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SKAGIT RIVER GENERAL INVESTIGATION
Seattle District 2011 Response to HQUSACE Comments to the 2009 FSM Read-Ahead Packet
Attachment 2d
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Revised Text to Section 5.3 Without Project Conditions Economics of the 2009 FSM Read-Ahead Report

September 2011 Response to HQUSACE Comments to the 2009 FSM Document.

This document is a revision of the Without Project Condition Economics section of the 2009 FSM Read Ahead document per HQUSACE comments received in 2009.

Economics

An economic analysis was conducted to estimate the expected future without-project flood inundation damages for the study area. The analysis is based upon geotechnical assumptions regarding levee performance and associated hydraulic modeling results. Recently, a levee risk and reliability was updated consistent with current guidance and to reflect local levee improvements. Revision to the hydraulic modeling is underway and will be completed in 2012, depending on project funding. The levee risk and reliability analysis results are not expected to have an extreme effect on the economic damage assessment of future without project conditions. The future without project condition will be updated after completion of the hydraulic modeling to include all updated levee, hydrology, hydraulics, and economic data. The most recent update of the future without-project economic analysis was in 2004. An update to the economic inventory was completed in 2010, but is not yet reflected in the results presented in this report. The 2004 analysis was based on 2000 conditions, with exception to the agriculture, which is based on the 2003 Census of Agriculture. The results presented in this report are based on the 2000 economic conditions. Costs were updated from the 1 October 2000 price level to the 1 October 2010 price level. The current discount rate of 4-1/8 percent is used in discounting, compounding, and annual equivalence as determined by EGM 11-01, Federal Interest Rates for Corps of Engineers (Corps) Projects for Fiscal Year 2011. A 50-year planning period is assumed starting with a base year in 2004. The base year of the period of analysis is the first year that benefits accrue from any of the alternatives considered. A future update to the future without project conditions, along with the alternatives analysis, will revise the base year and future year assumptions. In the 2004 economic analysis, it was assumed that there would be little change in the hydrology and hydraulics over the period of analysis, so no most likely future years were projected for the analysis presented at this stage. The analysis presented here is based on the 2004 economic analysis of future without project condition, with an inventory of economic conditions conducted in 2000 and agricultural conditions and prices in 2003, and has been revised with current prices and application of the fiscal year 2011 discount rate. Agriculture prices and conditions were not updated for this revision to the analysis.

The methodologies employed in the economic assessment are in conformance with the Corps' Planning Guidance Notebook, ER 1105-2-100, dated 22 April 22 2000, as amended. This analysis incorporates risk and uncertainty as directed by ER 1105-2-101, Risk Analysis for Flood Damage Reduction Studies, dated 3 January 2006, and EM 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies, dated 1 August 1996. Uncertainty is inherent in all economic related input variables used in a typical flood damage analysis whether they may be ground elevations; first floor elevations determined by "windshield survey"; valuation of structures; generic depth-damage functions; content values based on content-to-structure value ratios; or assignment of occupancy type to structures for purposes of depth-damage calculations. Key hydrologic and hydraulic inputs such as frequency-discharge and stage-discharge relationships also possess their own elements of uncertainty. Attempts are made to address uncertainty by characterizing input variables in probabilistic terms rather than deterministic terms. Input data will typically be expressed as mean or median values with ranges determined by associated measures of variability.

Damages were evaluated with uncertainty in each hydrologic, hydraulic and economic variable using HEC-FDA, certified version 1.2.4. The flood depth inputs for the damage assessment for Reaches 1 through 7 are provided from the Flo-2D hydraulic model. Because there are levee sections in these lower reaches, flooding can occur when levees are overtopped or from failures below the top of levee. In the upstream reaches 8-10, modeled floods occur as water surface elevations exceed the top of the channel inundating the surrounding structures. HEC-RAS modeling was used to determine flood depths for reaches 8-10.

A separate @RISK model was used throughout the basin to estimate structure damages using the hydraulic data provided. Damages were estimated for each flood event based on depth of flooding at each structure. Those damages for each event were then linked to stage based on the corresponding frequency. Then, stage-damage curves for each reach and for each damage category were entered into HEC-FDA. The @RISK model has not been certified nationally or for the project. As such, subsequent updates will employ currently certified models or will pursue model certification for @RISK.

Hydrology and hydraulics are not expected to significantly change for the Skagit River under future conditions. It was assumed that the existing and future flood plains would be the same. Future growth was considered but not included in the calculation of future damages. Skagit County's population was 102,979 (Census 2000), and the Washington State Office of Financial Management estimates the County's population to reach 218,000 by 2060, or an annual growth rate of 1.85%. Projected development in the existing flood plain would require flood proofing or construction above the base flood elevation for the 100-year event. Based on Corps guidance, losses for flood damage to future development within the 100-yr flood plain cannot be considered in the benefit computations. With this restriction, it was assumed that all future development would occur outside 100-yr flood plain or above the 100 water surface elevation. The remaining 200-yr and 500-yr event future development damages would have little impact on the future without project expected annual damages and were not estimated. For this study, it was assumed that the future without project damages would not be significantly different from the existing conditions.

Without Project Conditions

For the purposes of the economic study, the river was divided into two sections, downstream study reaches and upstream study reaches. The two sections were divided for several reasons. In the early stages of the study, the upstream project study limit was near Sedro Woolley. Prior to 2003, only the downstream reaches 1-7 were included. Operational changes to the Baker Dams were considered by Puget Sound Energy during their FERC relicensing efforts, and the upstream reaches 8-10 were added in 2003 to address potential flood damage reduction benefits from additional flood control storage. Data for these additional reaches were gathered in 2003. Another reason for the division was because different hydraulic models were used for each section. Flo2D was used for the downstream reaches to address the 2-dimensional nature of the flood plains where flooding due to levee failures is not adequately described by in-channel water surface elevations. HEC-RAS was used for the upstream reaches, where levee failure was not the contributing factor to inundation and where more conventional in-channel elevations could be used to determine flood depths. The downstream and upstream economic study reaches are shown in **Plates 10 and 11**.

The following damage categories were considered in the economic evaluation of existing and future without-project damages:

- Residential Inundation Damages to Structures and Contents
- Residential Clean-up Costs
- Emergency Costs
- Nonresidential Inundation Damages to Structures and Contents
- Nonresidential Clean-up Costs
- Traffic Delays
- Road Damages
- Sedro Woolley Wastewater Treatment Plant Damages
- Agricultural Damages

Some of the methods used to estimate damages are described below. Otherwise, methods used and the results of the analysis can be found in the economic appendix.

1.1.1.1 Land Use and Structure Value

Land use was inventoried for the area likely to be inundated by the 500-year flood event. A complete field survey of all commercial and industrial structures in the flood plain was undertaken in 2000. Data collected included structure use, type of construction, structure size, condition, and first floor elevation. A random sample of residential structures was performed in the field for the stratification of residential building class and quality. Characteristics inventoried included construction types, classes, and average first floor foundation adjustment factors.

Marshall & Swift Residential and Commercial Estimators were used to determine depreciated replacement values of structures. Structure data collected in the field including structure quality, condition, occupancy, construction type, and size were input into Marshall & Swift to determine structure values and a depreciation factor was applied to determine the depreciated replacement values. First-floor elevation error and standard deviation for risk-based analyses are based on Table 6-5 of EM 1110-2-1619. Risk-based errors and standard deviations for residential depreciated replacement values are based on a triangular distribution, with the upper and lower limits set at Marshall & Swift's quality of construction grades at one grade above and one grade below, as discussed in Chapter 6-2 of EM 1110-2-1619.

1.1.1.2 Content Value

The risk-based content damage valuation and variation for each residential structure is based on the Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements, dated10 October 2003. As specified by the EGM, damage to content is a direct function of structure value, which no longer requires the specific determination of content value. Residential content values were estimated for comparison purposes only to determine the total value of property at risk as 50% of the structure value. Non-residential content values were developed using content-to-structure value ratios by occupancy type from the Lake Pontchartrain Hurricane Protection Plan Report of CH2M Hill, Inc., prepared for the New Orleans District, U.S. Army Corps of Engineers. These non-residential content values were determined to be representative of the Skagit area due the similarity of land uses, comparable ranges of flood depths and durations, and were reviewed and approved for use in other Seattle District studies such as the Centralia Flood Damage Reduction Project, Chehalis River, Washington.

1.1.1.3 Farm Budget and Crop Data

Agricultural damages were derived using procedures outlined in the Planning Guidance Notebook and the Corps' Institute for Water Resources (IWR), IWR Report 87-R-10, National Economic Development Procedures Manual: Agricultural Flood Damage, dated October 1987. Agricultural crop acreages were calculated with the assistance of Skagit County in 2004. Spatial mapping of agriculture allowed for the overlaying of floodplains to identify flooded agricultural acreage. Table 1 displays the acreage of harvested crops for Skagit County based on the 2003 Census of Agriculture, U.S. Department of Agriculture, National Agricultural Statistical Survey, and Table 2 displays harvested acreages by reach and floodplain. Various crop budgets were obtained from the Cooperative Extension, Washington State University for northwest Washington (additional crop budgets for blueberries, raspberries and strawberries were obtained from the University of California Cooperative Extension, as these reports were not available in Washington). Historical crop yields and values for various flood plain crops were obtained from the U.S. Department of Agriculture, National Agricultural Statistics Service for Skagit County. Agricultural land restoration costs are based on previous Corps studies and farm budget reports. Monthly flood probabilities were derived by the Corps based on the percentage of historical annual peak discharges occurring in each month.

Table 1 – Skagit County Crop Harvest, 2003

Crop	Acres[4]	Percentage
Wheat, Winter	4,400	10%
Corn for Silage	7,200	16%
Potatoes	13,000	29%
Hay	11,500	25%
Blueberries	710	2%
Raspberries	1,400	3%
Strawberries	580	1%
Green Peas – Process	3,410	7%
Cucumbers	3,000	7%
Total	45,200	100%

Sources: USDA- Washington Agricultural Statistics Service, Washington State University Commercial Agricultural Statistics-Skagit County Cooperative Extension

Agricultural acreage for the study is treated as having a composite crop based on the above nine crops. Agricultural production acreage and locations were ascertained through the use of an overlay of floodplain boundaries on the County's GIS mapping of agricultural production acreage. Based on the agricultural acres inundated in the study area and the percentage of agricultural land harvested, a total of 48,804 acres are subject to losses in the 500-year flood plain. GIS land use was compared to the extent of the damage reach boundaries to determine the number of acres harvested in each reach within the 500-year flood plain. The acreage of the small events was determined based on the number of grids inundated from each event. Total harvested acreage, by floodplain and damage reach, for 2003 is listed in Table 2.

Table 2 – Floodplain Agricultural Acreage, 2003

Event	Harvested Acres By Reach										
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9	Reach 10	Total
5-yr[5]	0	0	0	0	0	0	0	0	0	0	0
10-yr	5,218	5,053	0	0	0	3,813	108	580	1,470	697	16,939
25-yr	10,940	6,298	0	3,362	0	4,351	175	694	1,739	841	28,400
50-yr	17,338	7,235	0	3,624	0	4,476	185	805	2,068	1,009	36,740
75-yr	19,594	7,432	1,583	3,810	0	4,512	185	855	2,250	1,097	41,318
100-yr	20,566	7,639	1,691	3,881	0	4,551	185	910	2,380	1,158	42,961
250-yr	21,543	9,199	1,700	3,952	0	4,621	200	1,102	2,823	1,360	46,500
500-yr	21,820	9,510	1,700	4,390	410	4,660	210	1,289	3,267	1,548	48,804

1.1.1.4 Depth Damage Curves

As noted above, single-family residential structural and content damages are based upon the risk-based guidance of EGM 01-03. For non single-family residences, the structural and content inundation damage curves employed are the Federal Emergency Management Agency (FEMA) National Flood Insurance Program's flood insurance rate review depth percent damage curves of 1998 for non-velocity zones. All of the depth-damage curves used in this study can be found in the Economic Technical Appendix to the feasibility report. Agricultural crop losses (damage to the potential harvest due to flooding) have been assumed to be 100% based on conversations with County Agricultural Advisors for reasons of actual loss of crops and the non-marketability of potentially surviving crops, except where noted in the analysis. Therefore agricultural flood damages were based on this 100% loss minus any variable costs not expended.

1.1.1.5 Residential Inventory

In the study area's floodplain there were 12,544 residential units counted from base maps prepared by the Corps in 2000. Marshall & Swift was used to determine the aggregate nominal depreciated structural value of approximately $1.8 billion that yielded an average residential unit cost of $140,500. The average residential structure is approximately 1,600 square feet in size, which yields a depreciated square foot cost of approximately $87, based on a sampling of residential structures in the flood plain. The total nominal content value of these structures is estimated at $881 million, or $70,250 per structure. All values have been updated to the 1 October 2011 price level. Residential structure and content values by reach are shown below in Table 5-6. Content values were set at 50% of structure value for estimation of total value of property at risk.

Table 5-6 - Residential Structure & Content Values

Location	Structures	Structure Value ($1,000)	Content Value ($1,000)
Reach 1 – Burlington	4,790	668,991	334,496
Reach 2 – W. Mount Vernon	2,007	280,306	140,152
Reach 3 – Fir Island	197	27,514	13,757
Reach 4 - Mount Vernon	2,750	384,076	192,039
Reach 5 – Big Bend	88	12,291	6,145
Reach 6 – Nookachamps	465	64,943	32,472
Reach 7 – La Conner	343	47,905	23,952
Reach 8 - Sedro Woolley	1,233	199,921	99,960
Reach 9 – Lyman	175	30,562	15,280
Reach 10 – Hamilton	496	45,899	22,950
Total	12,544	1,762,409	881,203
This economic inventory was completed in 2000. All dollar values are expressed at the 1 October 2010 price level.			

1.1.1.6 Nonresidential Inventory

Within the study area there were 1,639 non-residential (agricultural, commercial, public, and industrial) properties in 2000, with a total floor space of 11,210,860 square feet. The total nominal depreciated structure value of these properties is $831 million with a total content value of $856 million. The average cost per square foot of these structures is $74. Overall content-to-structure value ratio for these structures is 103%. All values have been updated to the 1 October 2011 price level. Non-residential structure and content values by location are shown in Table 5-7.

Table 5-7 - Nonresidential Structure & Content Values

	Number	Structure Value (in $1,000's)	Content Value (in $1,000's)	Sq. Footage
Reach 1	357	354,864	378,496	4,244,800
Reach 2	81	41,819	37,475	495,260
Reach 3	420	8,621	6,366	351,300
Reach 4	482	312,972	326,239	4,370,200
Reach 5*	29	19,925	18,984	323,880
Reach 6	24	8,596	8,575	103,830
Reach 7	133	59,511	59,724	859,190
Reach 8	60	19,620	15,312	291,000
Reach 9	28	2,102	1,592	94,600
Reach 10	25	3,400	2,909	76,800
Total	1,639	831,430	855,671	11,210,860
This economic inventory was completed in 2000. All dollar values are expressed at the 1 October 2010 price level.				

1.1.1.7 Flood Damage Model

For this Skagit River study, expected annual damages were estimated using the Corps risk-based Monte Carlo simulation program called HEC-FDA. The HEC-FDA program integrates hydrology, hydraulics, geo-technical and economic relationships to determine damages, flooding risk and project performance. Uncertainty is incorporated for each relationship, and the model samples from a distribution for each observation to estimate damage and flood risk. The Skagit River model includes the following relationships for each damage reach:

- Probability-Discharge (with uncertainty determined by period of record)
- Inflow-Regulated Outflow (uncertainty in outflow based on a triangular distribution with a minimum and maximum value provided)
- Stage-Discharge (stage in the channel with estimated error in feet)
- Stage-Damage (for each damage category, with mean and standard deviation using a normal distribution)
- Levee Failure Probability (based on two points Probable Non-Failure (PNP) and Probable Failure Points (PFP)

Economic damage inputs to the HEC-FDA model were initially analyzed by category and by reach using Excel with @RISK at each flood plain mapping determination (10-, 25-, 50-, 75-, 100-, 250- and 500-year) to develop an overall "stage-damage" function by category and by reach with error for the HEC-FDA model. More detail about the procedures for estimating flood damages using @Risk, along with the results and the corresponding frequency damage functions, are described in the economic technical appendix to the feasibility report.

The category with the greatest expected annual damages was damage to structures and contents. Tables 5-8 and 5-9 show damages at the 1 October 2010 price level by event for residential and non residential structures and contents.

Table 5-8 - Total Residential Inundation Damages by Event

Flood Event	Structures	Structure Damage (in $1,000's)	Content Damage (in $1,000's)	Total Damage (in $1,000's)
10-year	2,091	63,173	35,844	99,017
25-year	5,839	218,103	122,108	340,210
50-year	7,635	322,699	178,806	501,505
75-year	8,495	390,794	215,152	605,946
100-year	9,345	467,272	255,897	723,168
250-year	10,812	653,354	353,063	1,006,417
500-year	11,841	862,389	460,250	1,322,639
The economic inventory was completed in 2000. All dollar values are expressed at the 1 October 2010 price level.				

Table 5-9 - Total Nonresidential Inundation Damages by Event (in $1,000's)

Flood Event	Inundated Structures	Structure Damage	Content Damage	Total
10-year	239	61,201	51,500	112,702
25-year	682	136,013	130,898	266,911
50-year	840	169,792	171,592	341,384
75-year	997	185,696	193,779	379,474
100-year	1,032	205,056	218,099	423,155
250-year	1,149	246,331	273,298	519,629
500-year	1,274	306,795	356,577	663,373
The economic inventory was completed in 2000. All dollar values are expressed at the 1 October 2010 price level.				

1.1.1.8 HEC-FDA Model Results

Residential, non-residential, and agricultural damages with uncertainty by event frequency were correlated to stage and entered into the HEC-FDA model by reach. Losses to the WWTP, traffic delays and road damages were also linked to stage and entered into the model. The HEC-FDA model processed this data through its random flood generation routine for the derivation of expected annual damages and project performance levels. The overall results of this modeling are presented in Table 5-10. Expected annual damage from the model is estimated to be $100.9 million, based on the 1 October 2010 price level.

Table 5-10 - HEC-FDA Expected Annual Damages by Reach

Expected Annual Damage for the Without Project Condition[1]
(Damage in $1,000's)
(Analysis is based upon 4.125% discount rate, 1 Oct 2010 price level, and a 50-year period of analysis)

	Damage Categories										Total
	Residential			Public Assist-ance	TRA	Non-Residential			Agricult-ural Damages	Traffic Delays	
	Structure	Content	Cleanup			Structure	Content	Cleanup			
Reach 1	14,387	7,961	2,422	2,207	639	11,196	11,483	1,549	881	1,067	53,793
Reach 2	4,624	2,541	694	632	184	132	112	22	1619	0	10,559
Reach 3	73	42	16	15	4	17	13	2	32	0	213
Reach 4	6,623	3,627	929	847	245	4,012	4,495	1,022	132	0	21,931
Reach 5	128	69	15	14	4	178	197	38	1	0	644
Reach 6	3,007	1,648	418	381	110	191	215	34	536	0	6,541
Reach 7	917	528	230	210	61	825	694	170	11	0	3,646
Reach 8[2]	132	236	60	54	16	48	14	6	5	6	577
Reach 9	447	252	61	50	15	45	40	0	9	28	946
Reach 10	782	371	133	184	54	67	56	5	56	0	1,706
Road Damages											352
TOTAL	**31,120**	**17,275**	**4,978**	**4,592**	**1,331**	**16,713**	**17,318**	**2,848**	**3,281**	**1,101**	**100,908,000**

1 – Results presented in this table are based on the 2004 economic analysis, with updates to prices to the 1 October 2010 price level, and use of the current discount rate of 4-1/8%. The damages in this table reflect the 2000 economic conditions, and 2003 agricultural conditions and prices.2 --[*]For the Sedro Woolley Waste Water Treatment Plant, all damages (to include structure/content/processing functions) are listed in Reach 8 as non-residential structure damage.

HEC-FDA computed damages by integrating discharge-probability, stage-discharge, stage-damage and levee failure relationships with uncertainty. For many reaches, levee failure in the form of probable failure and probable non-failure points (PFP and PNP) in the model affects the non-damaging frequency. The Monte-Carlo simulation ran up to 500,000 iterations creating a range of expected values based on the hydrologic, hydraulic, geo-technical and economic relationships. The model aggregated these relationships creating a distribution of expected annual damages with the mean values by reach and category displayed in Table 5-10.

The results of economic modeling of flood damages show that under the without project condition, flooding is expected to present a serious and frequently occurring problem for the Skagit River basin. Some highlights identified through the current analysis include:

- Identification of over 14,200 structures that are at risk of flooding with a total property value (structure and content) of over $4.3 billion;
- Estimation of potential total losses from a single flood event as great as $2 billion;
- Estimation of expected annual damages to property and associated losses of over $96.5 million, with direct residential damages accounting for nearly 55% of the losses; and
- Estimation of $100.9 million in total annual damages associated with structures and contents, agriculture, traffic delay costs, and road damages/repairs (NOTE: all values are presented at the 1 October 2010 price level).

The high levels of damages in the study area are a function of the large aerial extent of the developed floodplain and the frequency of expected flooding. Both the high expected annual damages and high probability of flooding indicate that the without project flood risk should be reduced. Without action, Skagit River flooding is expected to remain a frequently occurring problem with potentially devastating effects in the study area. This without project analysis will serve as a baseline for further alternative analysis during the next phase of study.