0.051	7.6	1905.39	2.6
13.00	T	293.6	57.7	44.6	5.1	6.6	0.0090	0.053	7.9	2317.35	2.9
14.00	T	339.9	61.9	48.1	5.5	7.1	0.0090	0.055	8.0	2718.75	3.1
15.00	T	389.0	64.7	49.7	6.0	7.8	0.0090	0.057	8.2	3190.22*	3.4

STAGE	ALPHA	FROUDE
1.00	1.00	0.78
2.00	1.00	0.78
3.00	1.00	0.75
4.00	1.00	0.71
5.00	1.00	0.68
6.00	1.00	0.65
7.00	1.00	0.62
8.00	1.00	0.61
9.00	1.00	0.59
10.00	1.00	0.58
11.00	1.00	0.57
12.00	1.00	0.56
13.00	1.00	0.54
14.00	1.00	0.53
15.00	1.00	0.52

******************************WinXSPRO*********************************
D:\WINXSPRO\JOMU\ALHMBR2.OUT
Input File: D:\WINXSPRO\JOMU\ALHMBRA2.DAT
Run Date: 02/06/02
Analysis Procedure: Hydraulics
Cross Section Number: 1
Survey Date: 01/24/02

Subsections/Dividing stations
A

Resistance Method: Manning's n

SECTION	A
Low Stage n	0.035
High Stage n	0.057

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
1.00	T	5.4	8.6	7.9	0.6	0.7	0.0090	0.029	3.6	19.33	0.4
2.00	T	15.3	13.0	11.7	1.2	1.3	0.0090	0.031	5.1	77.66	0.7
3.00	T	28.2	16.3	14.2	1.7	2.0	0.0090	0.033	6.2	174.67	1.0
4.00	T	43.7	19.6	16.8	2.2	2.6	0.0090	0.035	6.9	302.02	1.3
5.00	T	61.8	22.8	19.2	2.7	3.2	0.0090	0.037	7.4	458.87	1.5
6.00	T	82.1	25.8	21.5	3.2	3.8	0.0090	0.039	7.8	643.68	1.8
7.00	T	104.7	28.9	23.8	3.6	4.4	0.0090	0.041	8.1	850.95	2.0
8.00	T	129.8	32.2	26.3	4.0	4.9	0.0090	0.043	8.3	1081.15	2.3
9.00	T	157.3	35.3	28.7	4.5	5.5	0.0090	0.045	8.5	1338.80	2.5
10.00	T	187.2	38.4	31.1	4.9	6.0	0.0090	0.047	8.7	1619.61	2.7
11.00	T	219.5	41.5	33.4	5.3	6.6	0.0090	0.049	8.8	1922.63	3.0
12.00	T	254.0	44.7	35.6	5.7	7.1	0.0090	0.051	8.8	2242.30	3.2
13.00	T	290.7	48.0	37.9	6.1	7.7	0.0090	0.053	8.9	2576.49	3.4
14.00	T	330.3	54.4	43.3	6.1	7.6	0.0090	0.055	8.6	2824.73	3.4
15.00	T	377.5	63.0	51.0	6.0	7.4	0.0090	0.057	8.2	3087.94	3.4

STAGE	ALPHA	FROUDE
1.00	1.00	0.77
2.00	1.00	0.78
3.00	1.00	0.77
4.00	1.00	0.75
5.00	1.00	0.73
6.00	1.00	0.71
7.00	1.00	0.68
8.00	1.00	0.66
9.00	1.00	0.64
10.00	1.00	0.62
11.00	1.00	0.60
12.00	1.00	0.58
13.00	1.00	0.56
14.00	1.00	0.55
15.00	1.00	0.53

```
*****************************WinXSPRO********************************
D:\WINXSPRO\JOMU\ALHMBR3.OUT
Input File:               D:\WINXSPRO\JOMU\ALHMBRA3.DAT
Run Date:                 02/06/02
Analysis Procedure:       Hydraulics
Cross Section Number:     1
Survey Date:              01/24/02
```

Subsections/Dividing stations
A

Resistance Method: Manning's n

SECTION	A
Low Stage n	0.035
High Stage n	0.057

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
1.00	T	2.3	4.4	3.7	0.5	0.6	0.0090	0.029	3.2	7.24	0.3
2.00	T	6.9	7.2	5.5	0.9	1.2	0.0090	0.031	4.4	30.26	0.5
3.00	T	16.2	14.1	11.8	1.1	1.4	0.0090	0.033	4.7	75.96	0.6
4.00	T	28.8	16.8	13.5	1.7	2.1	0.0090	0.035	5.8	167.00	1.0
5.00	T	43.2	19.5	15.3	2.2	2.8	0.0090	0.037	6.5	281.13	1.2
6.00	T	59.4	22.1	17.0	2.7	3.5	0.0090	0.039	7.0	415.38	1.5
7.00	T	77.4	25.1	19.1	3.1	4.1	0.0090	0.041	7.3	565.77	1.7
8.00	T	97.5	28.0	21.2	3.5	4.6	0.0090	0.043	7.5	736.05	2.0
9.00	T	119.8	31.0	23.4	3.9	5.1	0.0090	0.045	7.7	926.64	2.2
10.00	T	144.3	34.1	25.6	4.2	5.6	0.0090	0.047	7.9	1136.53	2.4
11.00	T	171.0	37.2	27.9	4.6	6.1	0.0090	0.049	8.0	1364.86	2.6
12.00	T	200.1	40.3	30.2	5.0	6.6	0.0090	0.051	8.1	1614.17	2.8
13.00	T	231.5	43.5	32.7	5.3	7.1	0.0090	0.053	8.1	1881.33	3.0
14.00	T	265.7	47.2	35.6	5.6	7.5	0.0090	0.055	8.1	2160.96	3.2
15.00	T	302.8	50.8	38.6	6.0	7.8	0.0090	0.057	8.1	2466.98	3.3

STAGE	ALPHA	FROUDE
1.00	1.00	0.70
2.00	1.00	0.69
3.00	1.00	0.71
4.00	1.00	0.70
5.00	1.00	0.68
6.00	1.00	0.66
7.00	1.00	0.64
8.00	1.00	0.62
9.00	1.00	0.60
10.00	1.00	0.58
11.00	1.00	0.57
12.00	1.00	0.55
13.00	1.00	0.54
14.00	1.00	0.53
15.00	1.00	0.51

Joma

Channel Cross Section # XS1
Location: 80' upstream f/Gravesite Corner

Date: 8/14/01
Crew: π Inglis
Instr Loc: ___ Right ___ Left

	Mon Elev		Rod	
Lx		+		=
Rx		+		=

π eye piece elev. = ______

Recorded in: ____ m X ft

Left Monument Pin Ht: ______
Condition: ______

Right Monument Pin Ht: ______
Condition: ______

Reference Dist: ______
Recent Survey Dist: ______

	Sta	Dist	RAW Depth ~~Top~~	Sag Adj.	Mid	~~Bot~~	Dist ~~H20~~ Depth	Vertical ~~Bed Mat'l~~	Comments
	-1	-4.0	-4.25				0	0	
	0	0	0	0			4	4.3	
	1	2'	5.2	.1			6	9.6	
	2	5'	5.0 Fill	.3		9.5'	9	9.6	14.1
	3	8'	5.9 Fill	.4		11.9'	12	10.6	16.6
	4	10'	10.2 Fill	.5		12.0'	14	15.0	16.8
EW	4a	11	12.4	.5			15	17.2	
thalweg	5	15'	12.5	.7			19	17.5	
EW	6	20'	12.0	.9			24	17.2	
	7	25'	4.5'	.9			29	9.7	
	8	30'	3.7'	.7			34	8.7	
	9	35'	3.5'	.5			39	8.3	
	10	40'	3.0	.3			44	7.6	
	11	45'	0'	0			49	4.3	
	12	48'	-1'				52	3.3	

Channel Cross Section # XS 2
Location: 10' Downstream from Gravesite Corner

Date: ______
Crew: ⊼ Ingis
Instr Loc: ___ Right ___ Left

	Mon Elev		Rod	
Lx		+		=
Rx		+		=

Left Monument Pin Ht: ______
Condition: ______

Right Monument Pin Ht: ______
Condition: ______

⊼ eye piece elev. = ______

Reference Dist: ______
Recent Survey Dist: ______

Recorded in: ___ m X ft

Sta	Dist	Raw Depth ~~Top~~	Sag Adj ~~Mid~~	Bot	Dist ~~H2O Depth~~	Vertical Bed Mat'l	Comments
-.5	-0.5	0	0		0	0	60.5
0	0	0.4	0		0.5	0.4	60.0
1	5	0.7	0		5.5	0.7	55.0
2	10	1.1	0		10.5	1.1	50.0
3	15	1.5	.4		15.5	1.9	45.0
4	20	1.5	.8		20.5	2.3	40.0
5	25	3.5	1.2		25.5	4.7	35.0
6	30	7.7	1.7		30.5	9.4	30.0
7	35	14.0	2.0		35.5	16.0	25.0
8	40	14.0	1.7		40.5	15.7	20.0
9	45	12.9	1.2		45.5	14.1	15.0
10	50	10.5	.8		50.5	11.3	10.0
11	55	7.5	.4		55.5	7.9	5.0
11a	59	4.7	.1		59.5	4.8	1.0
12	60	0	0		60.5	0	0

Channel Cross Section # XS3
Location: 50' downstream of Grave site Corner post.

Date:
Crew: [illegible]
Instr Loc: ___ Right ___ Left

	Mon Elev		Rod	
Lx		+		=
Rx		+		=

Cross section is 5' upstream of abutments.

Left Monument Pin Ht:
Condition:

Right Monument Pin Ht:
Condition:

π eye piece elev. =

Reference Dist:
Recent Survey Dist:

Recorded in: ___ m ___ ft

	Sta	Dist	Top	Mid	Bot	Dist. ~~H20 Depth~~	Vertical Bed Mat'l	Comments
	1	0	0	0		0	0	
	2	5	0.7	0		5	0.7	
	3	10	6.5	0		10	6.5	7.0 Dist to front face Abutment
	4	15	13.7	.2		15	13.9	
EW	5	20	14.3'	.3		20	14.6	Right Edge of Water
	5a	23'	16.2'	.4		23	16.6	Thalweg
	6	25	15.7	.4		25	16.1	
EW	6a	25.5'	14.2	.4		25.5'	14.6	Left Edge of Water
	7	30	9.9	.5		30	10.4	
	8	35	6.6	.4		35	7.0	
	9	40	3.5'	.3		40	3.8	
	10	45	1.4'	.1		45	1.5	
	11	47	0			47	0	

As the nation's principal conservation agency, the Department of the Interior has the responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-40 April 2002