COUNTY OF SANTA CRUZ
DEPARTMENT OF PUBLIC WORKS
INTER-OFFICE CORRESPONDENCE

DATE: December 16, 2010

TO: Bruce Laclergue, Flood Control Program Manager

FROM: Justine Wolcott, Resource Planner

SUBJECT: Pajaro River Bench Excavation Project- Estimated Benefit

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Three ATTCHMENTS support the following estimate:

ATTACHMENT 1: **Existing Conditions- Annual Damages**

= $12,053,000*.

***Note:** Likely Under-estimated figure: The Annual Damages in the 2009 draft of the Economics Appendix is considered to be likely under-estimated. Significant work is currently underway to revise damages in the agricultural category, as well as other potential damages categories. The expected result is that the next draft (planned to release in Spring 2011) will list a total annual damages figure that is greater than current.

ATTACHMENT 2: **Bench Excavation- With Project Benefit- Increase in Levee Carrying Capacity (cfs)**

= **2,000 cfs** greater

ATTACHMENT 3: **1995 Flood- Levee Capacity (cfs)**

= 21,900 cfs.

CONCLUSION: 1995 Flood peak flow: **21,900 cfs**

Bench Excavation Project Benefit: **2,000 cfs**

Result = Gain in capacity: 9%*

***Note:** Current flood stage for the U.S.G.S. Chittenden Gauge is 21,600 cfs. Therefore, the project benefit could be closer to 9.4%.

ATTACHMENT 1:
Existing Conditions- Annual Damages

Excerpt from Report:	U.S. Army Corps of Engineers General Re-evaluation Report-Economics Appendix; Draft 05/12/2009.
Pages 11- 17:	Explanation of economic factors for the 'without-project condition' for the Pajaro River Levee Reconstruction Project. This is equivalent to the 'existing condition' of the levee system. This is also equivalent to the 'without project condition' for the Pajaro River Levee Bench Excavation Project.
Table 11, page 17:	Total Expected Annual Damages for both main stem river banks (1M (main stem) and 2M) **= $12,053,000***.
***Note:**	Likely Under-estimated figure: The Annual Damages in the 2009 draft of the Economics Appendix is considered to be likely under-estimated. Significant work is currently underway to revise damages in the agricultural category, as well as other potential damages categories. The expected result is that the next draft (planned to release in Spring 2011) will list a total annual damages figure that is greater than current. For the March 1995 flood event, overall damages to residential, commercial, and agricultural property were estimated to be approximately $95 million dollars.

US Army Corps of Engineers

Pajaro River GRR

With-Project (F4) Economics
Spring 2009

complete frequency-damage curve for each damage category. The results of the simulations, including the mean damage and standard deviation, were then directly entered into the HEC-FDA program.

7.0 OTHER DAMAGE CATEGORIES

7.1 Agricultural Crop Damages

There are approximately 3,400 acres devoted to agriculture in Reach 1M and approximately 3,400 acres in Reach 2M along the main stem Pajaro River. There are approximately 300 acres devoted to agriculture in Reach 1T, approximately 1,850 acres in Reach 2T, approximately 100 acres in Reach 3T and close to 400 acres in Reach 4T in the floodplains along the Tributaries. A summary of the number of agricultural acres for the Main Stem and Tributaries is displayed in Tables 8 and 9 below, respectively. A map showing the locations of the sub-areas is in the Appendix, Figures B-1 and B-2.

Table 8: Main Stem
Number of Agricultural Acres in Floodplain

Damage Reach	Sub-Area	Number of Acres flooded by frequency event				
		10yr	25yr	50yr	100yr	500yr
1M	*A*	389	601	644	655	657
	B	2,194	2,470	2,578	2,635	2,722
	C	0	0	0	0	0
	Sub-Total	2,583	3,071	3,222	3,290	3,379
2M	*D*	1,483	1,706	1,721	1,728	1,735
	E	0	0	0	0	0
	F	435	468	477	482	487
	G	900	987	1,052	1,088	1,142
	Sub-Total	2,818	3,161	3,250	3,298	3,364
	Total	**5,401**	**6,232**	**6,472**	**6,588**	**6,743**

Table 9: Tributaries
Number of Agricultural Acres in Floodplain

Damage Reach	Sub-Area	Number of Acres flooded by frequency event				
		10yr	25yr	50yr	100yr	500yr
1T	*H*	160	233	269	285	307
	I	0	0	0	0	0
	Sub-Total	160	233	269	285	307
2T	*J*	0	0	0	0	0
	K&L	740	1,204	1,446	1,662	1,849
	Sub-Total	740	1,204	1,446	1,662	1,849
3T		47	67	79	91	92
4T		75	327	356	367	367
	Total	**1,022**	**1,837**	**2,150**	**2,405**	**2,615**

7.1a Sources of Agricultural Data

The agricultural land use in the Pajaro River floodplain is characterized by very intensive cropping. A high percentage of the land is devoted to growing high-value strawberry crops; other major crops include head and leaf lettuce, and other vegetable and fruit crops (e.g., cauliflower, broccoli, and raspberries). The data to conduct the damage analysis was obtained from several sources. These include:

1) The Monterey and Santa Cruz Counties Agricultural Commissioners' Office;
2) Monterey and Santa Cruz Counties crop budget reports;
3) The University of California's Cooperative Extension (UCCE);
4) Cost of production studies published by the UCCE;
5) Previous Pajaro River economic reports;
6) A report by the Pajaro Valley Water Management Agency (PVWMA) entitled, "Estimating Economic Impacts to Agricultural Production"; and
7) Field visits

More specifically, data for crop prices and yields for the various crops were obtained from the county crop budget reports and were averaged over a 6-year period (1998 to 2004); typical per acre variable costs, including cultural, harvest and post-harvest costs were obtained from UCCE production cost studies; land use and cropping patterns were based on information from the PVWMA report, Monterey County and Santa Cruz County agricultural commissioners offices, information from previous Corps reports, and field visits to the area.

7.1b Direct Production Investment Losses and Income Losses

As described in IWR Report 87-R-10[3] Flooding damage to agriculture can be categorized as either direct production investment (DPI) loss, or income loss. Analyses of DPI losses per acre and income losses per acre for each major crop type formed the basis for determining total expected damages per acre for each crop. Direct production investment costs are those costs needed to bring the product to market and include pre-harvest costs (e.g., land preparation, fertilizer application, equipment costs, labor costs, seed, planting, etc.) but do not include variable harvest costs. Income losses represent net income plus fixed costs related to land, labor and management, as well as pre-harvest and post-harvest activities; it is the difference between the maximum damageable value of a crop (average price multiplied by average yield) and direct production investment costs. Direct production investment losses per acre for each crop type were based on typical monthly production costs incurred during the growing season and the probability of experiencing a flood event during a particular month[4]. Net income losses per acre for each crop type were interpolated from ranging analysis tables (net return per acre above cash costs) published by the UCCE; interpolation was based on average yields and average prices over at least a 3-year period (in some cases, such as for strawberries, a longer period was used to derive average yields and prices). A summary of DPI losses per acre and income losses per acre for each crop type are shown in Table 10 below.

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[3] *National Economic Development Procedures Manual – Agricultural Flood Damage,* USACE Institute for Water Resources, 1987

[4] The probabilities of flooding by month for the study area were developed by the Water Resources Section, San Francisco District and taken from previous reports. Monthly flood probabilities were pegged to historical peak annual flows. Fifty-six years of flow data for the area were evaluated to determine the frequency of peak annual flows for each month. Monthly realizations of peak annual flows were then computed as a percentage of all peak annual flows. These monthly percentages formed the basis for determining the likelihood of a flood occurring in a particular month.

Table 10: DPI Losses, Net Income Losses, and Expected Damages per Acre FY 2008 Price Level, ($)

Crop	DPI Losses Per Acre	Income Losses Per Acre	Expected Damage Per Acre
Strawberries	7,741	7,675	15,416
Head Lettuce	1,195	0	1,195
Leaf Lettuce	1,521	0	1,521
Raspberries	1,166	1,413	2,579
Broccoli	628	99	728
Cauliflower	994	343	1,337

Section G of the Appendix includes tables that show in more detail the derivation of DPI losses per acre and net income losses per acre for each crop type considered. The tables in the Appendix show the following: 1) the monthly probabilities and production costs used to calculate direct production investment losses for a particular crop, 2) the average prices and average yields for a particular crop, 3) the ranging analysis table for net returns per acre for a particular crop, 4) the interpolation of the ranging analysis table using the average yield and price to determine an estimated net income loss per acre for a particular crop, and 5) an example of the calculation of weighted expected damage per acre (weighted for the likelihood of having a certain type of crop present).

The following paragraphs describe some of the relevant details associated with the major crop types in the study area.

Strawberries: Based on information from the Monterey and Santa Cruz County agricultural commissioner's offices, information from previous Corps reports, data from the PVWMA report, and numerous field visits, it was estimated that at any given time strawberry crops comprise approximately 50% of the acreage devoted to agriculture in the study area. Strawberries are typically planted in October and harvested from April through early October. Peak harvest occurs in June and July.

Production data for strawberries were calculated based on crop budget reports published by the Santa Cruz County and Monterey County agricultural commissioner's offices and information contained in production cost studies published by the University of California Cooperative Extension (UCCE). Average price per tray received by producers between the years 1998 and 2006 was approximately $7.19. Average yield over the same time period was approximately 4,674 trays per acre. The average gross income per acre, therefore, was approximately $33,600.

Head and Leaf Lettuce: Based on information from the Monterey and Santa Cruz County agricultural commissioner's offices, crop budget reports, and UCCE's production costs studies, lettuce consistently ranks as a major crop both in terms of yield and production value in Monterey and Santa Cruz Counties. In these counties, lettuce is typically planted from late December through mid August and harvested from April through October, therefore there are 3 "seasons" for lettuce growing – spring, summer, and fall.

Detailed monthly production cost studies for lettuce grown in Monterey and Santa Cruz Counties could not be found. Therefore, on the advice of experts at the Santa Cruz County Agricultural Commission, the production cost study for lettuce grown in Ventura County (which does have detailed cost break downs) was used to extrapolate percentage-based monthly cultural and harvest costs, which were then applied to aggregate production costs published in the cost studies for lettuce grown in Monterey and Santa Cruz counties. In order to extrapolate production costs from Ventura County, two growing seasons were assumed (January through April and June through September), each lasting four months.

For leaf lettuce, the average price per carton received by producers between the years 1998 and 2006 was approximately $7.88; average yield over the same time period was approximately 880 cartons per acre. The average gross income per acre, therefore, was approximately $6,934. For head lettuce, the average price per carton was approximately $7.40 over the 1998 to 2006 time period; the average yield was approximately 852 cartons per acre.

Other crops (raspberries, broccoli, and cauliflower): For this analysis, three crops – raspberries, cauliflower, and broccoli -- were used to represent the various other crops typically grown in the study area.

Raspberries: The average yield for raspberries in Monterey and Santa Cruz Counties is estimated to be approximately 2,387 flats per acre. The average price per tray received by producers is approximately $12.54. Average gross income per acre, therefore, is approximately $29,933. Since raspberries are a perennial crop, it was assumed that there would be a reduction in yield (10%) rather than a total loss of crop.

Cauliflower: Between 1999 and 2006 the average yield for cauliflower in Monterey and Santa Cruz Counties was approximately 698 boxes per acre. The average price per box received by producers was approximately $8.17. Average gross income per acre, therefore, was approximately $5,703.

Broccoli: Average yield and price for broccoli was based on data from Monterey County between 1999 and 2006. The average yield for broccoli during this time period was approximately 662 boxes per acre. The average price per box received by producers was approximately $7.40. Average gross income per acre, therefore, was approximately $4,899.

7.1c Assumptions Associated With Duration of Flooding and Depth of Flooding

Agricultural damages from flooding are also dependent on the duration of flooding and the depth of flooding (to a lesser degree). Flooding from past events has lasted longer than 3 days, which is long enough to completely destroy strawberry crops and place them at risk for e-coli contamination. It was assumed that all annual crops (strawberry, lettuce and other vegetable crops) would be a complete loss after even short duration (3 days) flooding. Conversely, it was assumed that perennial crops such as raspberries would suffer only a reduction in yield (10% in this case) rather than a complete loss.

7.1d Expected Damages and Cropping Patterns: Computation of Weighted Damage Using a Risk Analysis Approach

The expected damage per acre of each crop type analyzed was used to compute a weighted average damage per acre based on the cropping pattern of a particular area in the floodplain. Sub-areas within the study area were delineated and the number of agricultural acres flooded during specific frequency events (10yr, 25yr, 50yr, 100yr, and 500yr) was multiplied by the weighted damage per acre to derive a total damage for that area and for that frequency event.

Since there is uncertainty in the number of acres devoted to a particular crop at any given time, a probabilistic approach was used to describe the crop pattern. Data used to describe this uncertainty was mainly obtained from the aforementioned PVWMA report, as well as several field visits to the area. Based on information in the PVWMA report, it was assumed that at any given time 14% of any particular area was uncultivated. Also, the cropping pattern for the entire area was set to be dependent upon the percentage of acres in the floodplain devoted to strawberries in three general areas: 1) Santa Cruz County downstream of the confluence of the Pajaro River and Salsipuedes Creek, 2) Santa Cruz County upstream

of the confluence, and 3) Monterey County. In Santa Cruz County, the percentage of acres devoted to strawberries was set to a triangular distribution having a minimum value of zero (0%), a most likely value of 50% and a maximum value of 75%. For the remaining areas, the percentage of acres devoted to strawberries was set to a triangular distribution having a minimum value of 80%, a most likely value of 90%, and a maximum value of 100%. In all areas, the percentage of acres devoted to the remaining crop types was dependent upon the percentage of acres devoted to strawberries as determined via Monte Carlo simulation using risk analysis software (@Risk). The ratios used to determine the percentage of crops other than strawberries were 35/78 (head lettuce), 10/78 (leaf lettuce), 5/78 (raspberries), 14/78 (broccoli), and 14/78 (cauliflower).

The weighted damage per acre for Santa Cruz County downstream of the confluence is $6,957; for the area upstream of the confluence in Santa Cruz County and in Monterey County the weighted damage per acre is $13,542. These values were then applied to the number of acres in each agricultural sub-area to determine total damages for each frequency event in each sub-area. Total damages for each frequency event were then linked to stage to derive stage-damage curves for each area. These curves were then entered directly into the HEC-FDA program in order to calculate expected annual damages for agriculture.

More details on the agricultural crop damage analysis (including the estimated damages for each of the impact areas) can be found in section G of the Appendix.

7.2 Automobile Damages

The estimated number of automobiles that would be impacted by a flood was based on an estimated number of residential households, an assumed number of cars per household, and an assumed percentage of automobiles that would be impacted in a flood. The number of households was determined based on an inventory of structures impacted by the various frequency flood events; the number of cars per household was estimated at two and is consistent with values used in previous District studies; the percentage of automobiles that would be impacted by a flood event was assumed to be 2/3 and is also based on values used in previous District studies. This value takes into account that damages to automobiles could be avoided if there is sufficient warning time to remove them from the flooded area, but also that there is a risk that levee failure scenarios could reduce the amount of warning time to residents in the area.

The derived estimated number of automobiles that would be impacted was then multiplied by an average automobile value to derive an estimated value of damageable automobile property per event. The average automobile value was calculated using information provided in the paper, "California Vehicle License Fees: Incidence and Equity[5]". According to this paper, the state of California assessed a vehicle license fee (VLF) on all privately owned, registered vehicles through the year 1997. This fee was computed as 2% of a vehicle's value, which was based on the most recent purchase price and a fixed depreciation factor. With the additional information from the 1997 California Legislative Analyst's report that estimated an average 1997 VLF of $171, an average value of an automobile (less depreciation) in California could be computed by dividing the average VLF ($171) by the 2% uniform tax rate. This value was computed to be $8,550, which was then updated for this report to reflect FY 2008 price levels. The estimated average value included in this analysis was $10,800.

The vehicles were assigned to the residential structures within the floodplain, and the same procedures that were used for structures were used to calculate damages to vehicles from flooding. The depth-percent damage curve used in this procedure is included section C of the Appendix.

[5] Authors: Jennifer Dill, Todd Goldman, and Martin Wachs; University of California at Berkeley.

7.3 Emergency Costs

Across California, the 1995 winter storms resulted in a total of approximately $81 million in direct payments to approximately 29,200 families living within the forty-two counties that were declared flood disaster areas. These payments covered costs related to temporary housing, repairs, counseling and any other emergency-type services. Additionally, there were administrative costs associated with operating the Disaster Assistance Program representing approximately 25% of the direct payments, or $20 million. The average payment per family, therefore, was approximately $3,500. This value was increased to $4,400 to reflect current price levels.

To annualize costs (damages) associated with emergency activities, a relationship between depth of flooding above the first floor of a structure and percent damages (percent of emergency costs incurred) was assumed. For this analysis it was assumed that 100% ($4,400) of the emergency costs would be incurred if the depth of flooding reached the first floor of a structure and zero emergency costs were incurred if flooding was below the first floor. This single step function was necessary as a result of the lack of information on the relationship between in-structure flood depth and emergency cost. This depth-percent damage relationship was entered into the HEC-FDA model in order to compute expected annual damages/costs associated with emergency operations.

8.0 DAMAGE ANALYSIS USING HEC-FDA

The Corps' Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) program was used to compute expected annual without-project damages and engineering performance statistics within a risk analysis format.

The HEC-FDA program was also used to formulate and evaluate flood damage reduction plans. The results from the program allowed for a comprehensive comparison of the alternatives from an economic perspective (expected benefits and the reliability of these benefit estimates) as well as from an engineering perspective (the reliability of predicted flood levels, the probability of these levels being exceeded, long-term risk, and conditional non-exceedance probabilities by event).

9.0 RESULTS: EXPECTED ANNUAL DAMAGES

Expected annual damages (EAD) are the probability-weighted value of damages expected per year when considering a very long time horizon. This value was computed in HEC-FDA based on four main contributing relationships: frequency-discharge, stage-discharge, stage-damage, and geotechnical levee failure curves. The without-project EAD by damage category, damage reach, and sub-area for both the Main Stem and the Tributaries are displayed in Tables 11 and 12. The event-based damage estimates can be seen in Tables F-1 through F-8. As a test of reasonableness, the damage per residential and commercial structure along the main stem for the 500-year event was calculated. A very high (or very low) ratio of damage to damageable property could indicate an error in the analysis that could result in damages being overestimated (or underestimated). From an aggregated perspective, the average damage per structure (structures and contents) was found to be between one-quarter and one-half of the average value of damageable property for each of the structure types. This result indicates that the event-based damage estimates are reasonable.

Table 11: Main Stem
Expected Annual Damages by Damage Category and Reach
Without-Project Condition
FY 2008 Price Level, ($1,000s)

Damage Reach	Sub-Area	Expected Annual Damage by Damage Category							
		Agriculture	Auto	CIW*	Emergency Costs	Green-house	Public	Resi-dential	Total
1M	*A*	645	0	0	0	0	0	0	645
	B	1,470	0	0	0	0	0	0	1,470
	C	0	32	440	81	254	119	554	1,481
	Sub-Total	2,115	32	440	81	254	119	554	3,596
2M	*D*	881	15	0	8	0	0	54	958
	E	0	174	4,850	203	0	109	1,341	6,677
	F	261	0	0	0	0	0	0	261
	G	561	0	0	0	0	0	0	561
	Sub-Total	1,703	189	4,850	211	0	109	1,395	8,457
	Total	**3,818**	**221**	**5,290**	**292**	**254**	**228**	**1,949**	**12,053**

*Commercial/Industrial/Warehouse

Table 12: Tributaries
Expected Annual Damages by Damage Category and Reach
Without-Project Condition
FY 2008 Price Level, ($1,000s)

Damage Reach	Expected Annual Damage by Damage Category								
	Sub-Area	Agriculture	Auto	CIW*	Emergency Costs	Green-house	Public	Resi-dential	Total
1T	*H*	145	0	0	0	0	0	0	145
	I	0	268	4	266	35	22	2,262	2,858
	Sub-Total	145	268	4	266	35	22	2,262	3,003
2T	*J*	0	163	1,679	188	1	104	1,333	3,467
	K & L	780	0	0	0	0	0	0	780
	Sub-Total	780	163	1,679	188	1	104	1,333	4,247
3T		15	19	12	30	0	0	363	439
4T		173	1	196	6	0	0	52	428
	Total	**1,113**	**451**	**1,891**	**490**	**35**	**126**	**4,010**	**8,117**

*Commercial/Industrial/Warehouse

10.0 RESULTS: PERFORMANCE STATISTICS

The following engineering performance results shown in Tables 13 and 14 were computed by the HEC-FDA program using the frequency-discharge, stage-discharge (rating), and geo-technical levee failure curves provided by the Engineering Division of the San Francisco District U.S. Army Corps of Engineers. The results reflect the without-project condition at a specific location (index point) within a damage reach. The following paragraphs will help define the terms used in these two tables.

Annual Exceedance Probability (AEP): This represents the percent chance of a target stage (in this case the without-project top of levee) being exceeded in any given year, thereby causing flooding and

ATTACHMENT 2:
Bench Excavation- With Project Benefit- Increase in Levee Carrying Capacity (cfs)

Report:	Northwest Hydraulic Consultants: Letter Report- Pajaro River Bench Excavation Analysis; Draft 01/27/2004.
Page 7:	Conclusion 6) of the letter report states that the with-project condition for the bench excavation project is approximately **2,000 cfs** greater than the current condition, as follows: “The average capacity of the excavation concept (Model C) is approximately 2,000 cfs greater than the Post 1998 Flood geometry (Model B) capacity”.

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File 50275

January 27, 2004

Bruce Laclergue
Santa Cruz County
Flood Control and Water Conservation District, Zone 7
701 Ocean Street
Santa Cruz, CA 95060

RE: Pajaro River Bench Excavation Analysis

Dear Mr. Laclergue:

As requested, Northwest Hydraulic Consultants (**nhc**) has evaluated the sensitivity of Pajaro River water surface profiles between Highway 1 and Murphy's Crossing to channel vegetation conditions and partial excavation of benches located between the channel and levees. Results are compared to computed water surface profiles representing vegetation thinning in the Management Plan Alternative #2 (mitigated Alternative #6 in the Final EIR, and in the 1601 permit from the Department of Fish & Game as of October 2003).

The analysis provides an assessment of the initial hydraulic benefits of bench excavation. The analysis does not consider possible impacts to, or limitations presented by, underground utilities or bridge structures. In addition, the analysis does not include an assessment of the long-term sustainability of the project with regard to sedimentation or vegetation maintenance within the excavated area. Observations during past flood events indicate that substantial sediment deposition can occur on the benches during large flood events and could result in a substantial reduction in the immediate hydraulic benefits described by this analysis. A further assessment of the excavation projects impacts on sedimentation, lateral channel stability, underground utilities, and bridge scour should be conducted if the project is found to be viable based on the hydraulic analysis presented herein.

The concept evaluated involves the excavation of benches on both sides of the river to create a new bench elevation no lower than the water surface profile of the two-year flood. The entire width of bench would not be excavated. Only bench areas extending beyond a minimum buffer width, measured from the existing levee toe, would be excavated. The purpose of the buffer is to reduce the potential of bank erosion undermining the levee toe.

<u>Excavation Concept and Hydraulic Model Development</u>

Hydraulic models with three different cross section geometries were used in the analysis of the excavation concept. Hydraulic Model A reflects the geometry of the Pajaro River in 1996. Hydraulic Model B reflects the geometry of the Pajaro River after the 1998 flood. Hydraulic Model C reflects the geometry of the excavation concept.

For each geometric condition, water surface profiles were computed for five Manning's roughness scenarios. The first scenario included channel and bench roughness values as defined by Management Plan Alternative #2. For the remaining scenarios, four Manning's Roughness values were specified for the channel upstream of Highway 1. Models were developed with Manning's Roughness values of 0.030, 0.040, 0.060, and 0.080 in the channel. A Manning's Roughness value of 0.040 (mowed grass condition) was assumed for the bench area in all four scenarios. Manning's Roughness of 0.030 in the channel is considered the lower limit of potential roughness values, and assumes nearly all vegetation would be removed and the banks would be uniformly protected with rock revetment. Likewise, a Manning's roughness of 0.080 in the channel is assumed the upper limit of roughness (generally unmaintained condition). A schematic showing the Management Plan Alternative #2 Roughness values is provided on Sheet 2 of the attached drawing set "Pajaro River, Bench Excavation Concept."

Hydraulic Model A - 1996 Condition:

Hydraulic Model A was based on the HEC-2 hydraulic model developed by CH2MHill to simulate the hydraulic characteristics of Pajaro River Management Plan Alternative #2. The model is described in the report "Pajaro River Management and Restoration Plan, August 1997." The model extends from the River's mouth to Murphy's Crossing and contains 116 cross sections surveyed in the summer of 1995, October 1996, and December 1996. The Manning's roughness values in the model were based on an initial calibration to storm events of February 20, 1996 (8,430 cfs at USGS Chittenden Gage) and January 3, 1997 (15,800 cfs at USGS Chittenden Gage) and final adjustments to reflect the proposed conditions under Management Plan Alternative #2. The model was previously converted to HEC-RAS and formed the basis of hydraulic modeling conducted for the Pajaro River Flood Protection Project, Community Planning Process.

Hydraulic Model B - Post 1998 Flood Condition:

Cross sections in the Management Plan Alternative #2 hydraulic model (Hydraulic Model A) were modified and updated to account for bank erosion that occurred during the 1998 flood. Modifications were made by measuring the distance between the channel bank and the levees using a set of 1"=100' photographic maps obtained from the **nhc** report "Pajaro River 1988 Bank Erosion Assessment, October 1998" completed for Santa Cruz County Flood Control and Water Conservation District, Zone 7. The map set shows a comparison of the 1996 and 1998 banklines. The elevation of the 1996 bank toe was used for the elevation of the 1998 bank toe. The estimated aerial extent of the bank erosion was digitized from the map set and is shown on Sheets 3 through 14 of the attached drawing set "Pajaro River, Bench Excavation Concept." A typical cross section showing the modified geometry of Model A is shown on Sheet 2.

Hydraulic Model C - Excavation Concept Condition:

Cross sections in Hydraulic Model B were modified to incorporate the bench excavation concept. The concept involves the excavation of benches on one or both sides of the river to create new benches at an elevation no lower than the water surface profile of the two-year flood. Elevations for excavated benches were determined by calculating the water surface-profile for the two-year flood using Hydraulic Model B and Pajaro River Management Plan Alternative #2 Manning's roughness values. The two-year flood profile was based on

discharges of 3,000 cfs from Murphy's Crossing to Salsipuedes Creek and 3,500 cfs from Salsipuedes Creek to the River's Mouth. These two-year flood design flow rates were based on the Corps of Engineers April 1997 hydrologic report.

An excavation buffer area was developed for defining the maximum width of the proposed bench excavation. Only bench areas extending beyond the minimum excavation buffer width, measured from the existing levee toe towards the channel, would be excavated. The purpose of the excavation buffer area is to reduce the potential of future bank erosion undermining the levee toe.

The width of the excavation buffer area was based on observations of bank erosion following the 1998 flood and location of the excavation with respect to river planform and structures or other facilities in the floodplain. The set of 1"=100' photographic maps showing a comparison of the 1996 and 1998 banklines were obtained from the report "Pajaro River 1998 Bank Erosion Assessment, October 1998". The amount of bank erosion that occurred between 1996 and 1998 was measured at 250-foot increments along the channel from the Thruwachter Road Bridge to Murphy's Crossing. In straight reaches, the maximum amount of lateral bank erosion was 100 feet with 95 percent of the bank length retreating less than 60 feet. On the outside of bends, the maximum amount of lateral bank erosion was found to be 130 feet with 95 percent of the bank length retreating less than 70 feet. On the inside of bends, the maximum amount of lateral bank erosion was 110 feet with 95 percent of the bank length retreating less than 60 feet.

Based on the above observations, minimum excavation buffer widths of 50-feet wide in straight reaches and inside bends, and 100-feet wide on the outside of bends were assumed. Using these buffer widths as a guide, the proposed channel banks for the excavation concept were drawn on a set of maps showing the 1996 to 1998 bank erosion. The cross sections in Hydraulic Model B were modified to reflect these excavated areas with the new bench elevation set at the two-year flood. The location of the resulting excavation areas are shown on Sheets 3 through 14 of the attached drawing set "Pajaro River, Bench Excavation Concept." A typical cross section of the bench excavation concept is shown on Sheet 2. **nhc** recommends that a more rigorous assessment of the impacts on lateral channel stability and channel sedimentation be completed as part of bench excavation design studies.

Results

The bench excavation concept as shown on the attached map set and described above would involve the removal of 268,000 cubic yards of soil. Excavation quantities computed for each project reach and side of river are provided in Table 1.

A comparison of water surface profiles computed using Hydraulic Models A, B, and C and the Management Plan Alternative #2 Manning's roughness scenario are provided on Sheet 15 of the attached drawing set "Pajaro River, Bench Excavation Concept." The profiles are based on the 1998 peak discharge of 25,100 cfs from Murphy's Crossing to Salsipuedes Creek and 28,000 cfs from Salsipuedes Creek to the River's Mouth.

Water surface profiles were computed for Hydraulic Models A, B and C for the five Manning's Roughness Scenarios discussed above. Computed water surface elevations for a sample cross-section within each project reach are provided in Tables 2 though 6. Each table includes a comparison of each scenario's water surface elevation to the water surface elevation

computed using Model A geometry and Management Plan Alternative #2 Manning's roughness. The Model A geometry and Management Plan Alternative #2 Manning's roughness scenario serves as the basis of comparison because it was used in the evaluation of alternatives in the 1997 Pajaro River Management and Restoration Plan and the Final EIR.

For each cross section, the discharge capacity (discharge at which the water surface is three feet below the top of levee) was computed for Models A, B, and C using the Management Plan Alternative #2 Manning's roughness scenario. A summary of the maximum cross section capacity, minimum cross section capacity, and average cross section capacity for each reach is provided in Table 7. The minimum cross section capacity is the capacity limit of the project reach. Discharges in excess of this amount would be within 3-feet of the levee top at one cross section. The difference between the maximum and minimum cross section capacity indicates the variability in the freeboard within a project reach.

Table 1. Summary of Excavation Volume by Project Reach

Project Reach	Volume of Bench Excavation (Cubic Yards)	
	Monterey County side	Santa Cruz County side
1A. Pacific Ocean to Thurwachter Road	0	0
1B. Thurwachter Road to Highway 1	0	0
2. Highway 1 to Watsonville City Limit	5,000	64,000
3. Watsonville City Limit to Salsipuedes Creek	4,000	70,000
4A. Salsipuedes Creek to Coward Creek	14,000	76,000
4B. Coward Creek to Murphy's Crossing	4,000	31,000
Total	27,000	241,000

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Table 2. Comparison of Water Surface Elevations in Reach 1 (Highway 1 Bridge)

Model Geometry	Manning's Roughness Scenario				
	Plan 2	0.03 a/	0.04 a/	0.06 a/	0.08 a/
	Computed Water Surface Elevation (Feet NGVD29)				
Model A	24.7	NA	NA	NA	NA
Model B and C b/	23.4	NA	NA	NA	NA
	Stage Reduction - Distance Below Model A Geometry Alt. #2 Roughness (Feet)				
Model A	0.0	NA	NA	NA	NA
Model B and C b/	1.3	NA	NA	NA	NA

a/ All Manning's Roughness values downstream of Highway 1 Bridge are based on Plan 2.
b/ Bench excavation does not extend downstream of Highway 1 (Models B and C are identical).

Table 3. Comparison of Water Surface Elevations in Reach 2 (Cross Section 2012)

Model Geometry	Manning's Roughness Scenario				
	Plan 2	0.03	0.04	0.06	0.08
	Computed Water Surface Elevation (Feet NGVD29)				
Model A	29.3	28.0	29.1	30.8	31.8
Model B	28.1	26.6	27.7	29.6	31.1
Model C	27.6	26.4	27.4	29.1	30.4
	Stage Reduction - Distance Below Model A Geometry Alt. #2 Roughness (Feet)				
Model A	0.0	1.3	0.1	-1.5	-2.5
Model B	1.2	2.7	1.6	-0.3	-1.8
Model C	1.7	2.9	1.9	0.2	-1.1

Table 4. Comparison of Water Surface Elevations in Reach 3 (Cross Section 2028)

Model Geometry	Manning's Roughness Scenario				
	Plan 2	0.03	0.04	0.06	0.08
	Computed Water Surface Elevation (Feet NGVD29)				
Model A	34.3	32.6	34.0	36.1	37.5
Model B	33.0	30.9	32.4	34.9	36.7
Model C	32.4	30.5	31.9	34.2	36.0
	Stage Reduction - Distance Below Model A Geometry Alt. #2 Roughness (Feet)				
Model A	0.0	1.7	0.3	-1.8	-3.2
Model B	1.3	3.4	1.9	-0.6	-2.4
Model C	1.9	3.8	2.4	0.1	-1.7

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Table 5. Comparison of Water Surface Elevations in Reach 4A (Cross Section 2046)

Model Geometry	Manning's Roughness Scenario				
	Plan 2	0.03	0.04	0.06	0.08
	Computed Water Surface Elevation (Feet NGVD29)				
Model A	39.5	37.7	39.3	41.7	43.2
Model B	38.7	36.7	38.4	40.9	42.7
Model C	37.9	36.1	37.7	40.1	41.8
	Stage Reduction - Distance Below Model A Geometry Alt. #2 Roughness (Feet)				
Model A	0.0	1.8	0.2	-2.1	-3.7
Model B	0.8	2.8	1.2	-1.4	-3.2
Model C	1.6	3.4	1.9	-0.5	-2.3

Table 6. Comparison of Water Surface Elevations in Reach 4B (Cross Section 2082)

Model Geometry	Plan 2	Manning's Roughness Scenario 0.03	0.04	0.06	0.08
	Computed Water Surface Elevation (Feet NGVD29)				
Model A	52.5	50.3	52.1	54.9	56.8
Model B	52.2	49.9	51.7	54.6	56.6
Model C	52.0	49.8	51.6	54.3	56.3
	Stage Reduction - Distance Below Model A Geometry Alt. #2 Roughness (Feet)				
Model A	0.0	2.2	0.4	-2.4	-4.3
Model B	0.4	2.7	0.8	-2.1	-4.1
Model C	0.5	2.8	1.0	-1.8	-3.8

Table 7. Maximum, Minimum, and Average Cross-Section Discharge Capacity

Reach	Maximum Cross Section Capacity a/ (cfs)			Minimum Cross Section Capacity b/ (cfs)			Average Cross Section Capacity c/ (cfs)		
	Model A	Model B	Model C	Model A	Model B	Model C	Model A	Model B	Model C
1.	23000	27000	27000	17000	17000	17000	19000	20000	20000
2.	28000	31000	32000	26000	28000	30000	27000	29000	31000
3.	29000	32000	34000	25000	29000	31000	27000	30000	32000
4A.	25000	28000	31000	20000	22000	24000	23000	25000	27000
4B.	25000	27000	28000	20000	21000	21000	23000	24000	25000

a/ Maximum cross section capacity is based on the cross section with the highest capacity (water surface 3-feet below the top of levee) within the reach.
b/ Minimum cross section capacity is based on the cross section with the lowest capacity (water surface 3-feet below the top of levee) within the reach.
c/ Average capacity is the average maximum capacity for all cross sections within the reach.

Conclusions

The following conclusions can be drawn from the excavation and roughness sensitivity analysis.

1) The amount of stage reduction resulting from bank erosion during the 1998 flood was approximately the same as the amount realized by implementing the bench excavation concept. It should be noted that the geometry of the Post 1998 flood model (Model C) is based on lateral bank erosion observed from aerial photographs. Current cross section survey data would be required to confirm the bank erosion assumptions used in the Post 1998 flood model.

2) The excavation concept would not reduce the stage at Highway 1 because the excavation would not extend downstream of that location.

3) For each channel maintenance condition (i.e. Manning's Roughness scenario), the models indicate approximately 0.2 to 0.9 feet of stage reduction going from Post 1998 Flood geometry (Model B) to the excavation concept geometry (Model C).

4) The amount of stage reduction realized by implementing the bench excavation concept increases with increased channel roughness. For instance, excavation is more effective at reducing the water surface if the maintenance is not as aggressive.

5) Stage increases of approximately 5 to 6 feet are indicated by the models by going from the most maintained (lowest Manning's roughness) to the least maintained (highest Manning's roughness) condition.

6) The average capacity of the excavation concept (Model C) is approximately 2,000 cfs greater than the Post 1998 Flood geometry (Model B) capacity for the reach upstream of Highway 1.

If you have any questions regarding the analysis or have a need for additional information regarding the analysis, please call.

Sincerely,

NORTHWEST HYDRAULIC CONSULTANTS, INC.

northwest
hydraulic
consultants

Brad Hall

Principal

Encl.

Drawing Set, Pajaro River Bench Excavation Concept

ATTACHMENT 3:
1995 Flood- Levee Capacity (cfs)

Excerpt from Report:	U.S. Army Corps of Engineers- Project Information Report- Pajaro River Rehabilitation Project, PL 84-99 (Flooding of March 1995); May, 1995.
Pages 1- 5:	Page 5 lists the peak flow of the March 1995 Pajaro River flood at the Chittenden gauge as: **21,900 cfs.**
CONCLUSION:	1995 Flood peak flow: **21,900 cfs** Bench Excavation Project Benefit: **2,000 cfs** **Result = Gain in capacity: 9%***
***Note:**	Current flood stage for the U.S.G.S. Chittenden Gauge is 21,600 cfs. Therefore, the project benefit can be interpreted as slightly greater than 9%, being closer to 9.4%.

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PROJECT INFORMATION REPORT
PAJARO RIVER REHABILITATION PROJECT
PL 84-99

(Flooding of March 1995)

MAY 1995

Project Information Report
Pajaro River Rehabilitation Project--PL84-99

1. LOCATION

a. Location. The existing federal project is located along the border between Santa Cruz and Monterey counties in the Central Coast area in the State of California. The project consists of levees along the first 12 miles of the Pajaro River (from the mouth of the river), and 4.5 miles of Salsipuedes/Corralitos Creeks.

b. General Location Drawing. Please refer to Exhibit D.

2. OWNERS & SPONSORS.

The sponsors of the Federal project are the Monterey County Water Resources Agency-Zone 1, and the County of Santa Cruz. At the time the Federal Project was constructed, two other upstream counties also signed sponsorship agreements, but these upstream counties have not been active in the operation of the project. There are current on-going discussions and negotiations regarding the possible creation of a bi-county agency for operation and maintenance of the project.

3. SPONSOR POINT OF CONTACT.

The Points of Contact for the PL84-99 Rehabilitation work for Monterey County are Fred Gieger (408-755-4968) and Owen Stewart (408-755-4867). The Point of Contact for Santa Cruz County is Terry Reynolds (408-454-3520)

4. PROJECT CLASSIFICATION.

a. The existing levee which protects the City of Watsonville, the unincorporated developed area of Pajaro and the surrounding agricultural lands is a Federal project constructed by the Corps of Engineers.

b. The project was authorized by Section 10 of the Flood Control Act of December 1944 (Public Law 534, 78th Congress, 2nd Session), which provided for construction of levees on the Pajaro River from its mouth to mile 11.8 on the north bank and to mile 10.6 on the south bank and on its tributary, Salsipuedes Creek, from the confluence with the Pajaro River to high ground at mile

2.6 on the west bank and at mile 1.7 on the east bank.

5. CONSTRUCTION INFORMATION.

a. **Construction Start and Completion Dates.** The flood control project was completed in 1949.

b. **Original Cost.** The original cost for actual construction of this Federal flood control project was $748,000.

c. **Date and Cost of Recent Modifications.** There have been no recent modifications.

6. DESIGN DATA ON EXISTING FEDERAL PROJECT

a. **Levee Section** Levee dimensions vary according to location along the reach of the structure. Crown widths generally vary from 8 feet in the upper end to 12 feet in the lower end. Side slopes are 2H on 1V in the upper end, 2.5H on 1V in areas between the upper and lower ends, and 3H on 1V in the lower end. Levee heights vary from 8 to 12 feet above natural ground surface. For examples of typical levee sections, refer to Exhibits A and C.

b. **Level of Protection.** The project was designed and constructed to provide approximately up to a 50-year level of flood protection. Reanalysis of basin hydrology and project hydraulics indicates that the level of flood protection has been significantly reduced. This topic is discussed further in Section 11.b of this report.

c. **Description of Project.** This project, which consists of typically non-revetted earthen levees along both banks of the Pajaro River and Salsipuedes/Corralitos Creeks, protects approximately 8,000 acres of land in the Pajaro Valley. Included in the areas protected are the City of Watsonville, the unincorporated developed area of Pajaro, with 1990 populations of 31,000 and 3,330, respectively.

7. PREVIOUS PL 84-99 ASSISTANCE.

The Corps of Engineers expended approximately $1,300,000 for emergency levee restoration and protective riprap in 1956 and 1958. In April 1982, a PL84-99 Study Report was completed on four (4) erosion sites beginning approximately at 0.5 miles downstream of East Lake Avenue, where erosion of the Federal project levee face had occurred during a 30-year event on Salsipuedes Creek; the report recommended repair to these sites. The Corps expended $210,000 for rehabilitation of these four

sites in 1982. In April 1986, a PL84-99 Study Report was completed for three erosion sites along Salsipuedes Creek that recommended repair. The Corps expended $390,000 for these repairs. Following the Loma Prieta Earthquake of 17 October 1989, the San Francisco District completed a PL84-99 Study Report for restoration needs of the Federal levee project on Salsipuedes Creek and the Pajaro River. The report recommended repair of the damaged levees to their pre-earthquake section and alignment. The Corps expended approximately $1,500,000 to make these repairs. In April 1993, the S.F. District completed a PL84-99 Study Report of erosion damage to the Federal project levees along Salsipuedes Creek. The report recommended repair of the damaged levees on the right bank between Lakeview Road and East Lake Avenue. The Corps expended $52,700 to make these repairs.

8. MAINTENANCE.

a. Quality of Past Maintenance.

While past maintenance of the project has been less than adequate, the recent exceedance of the project's capacity is likely to have occurred with or without better past maintenance. The area between the levees has been allowed to develop a thick tree and scrub cover. Extensive deposition of river sediments has also occurred, which, along with vegetation, has contributed to a reduction in the flow carrying capacity of the flood control channel. The portion of the maintenance dealing with keeping the channel free of trees and other significant vegetation, and with removing sediment deposition, has been complicated by environmental concerns.

b. Annual Costs. Maintenance costs incurred by Monterey Co. have averaged $30,000 (labor and equipment) for direct maintenance annually in recent years. (In addition, Monterey Co. has been spending an additional $15,000 which has been related to maintenance, such as inspections, report preparation, meetings and coordination.) Santa Cruz Co. has been spending an average of $85,000 annually in recent years for such items as mowing, rodent control, flap gate maintenance, and pump maintenance. Thus, the two counties are spending about $115,000 annually for direct maintenance. There have also been some recent, more significant expenditures for channel bottom clearing work, which historically have not been undertaken on a regular basis.

9. DISASTER INCIDENT.

a. Date of Incident.

9 through 12 March, 1995.

b. Description of Flood Event

During the period 9 through 12 March 1995, a series of major storms brought heavy rains to the Pajaro River Basin, in which Santa Cruz, Monterey and San Benito Counties are located. Over 5 inches of rainfall were recorded in the upper basin and nearly 4 inches in the lower basin, for the 48-hour period preceding peak flows in the Pajaro River. Heavy rains resulted in peak flows of 21,800 cfs on 10 March 1995 (about 2200 hours) and 21,900 cfs on 11 March 1995 (about 0100 hours) on the Pajaro River above its confluence with Salsipuedes Creek. These flows exceeded the project's current flow capacity, and thus, caused the project to fail.

c. Frequency of Flood Event(s).

The peak flows for this recent flood event are representative of approximately a 20-year flood event, or a 5% chance of occurrence.

d. Comparison to Historical Floods.

Three-day recorded rainfall amounts measured at Watsonville during major storm events are presented in the following table:

Watsonville (inches)	Date	Peak (1) Discharge (cfs)
8.35	9-11 Dec '06	uk
5.67	12-14 Sep '18	uk
6.12	22-24 Dec '21	uk
4.91	10-12 Dec '37	uk
6.24	21-24 Dec '55	24,000
2.98	1-4 April '58	23,500
7.58	30 Jan -1 Feb '63	11,600
4.90	8-11 March '95	21,900

(1) Pajaro River above confluence with Salsipuedes Creek

It is important to note that infiltration rates have a large influence on the amount of runoff occurring in the basin. For example, the storm of 1-4 April 1958 produced nearly the same discharge as the 21-24 December 1955 storm even though the recorded three-day rainfall was only 2.98 inches at Watsonville.