FERC 2150
Baker Hydroelectric Project, Washington State

Update on Flood Control Provisions, with Emphasis on License Article 107(c)

From the Perspective of the Local Communities

For
United States Federal Energy Commission, Office of Energy Projects
Division of Hydropower Administration and Compliance

Presented by
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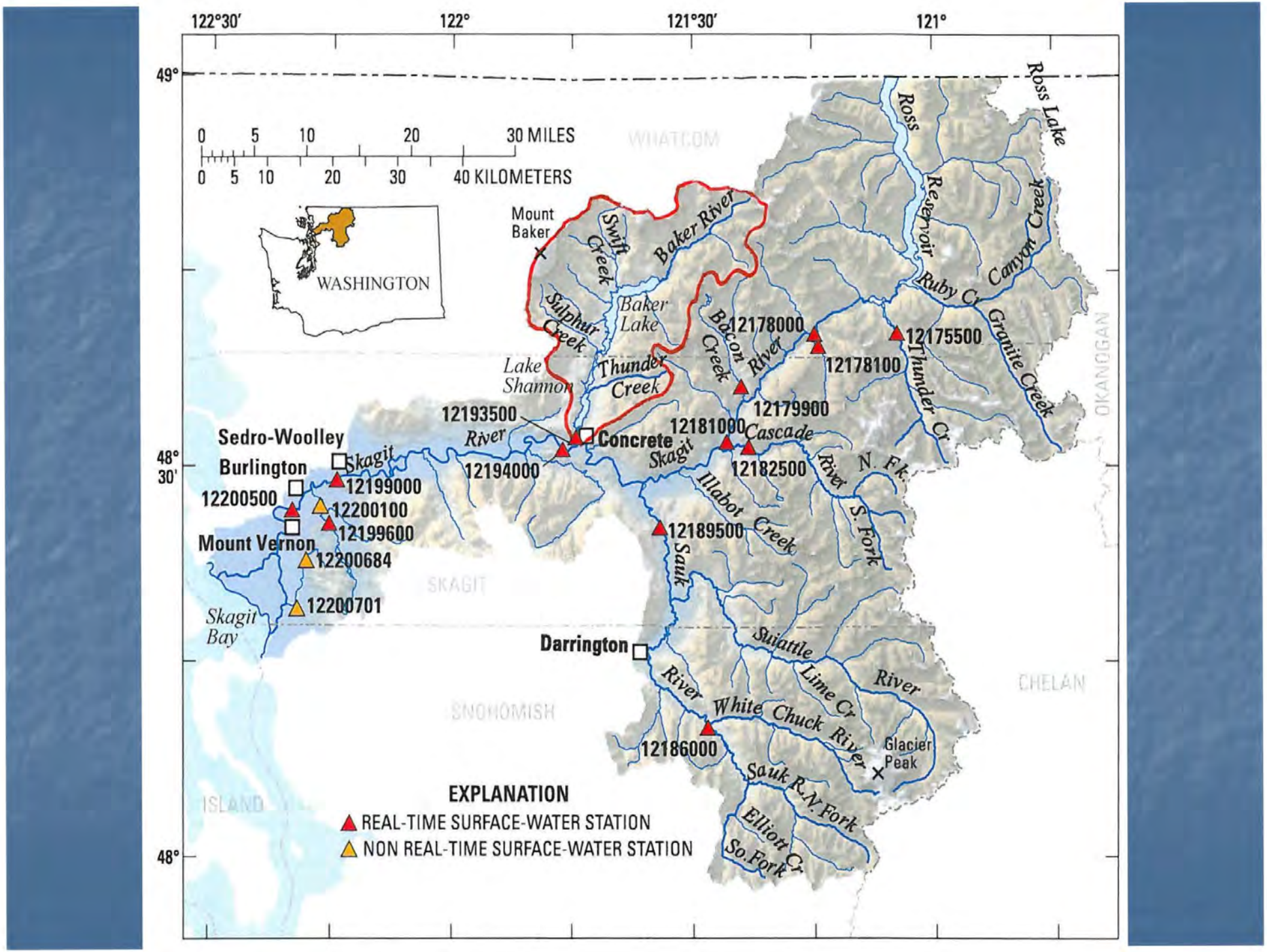
with
Skagit County; Cities of Mount Vernon, Sedro-Woolley, Burlington; Town of La Conner; Dike Districts 1, 12, and 17

Washington, D.C.
June 1, 2011

Overview

- Our interest
- Background: Skagit flood operations
- Significance of 107(c) reservoir drawdown in advance of a flood event
- Environmental concerns
- Potential path forward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Swift Creek
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Sulphur Creek
Baker Lake
Lake Shannon
Thunder Creek
Bacon Creek
Bacon River
Ross Lake
Ross Reservoir
Ruby Cr
Canyon Creek
Granite Creek
Thunder Cr
12178000
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Concrete
Cascade River
N. Fk. Skagit River
S. Fork Skagit River
Illabot Creek
12189500
Sedro-Woolley
Burlington
Mount Vernon
12199000
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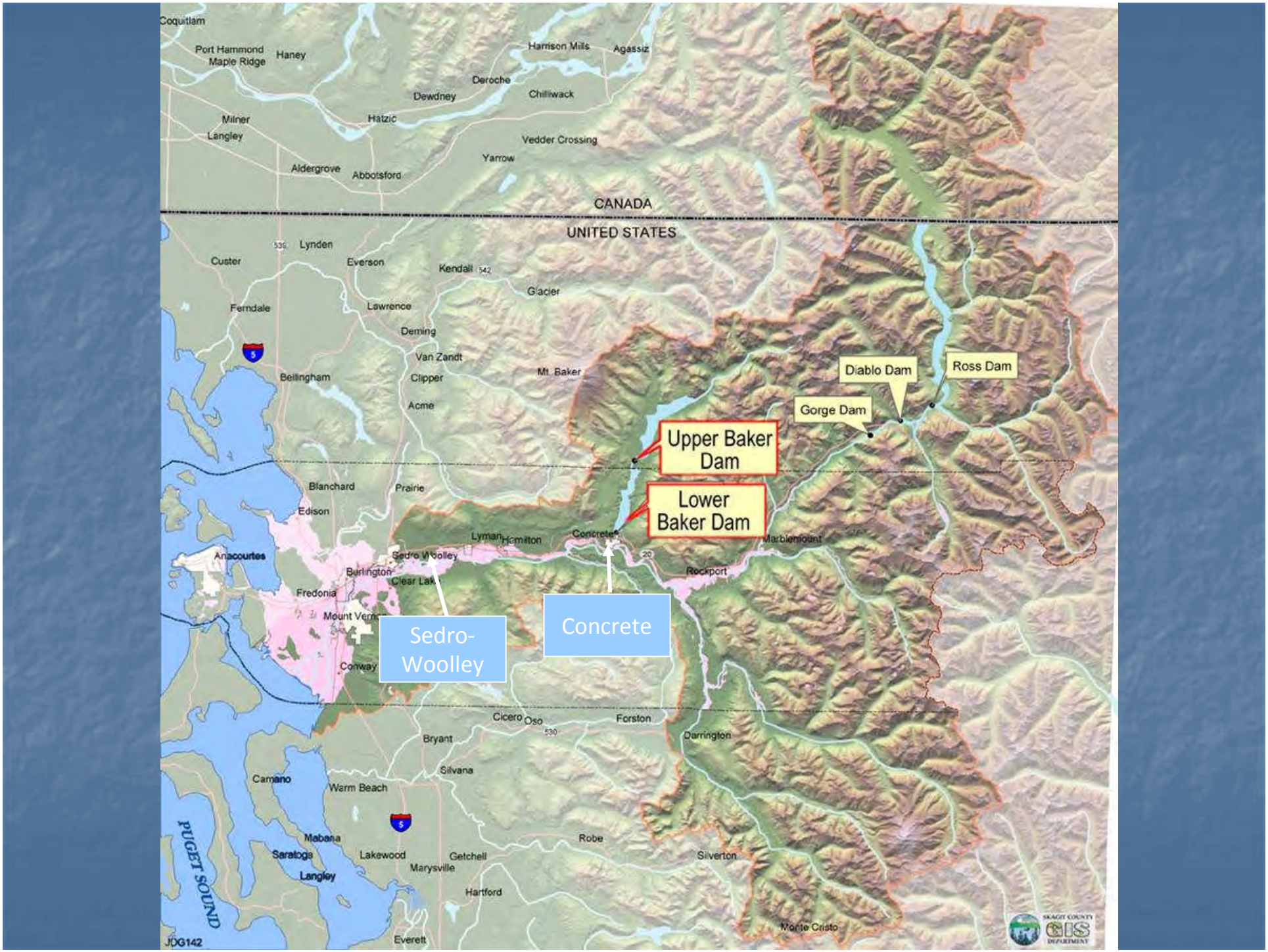
Skagit Bay
Darrington
Suiattle River
Lime Cr
White Chuck River
12186000
Glacier Peak
Sauk R. N. Fork
Elliott Cr
So. Fork
Sauk River
EXPLANATION
REAL-TIME SURFACE-WATER STATION
NON REAL-TIME SURFACE-WATER STATION


Coquitlam
Port Hammond
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Yarrow
Aldergrove
Abbotsford
CANADA
UNITED STATES
Lynden
Custer
Everson
Kendall
Glacier
Ferndale
Lawrence
Deming
Van Zandt
Bellingham
Clipper
Mt. Baker
Acme
Diablo Dam
Ross Dam
Gorge Dam
Upper Baker Dam
Lower Baker Dam
Blanchard
Prairie
Edison
Lyman
Hamilton
Concrete
Marblemount
Anacortes
Sedro Woolley
Burlington
Clear Lake
Rockport
Fredonia
Mount Vernon
Sedro-Woolley
Concrete
Conway
Cicero
Oso
Forston
Darrington
Bryant
Silvana
Camano
Warm Beach
Mabana
Saratoga
Lakewood
Getchell
Marysville
Robe
Silverton
Langley
Hartford
PUGET SOUND
Monte Cristo
Everett
JDG142

Why are we so interested?

- We know from experience: upstream flood storage in general, and Baker flood storage operation specifically, can result in significant peak flow reduction downstream
- During the relicensing negotiations, Skagit County's goal was for the Baker system to provide enough storage to capture its own 100-year flood event
- Adequate storage in the Baker system enables outflow to be reduced to zero near the Skagit flood peak, reducing Skagit water levels at least 1.5 feet
- Advance reservoir drawdown, prior to the Skagit hitting 58,000 cfs, keeps water out of a natural downstream basin, saving that storage for the Skagit flood peak and reducing downstream water level at least another 1.5 feet

Skagit Flood Operations:
Numbers

- Average Skagit flow ~ 17,000 cfs
  - Large Skagit flood flow > 200,000 cfs
  - Flood volume: A large Skagit flood generates > 1 million Acre-Feet above flood stage flow
  - Skagit Basin area ~ 3,100 mi^2
- Average Baker flow ~ 2,000 cfs
  - Large Baker flood flow > 40,000 cfs
  - Flood volume: A 100-year Skagit basin flood generates ~ 140,000 Acre-Feet
  - Baker Basin area ~ 297 mi^2

Skagit Flood Operations:
More Numbers

- ~ 60% of the Skagit basin is unregulated
  - Ross dam provides 120,000 AF
  - Upper Baker dam provides 74,000 AF
    - (Baker 100-year basin event generates 140,000 AF)
- The Baker basin (297 mi^2) can produce as much water as the Ross basin (999 mi^2)
- SIGNIFICANTLY: Ross, Upper Baker and Lower Baker often provide more than the minimum required storage

U.S. Engineer Office, 1937
Regarding Upper Baker Location, flood of 1917

100. Flood discharge records at the site are available for the floods of 1917 and 1921. Of these two, the 1917 flood was much the more severe, reaching a crest discharge of 36,800 second-feet, and having a three-day run-off of 125,700 acre-feet. . . . . This rate of discharge is so large, as compared with other streams of the Puget Sound area, as to suggest that the 1917 flood must have been nearly as large as any of recent years. It is assumed, therefore, that a storage of 120,000 acre-feet would adequately control any but the most severe floods on the Baker River. A dam about 280 feet high (foundation to walkway) would be required to create 120,000 acre-feet of storage.

22 Years Later

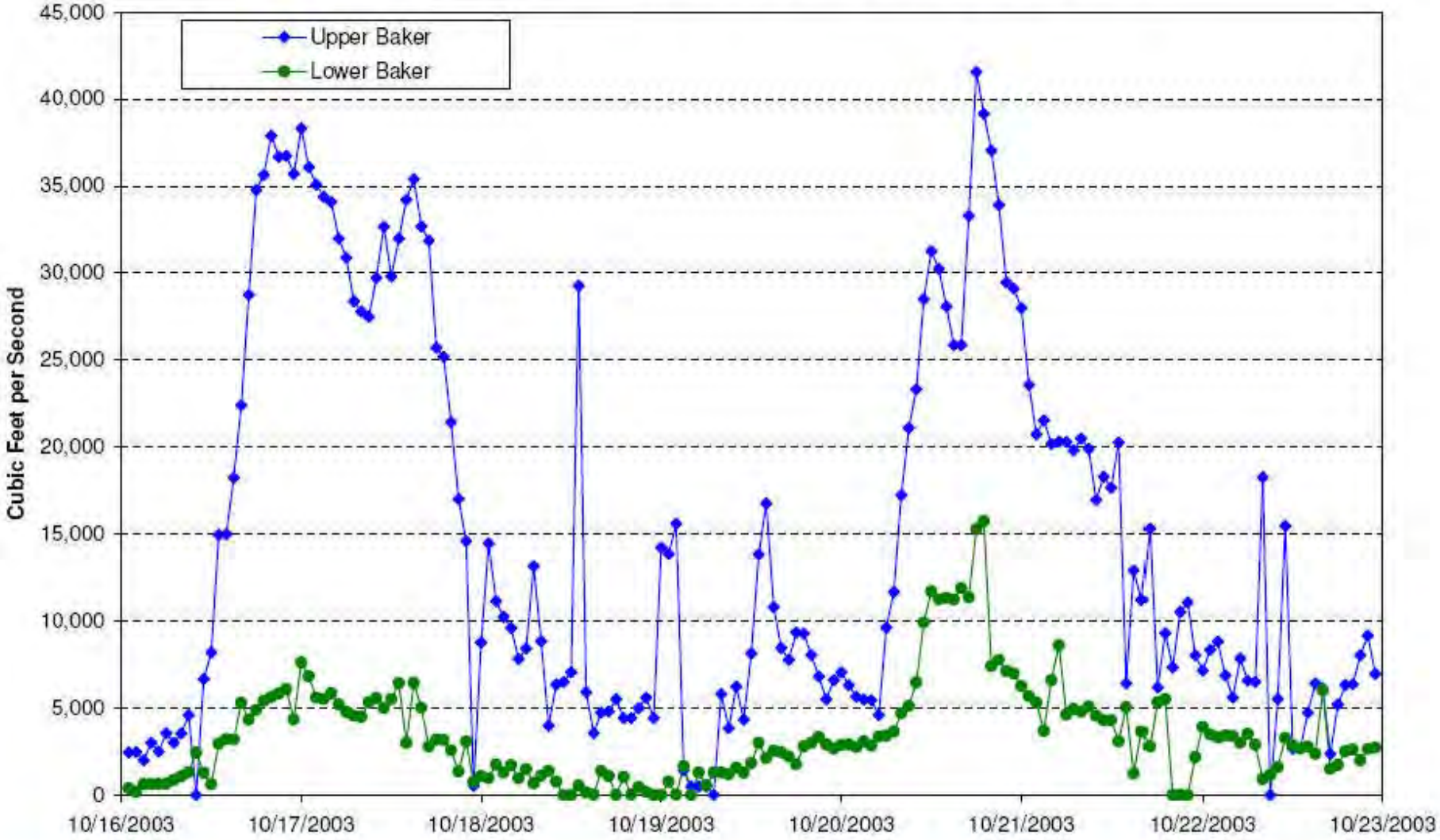
- Upper Baker Dam was completed and today provides 74,000 acre-feet of flood storage
- But this is not enough

2003 Skagit Flood of Record

- Baker inflow / storage / spill
- Ross inflow / storage / spill

October, 2003 Baker River Project Inflow

(Corps of Engineers, Hydrology and Hydraulics Report, August 2004)



Flood Control Reservoir Operations
Water Spilled or Used for Generation
Prior to Flood Peak at Concrete
October 2003 Flood

	Baker (297 mi²)	Ross (999 mi²)
Oct 16th-21st:		
Generation:	42,496 AF	(11,600
Spillway:	84,565 AF	Combined)
Total Outflow:	127,061 AF	11,600 AF

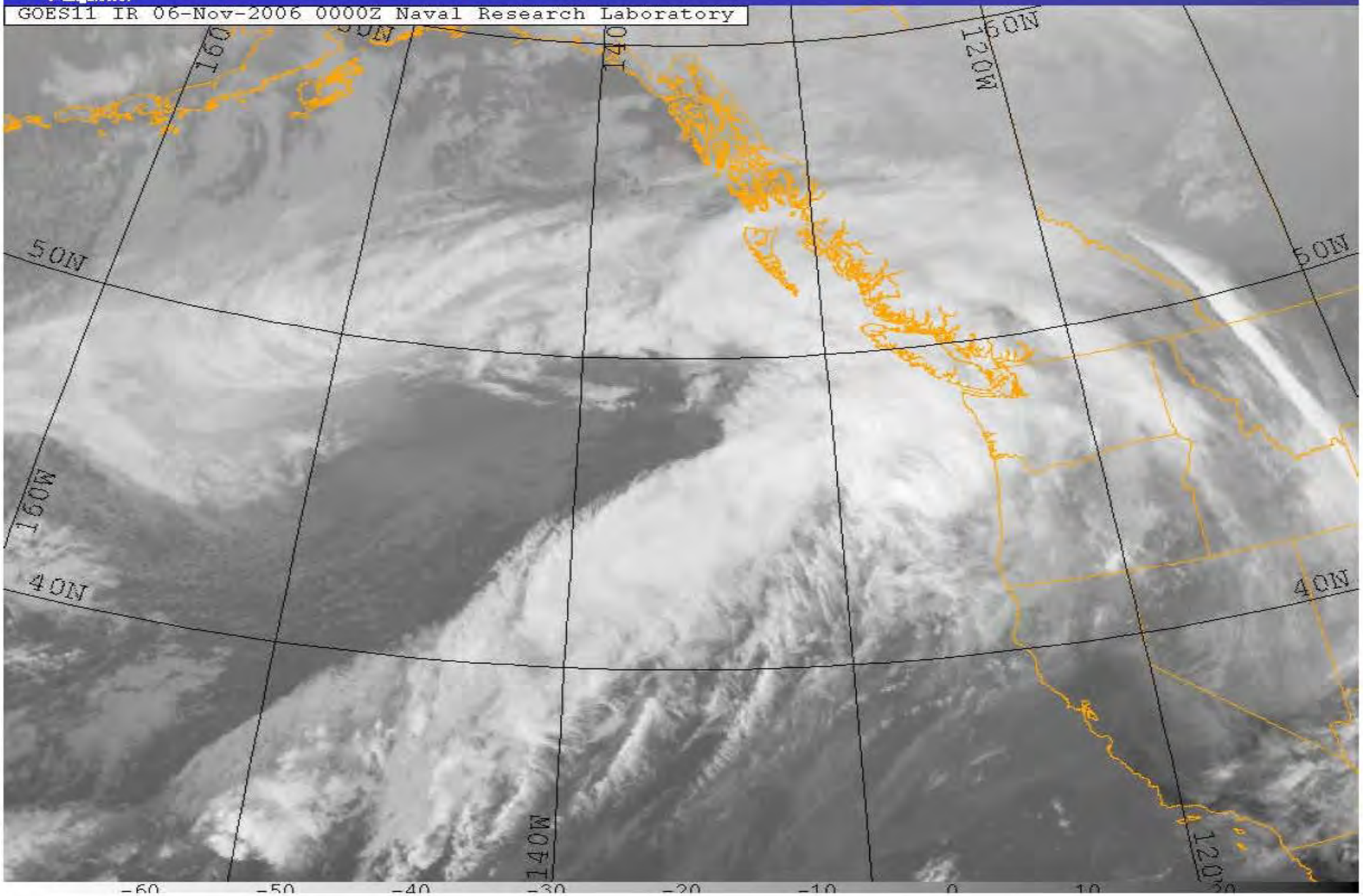
Oct 16th-21st:	Baker	Ross
Storage	103,013 AF	175,107 AF

Total storage/spill	Baker	Ross
	230,074 AF	186,707 AF

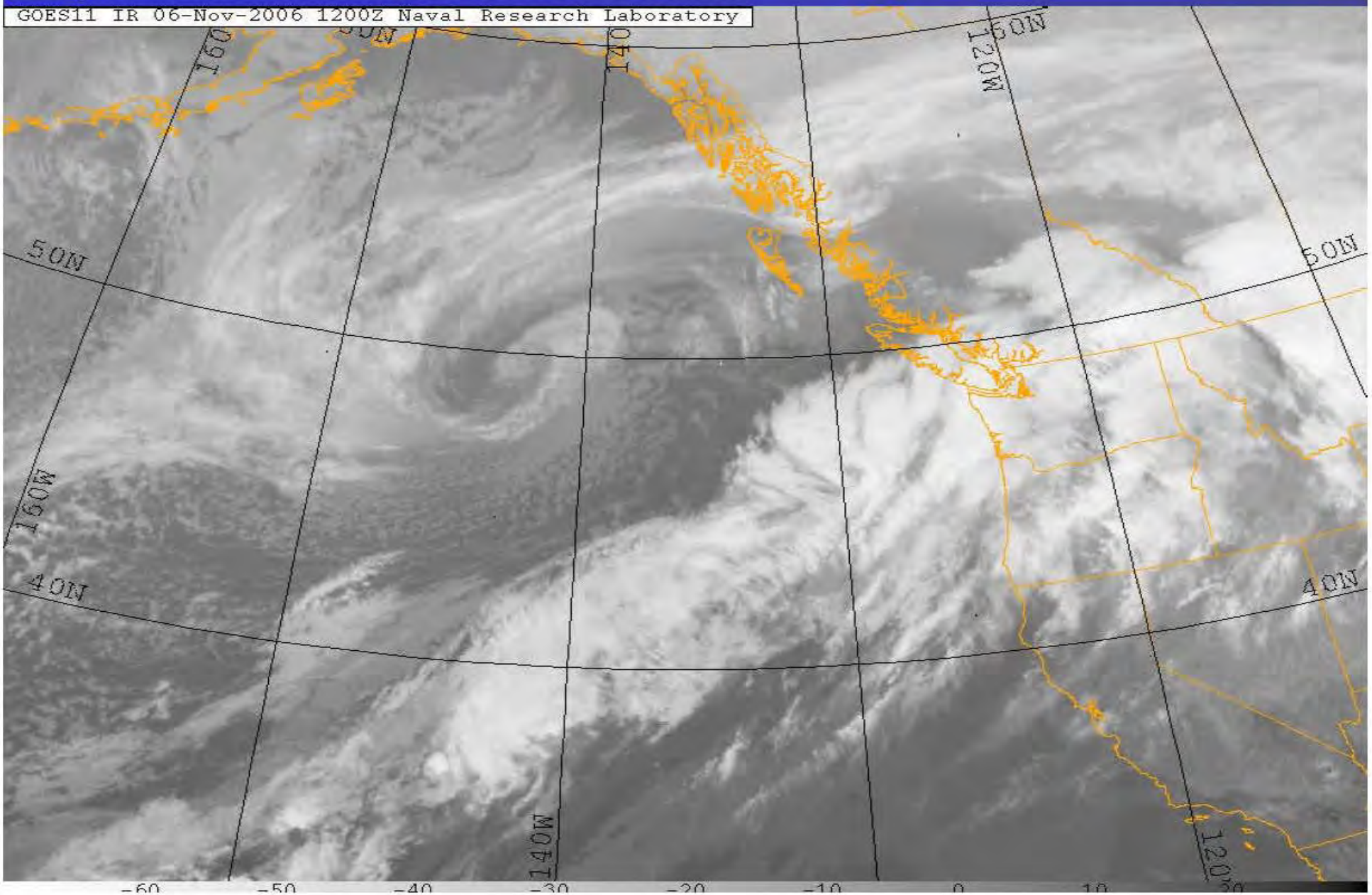
2006 Skagit Flood

- Concern at the time was that this flood was going to be a 500-year event
- Following slides are from a post-event Corps of Engineers briefing

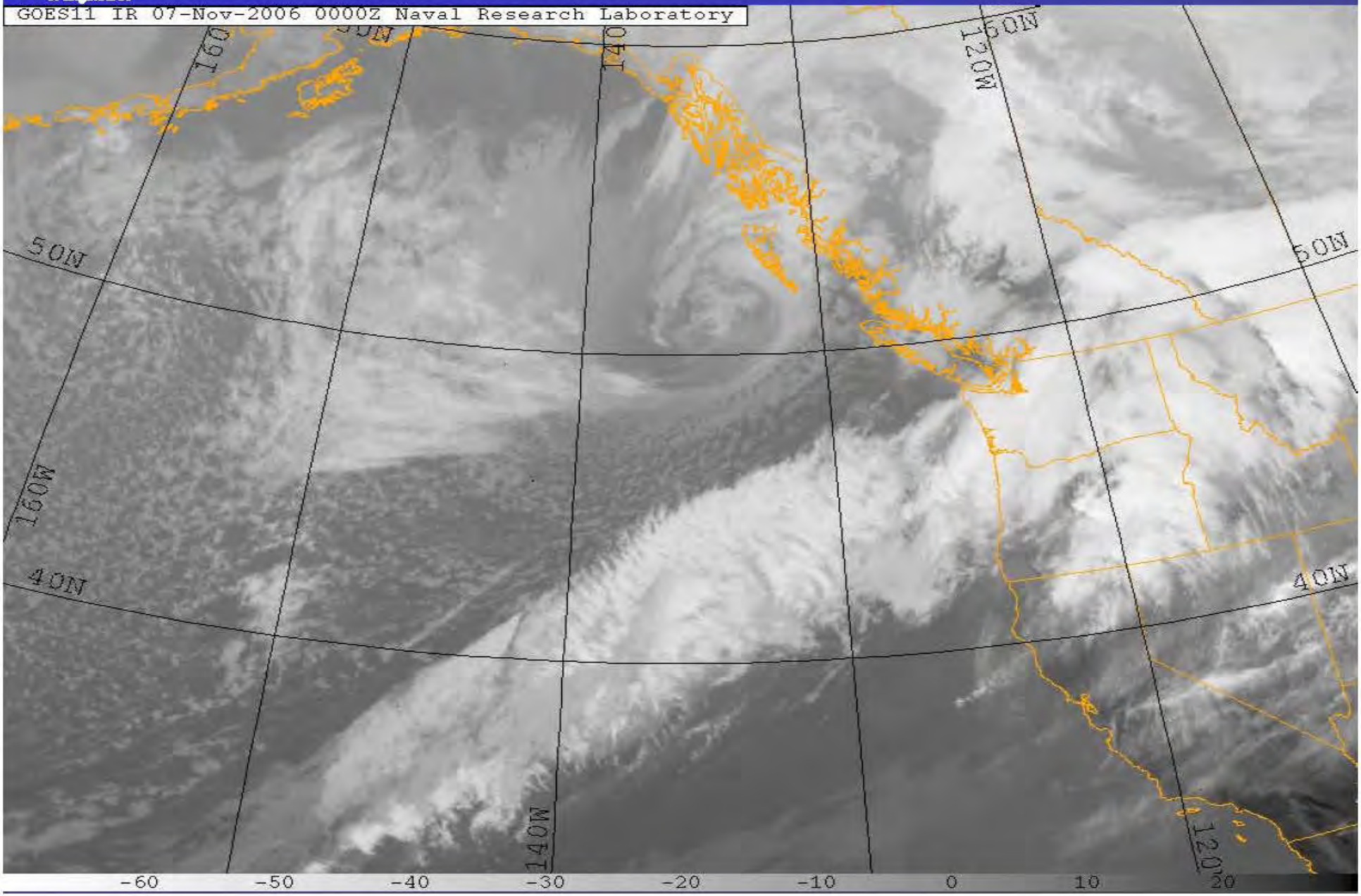
Storm Track 11/5/06 16:00



Storm Track 11/6/06 04:00



Storm Track 11/6/06 16:00



US Army Corps of Engineers

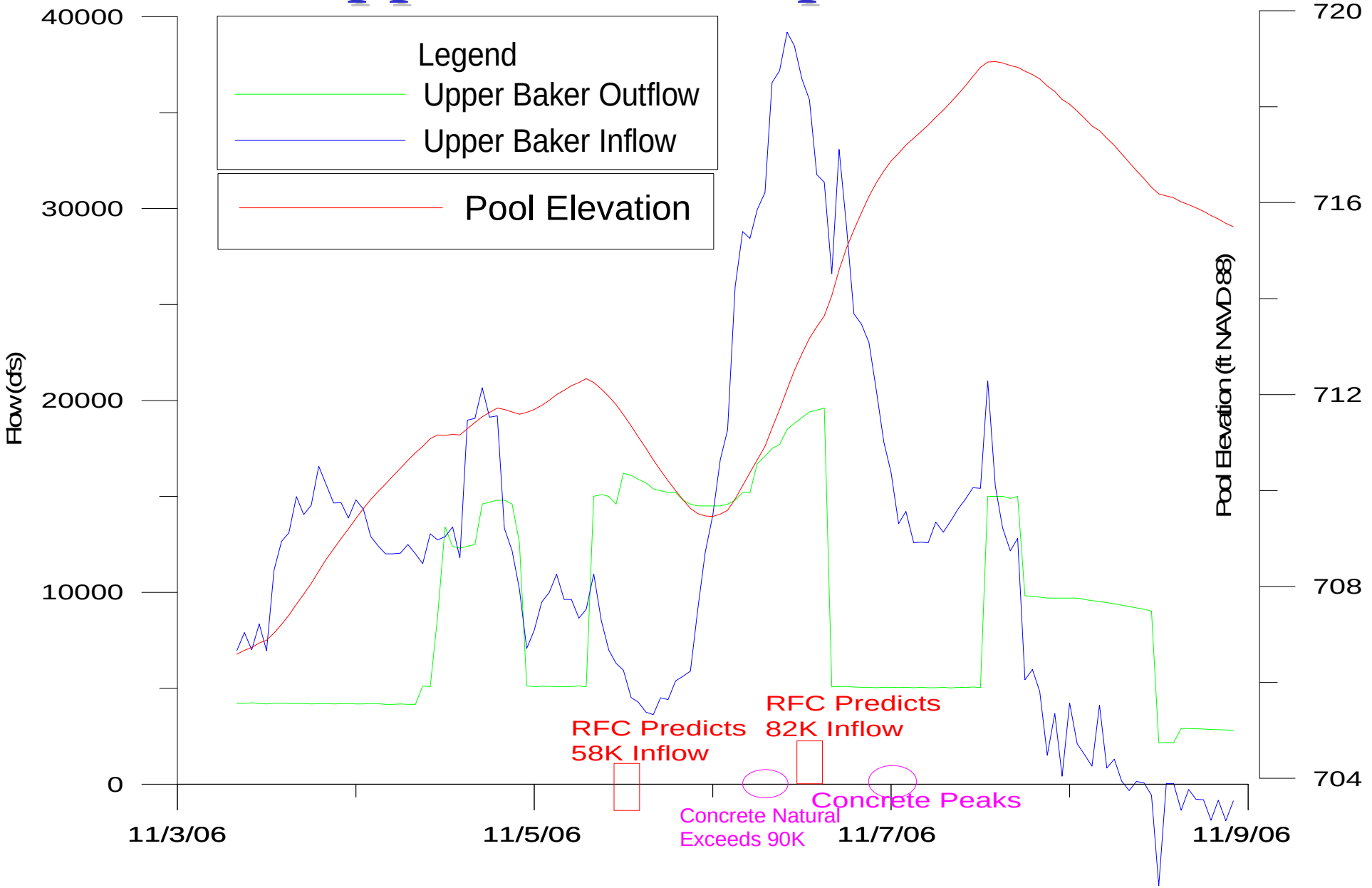
November 2006 Preceding Conditions

	Pool Elevation (ft)	Storage (acre-feet)
Upper Baker Requirement	722.0	27,900
Upper Baker Actual 11/3/06 08:00	706.59	93,711
Ross Requirement	1598.5	46,930
Ross Actual 11/3/06 08:00	1588.61	158,400

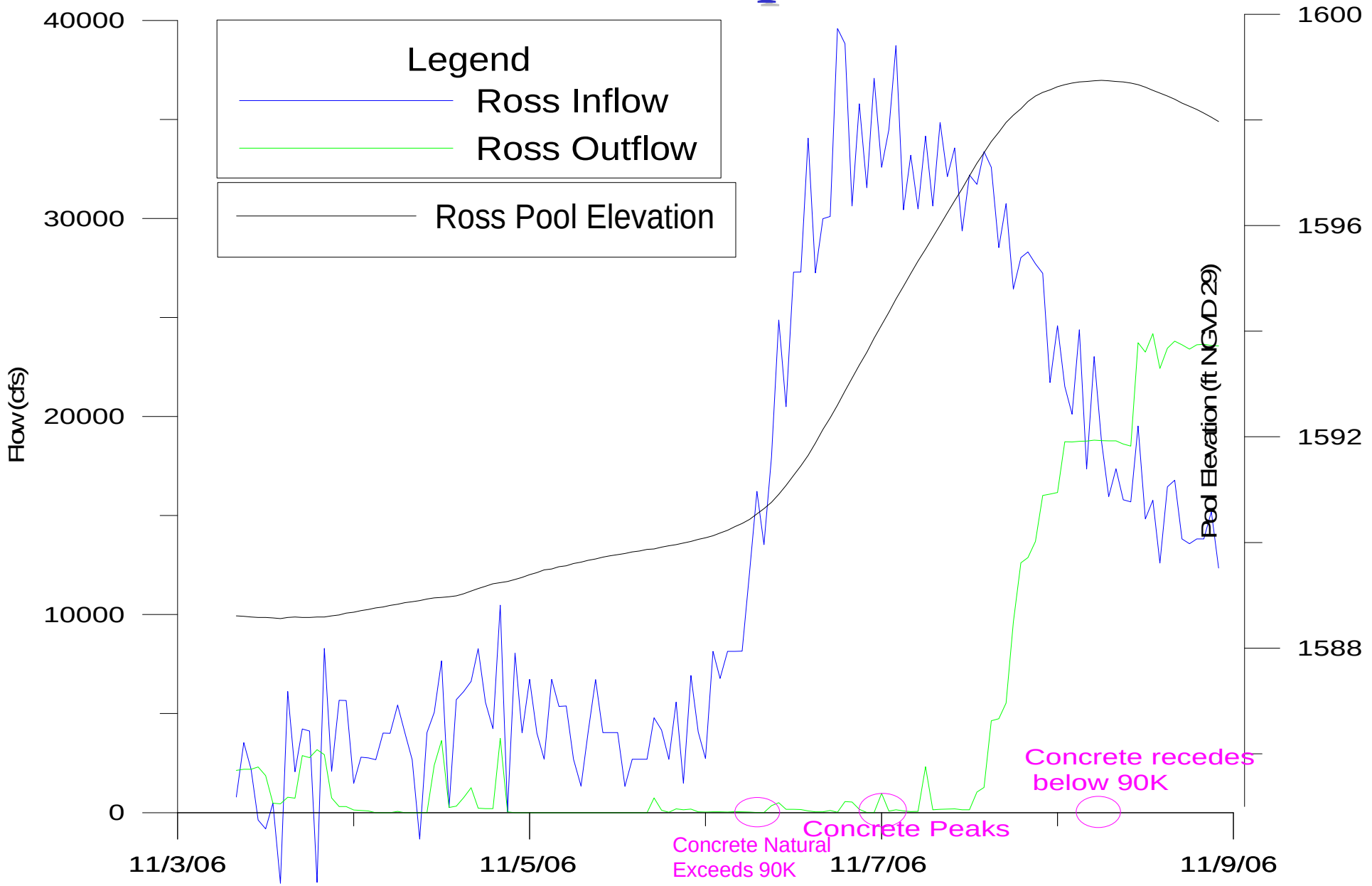
Editorial Note

The Corps typically does not include flood control impacts of Lower Baker Dam, because Lower Baker does not have federally-authorized flood storage. However, Lower Baker can be operated effectively for flood control and will gain additional flood control capability when the new turbine is installed.

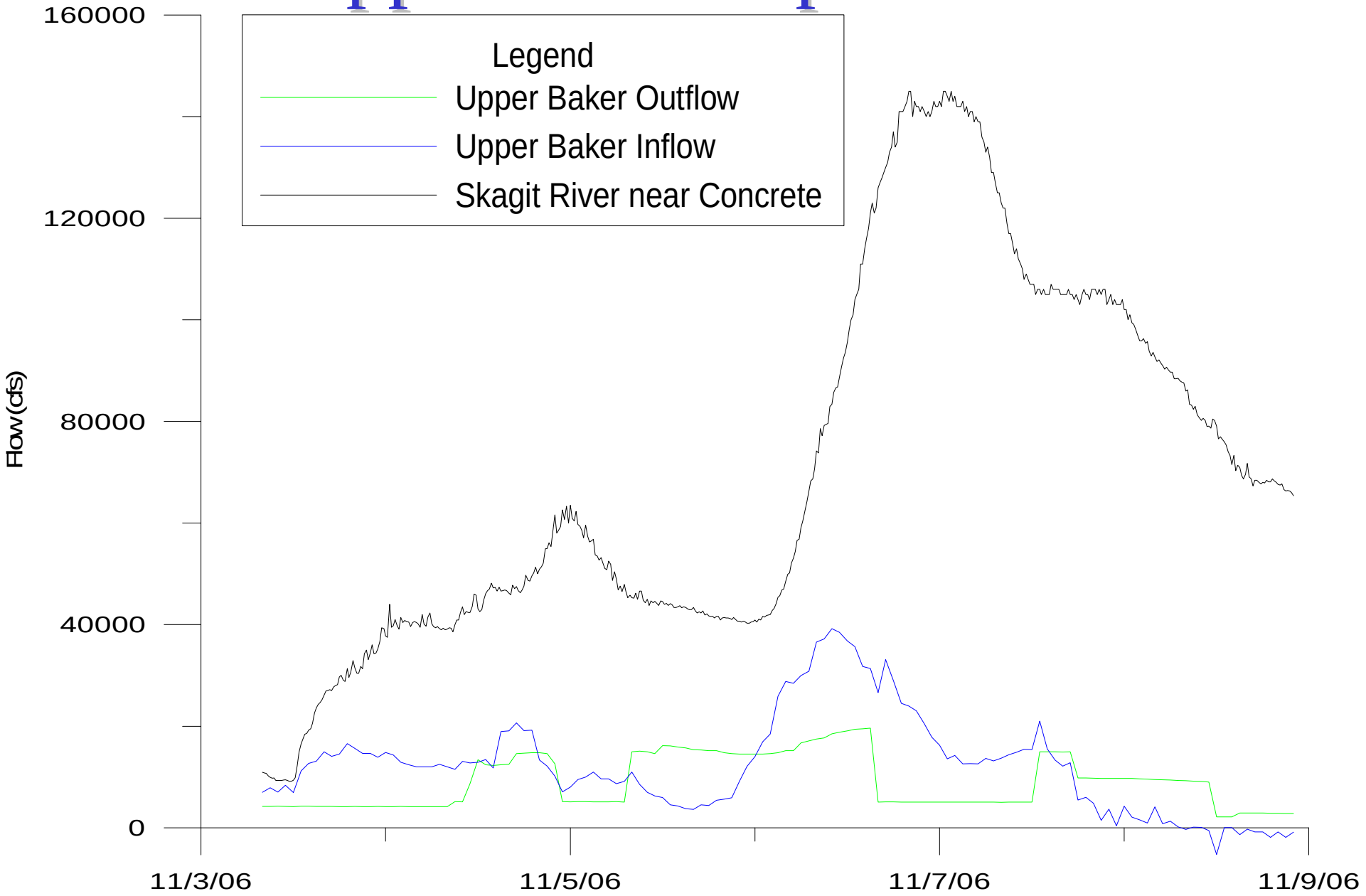
Upper Baker Operation



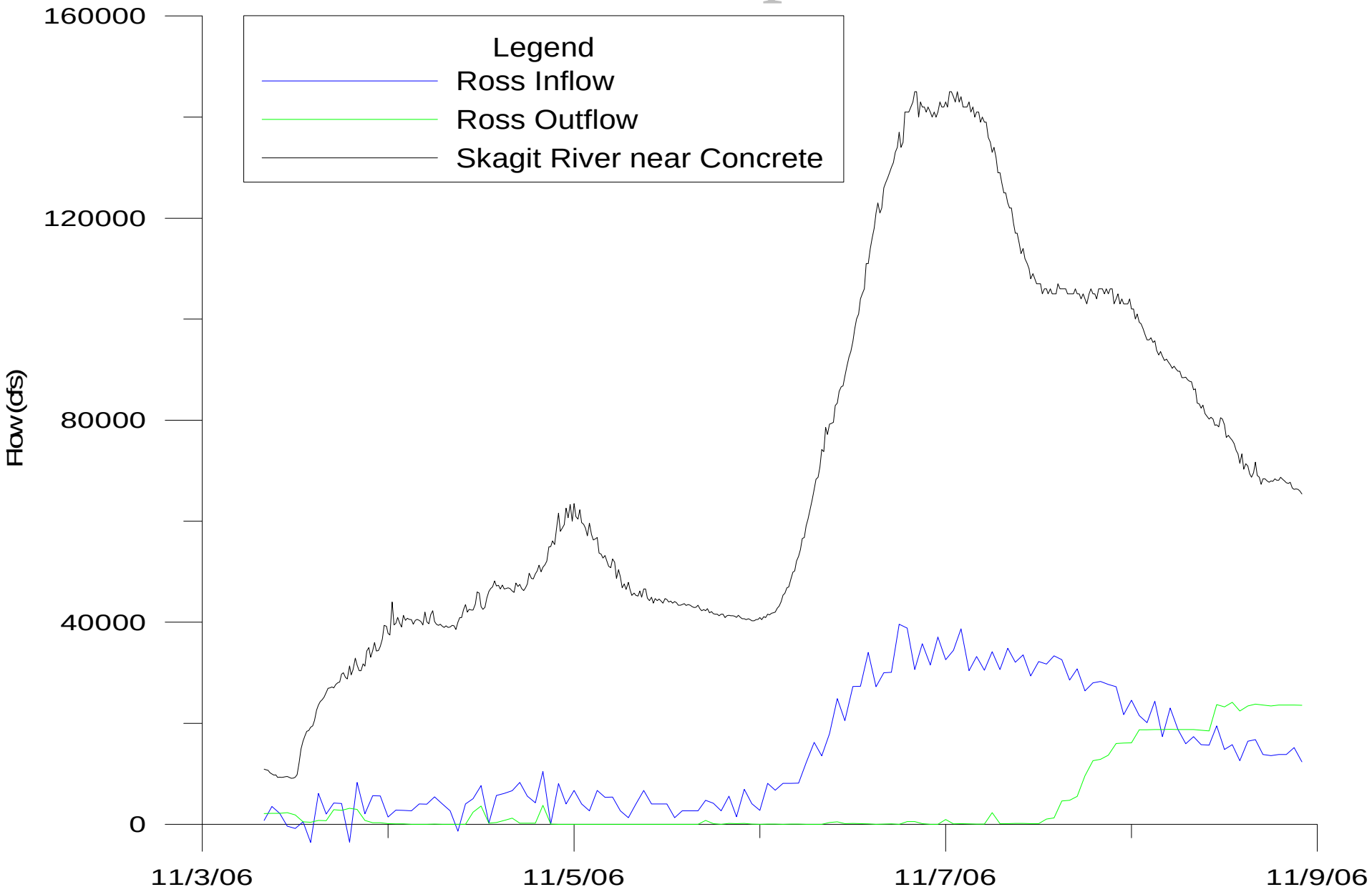
Ross Dam Operation



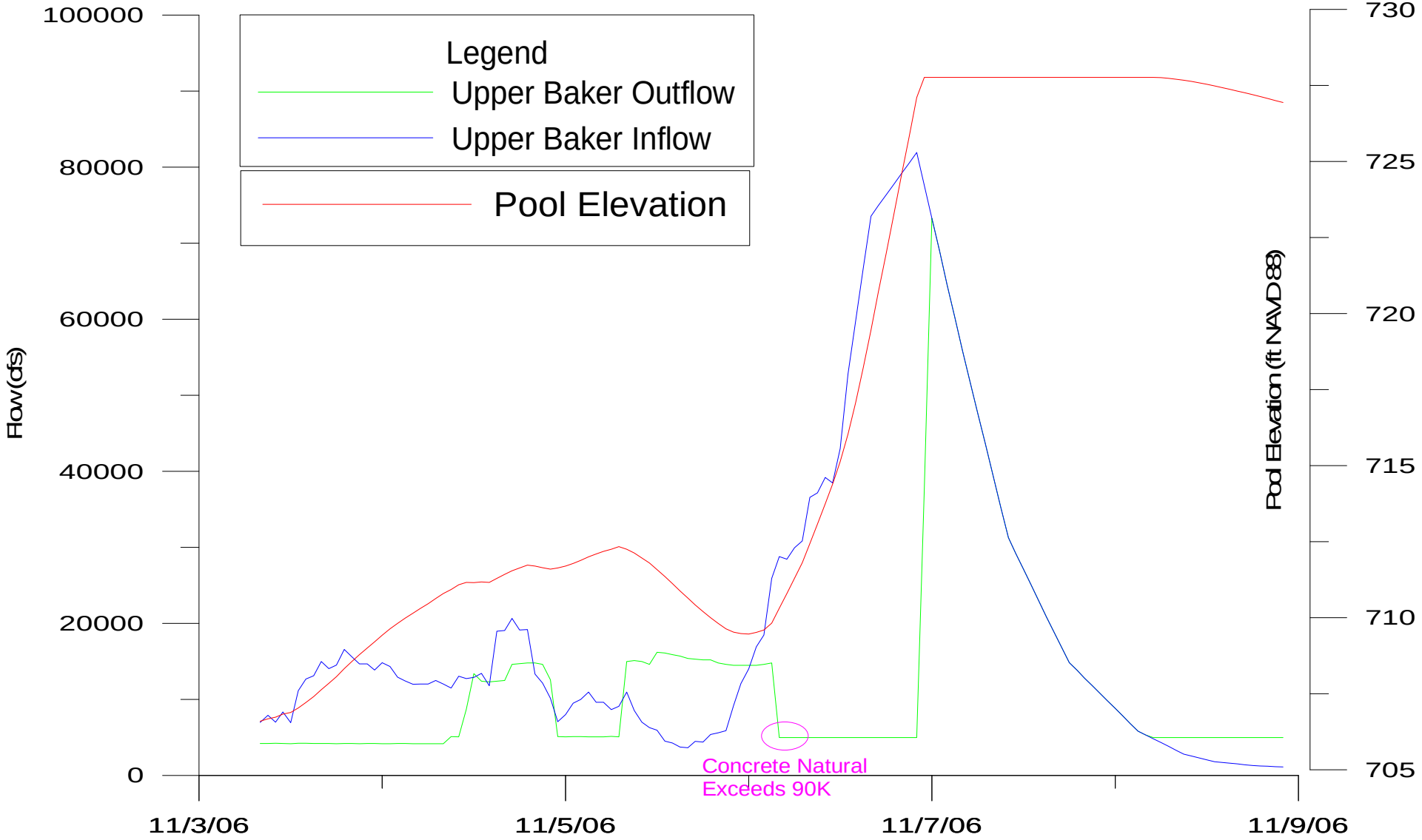
Upper Baker Operation



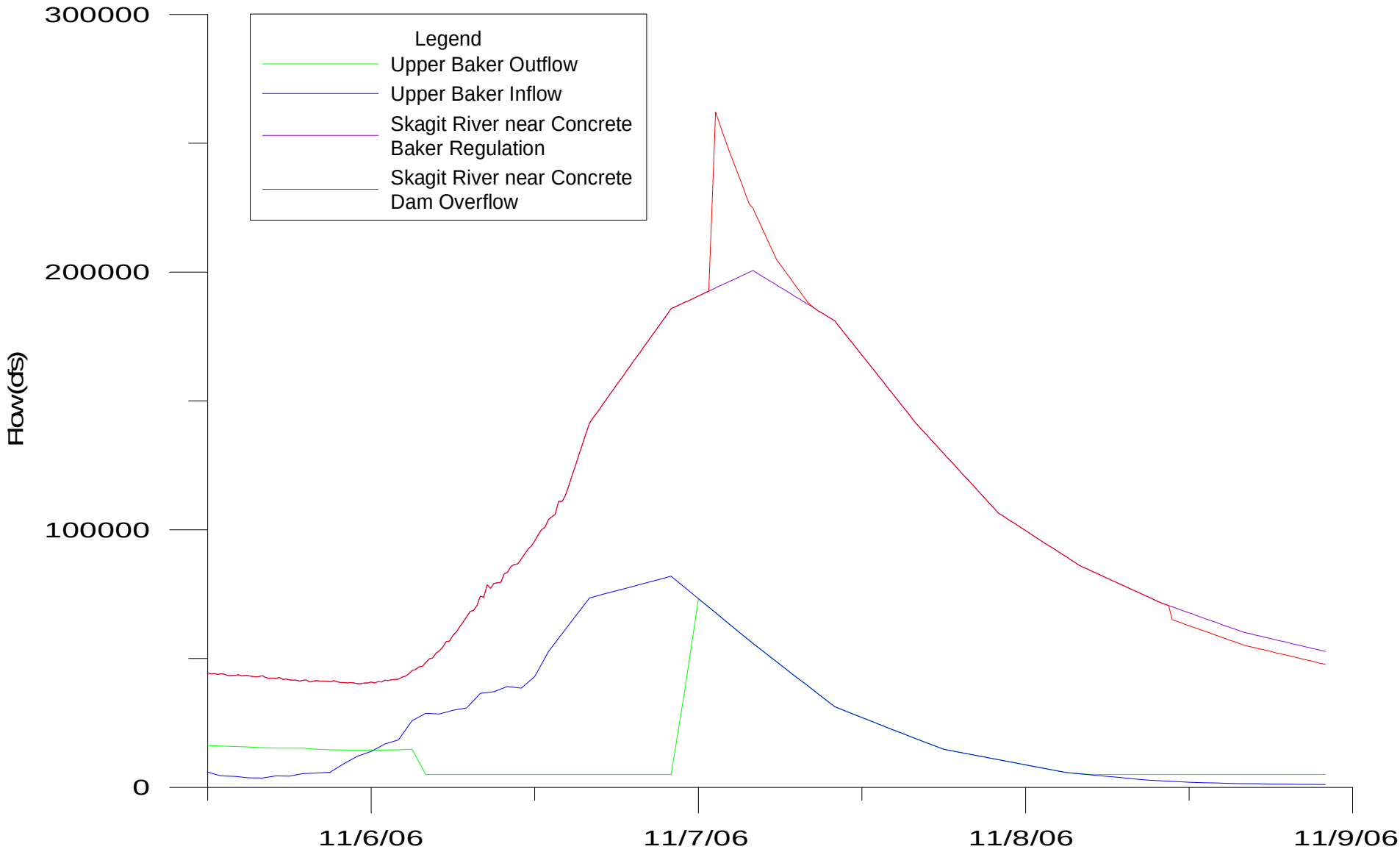
Ross Dam Operation



Upper Baker Operation with 80K inflow if only released 5,000 cfs



Upper Baker Operation with 80K inflow if only released 5,000 cfs



Editorial Note

Operating the Baker system to minimize downstream damages from a 500-year flood event presents completely different management strategies.

However, our proposed approach could also be responsive to such an event.

Summary
Skagit Flood Operations Related to Baker Flood Storage

- The Baker River basin is a prolific water generator during Skagit flood events
  - The Baker system can produce more water than the Ross drainage, which is over 3 times as large
- Existing flood storage is not adequate to capture a Baker 100-year flood – a goal of the downstream communities
- Drawing down the reservoirs in advance of a Skagit flood is an effective tool to gain additional flood storage at the time it is needed

License Article 107(c)

"Licensee shall consult with the ARG, and specifically Skagit County and the Corps of Engineers, to develop means and operational methods to operate the Project reservoirs in a manner addressing imminent flood events and consistent with the requirements of the license. Appropriate means and methods may include, without limitation, additional reservoir drawdown below the maximum established flood pool. Licensee shall submit a report to the Commission within three years following license issuance describing any operational changes developed as a result of this consultation."

Initial Approach to 107(c)

- PSE's initial approach was to evaluate whether imminent flood drawdown could be effective within all of the normal (not emergency) constraints of the license, as well as all of the constraints of the existing (and outdated) Water Control Manual

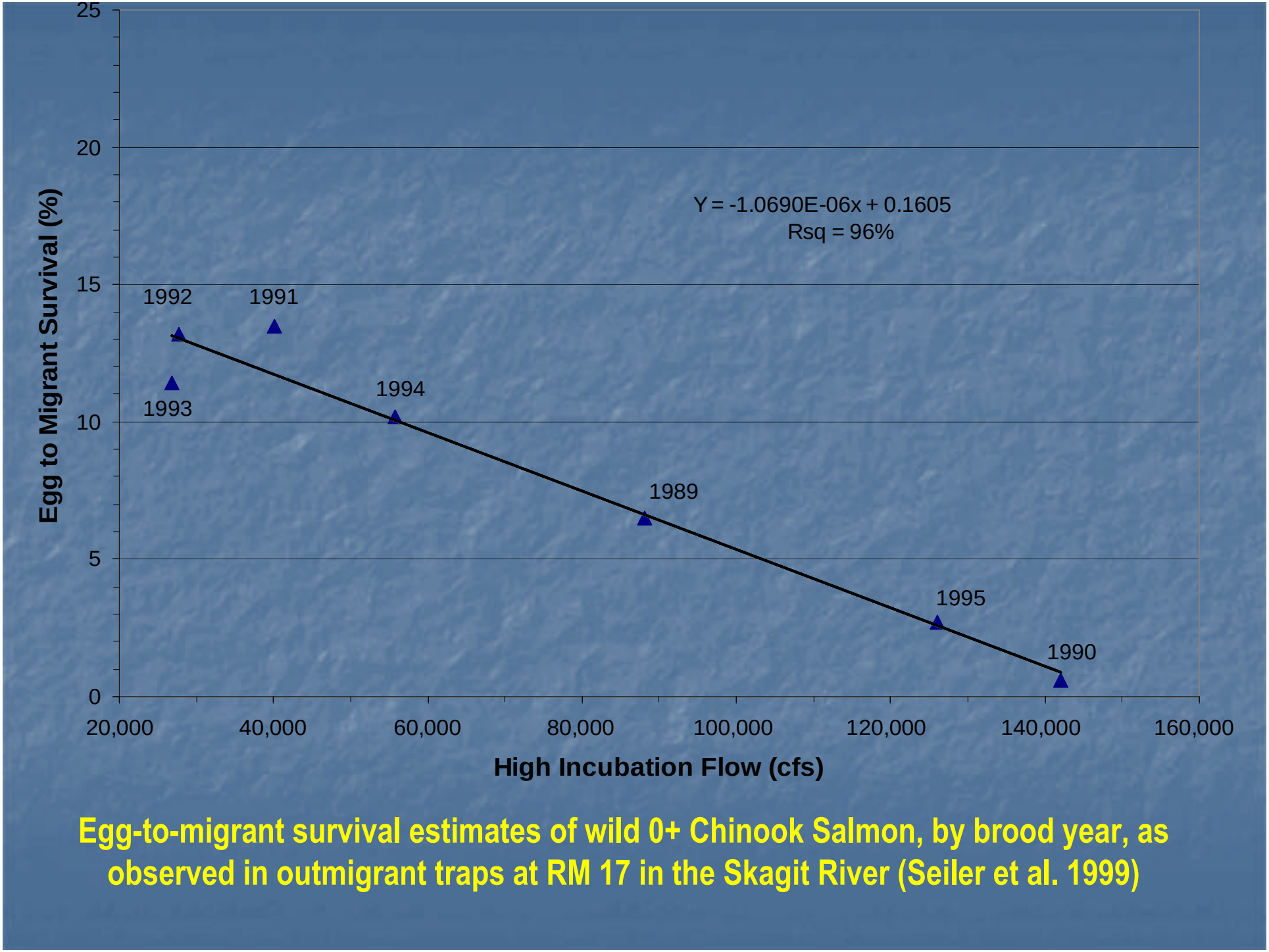
- Result: constrained approach doesn't work
  - 106 outflow constraint of 3,600 cfs is insufficient to draw down the reservoirs in 4-6 days before a flood

Next Steps to Address 107(c)

- PSE's next steps are under development
- PSE is working the issue through the Aquatics Resources Group
- A critical review of Tetra Tech's preliminary work, and a letter from area Mayors, prompted PSE to ask for additional input from all ARG representatives on May 10th

Environmental Concerns

1. Reservoirs will be drawn down, the storm will miss the basin, and reservoir levels will not recover
2. Project outflow above Article 106 flow regime will cause salmon to spawn in areas that will later be dewatered
3. On the other hand, egg-to-migrant survival is negatively impacted by Skagit flooding



Egg-to-migrant survival estimates of wild 0+ Chinook Salmon, by brood year, as observed in outmigrant traps at RM 17 in the Skagit River (Seiler et al. 1999)

Aquatics Table 1. Flows and reservoir elevations proposed for the Baker River Project, FERC No. 2150.

Lower Baker Development Engineering Module: Three turbines (one 4,100 cfs turbine, two 750-cfs turbines)							Upper Baker Development No changes to turbine configuration				
Period	**Min. Instream Flow (cfs)**	**Max. Instream Flow (cfs) [1]**	**Downramping Rates [2]**	**Flood Control Storage (AF)**	**Max Pool Level (ft) (NAVD 88)**	**Min Pool Level (ft) (NAVD 88)**	**Period**	**Flood Control Storage (AF)**	**Max Pool [3] Level (ft) (NAVD 88)**	**Min Pool Level (ft) (NAVD 88)**	**Max Daily Pool Level Change**
Aug 1-31	1,000	3,600	1-inch per hour day and night	No flood control requirement	442.35	404.75	Aug 1-31	No flood control requirement prior to 10/01	727.77	724.8	Max pool fluctuation ≤ 0.5 ft per rolling 24-hr period
Sep 1-3	1,000	3,600			442.35	404.75	Sep 3		727.77	724.8	
4-9	1,000	3,600			442.35	404.75	Sep 9		727.77	720.8	
10-30	1,000	3,200			442.35	404.75	Sep 30		727.77	718.8	No constraints on max daily pool level changes
Oct 1-7	1,000	3,200 [1]			442.35	389	Oct 7	Gradual drawdown to 74,000 AF by 11/15	727.11 [4]	713.8	
8-15	1,000	3,200 [1]			442.35	389	Oct 15		726.23 [4]	685	
16-20	1,000	3,200 [1]			442.35	389	Oct 20		725.68 [4]	685	
21-31	1,200	3,600 [1]			442.35	389	Oct 31		724.47 [4]	685	
Nov 1-15	1,200	3,600 [1]	2-inches per hour day and night		442.35	389	Nov 14		712.42 [4]	685	
16-30	1,200	3,600 [1]			442.35	389	Nov 15-30	74,000 AF 11/15 to 03/01	711.56	685	
Dec 1-31	1,200	3,600 [1]			442.35	389	Dec 1-31		711.56	685	
Jan 1-31	1,200	5,600			442.35	389	Jan 1-31		711.56	685	
Feb 1-15	1,200	5,600			442.35	389	Feb 1-15		711.56	685	
16-28	1,200	5,600	0 inches per hour day and 2 inches per hour night		442.35	389	16-28		711.56	685	
Mar 1-31	1,200	5,600			442.35	389	Mar 1-31	Gradual refill	718	685	
Apr 1-30	1,200	3,600			442.35	389	Apr 1-30	No flood control requirement after 04/01	718	685	
May 1-8	1,200	3,600			442.35	389	May 1-8		727.77	685	
9-14	1,200	3,600			442.35	389	9-14		727.77	713.8	
15-22	1,200	3,600			442.35	389	15-22		727.77	718.8	
23-31	1,200	3,600			442.35	389	23-31		727.77	724.8	Max pool fluctuation ≤ 0.5 ft per rolling 24-hr period
Jun 1-15	1,200	5,600			442.35	404.75	Jun 1-15		727.77	724.8	
16-30	1,200	5,600	1-inch /hour day and night		442.35	404.75	16-30		727.77	724.8	
Jul 1-31	1,200	5,600			442.35	404.75	Jul 1-31		727.77	724.8	

[1] Maximum release constraints eliminated when Baker Lake inflow > 10 % monthly exceedance flow OR Skagit River above the Baker River confluence > 24,000 cfs October through December.

[2] Downramping rates measured at the Baker River at Concrete, but based on stage changes observed at Transect 1 on the mainstem Skagit River below the Baker River confluence (RM 56.5).

[3] Maximum elevation unless otherwise directed by the District Engineer (Corps) during Flood Season.

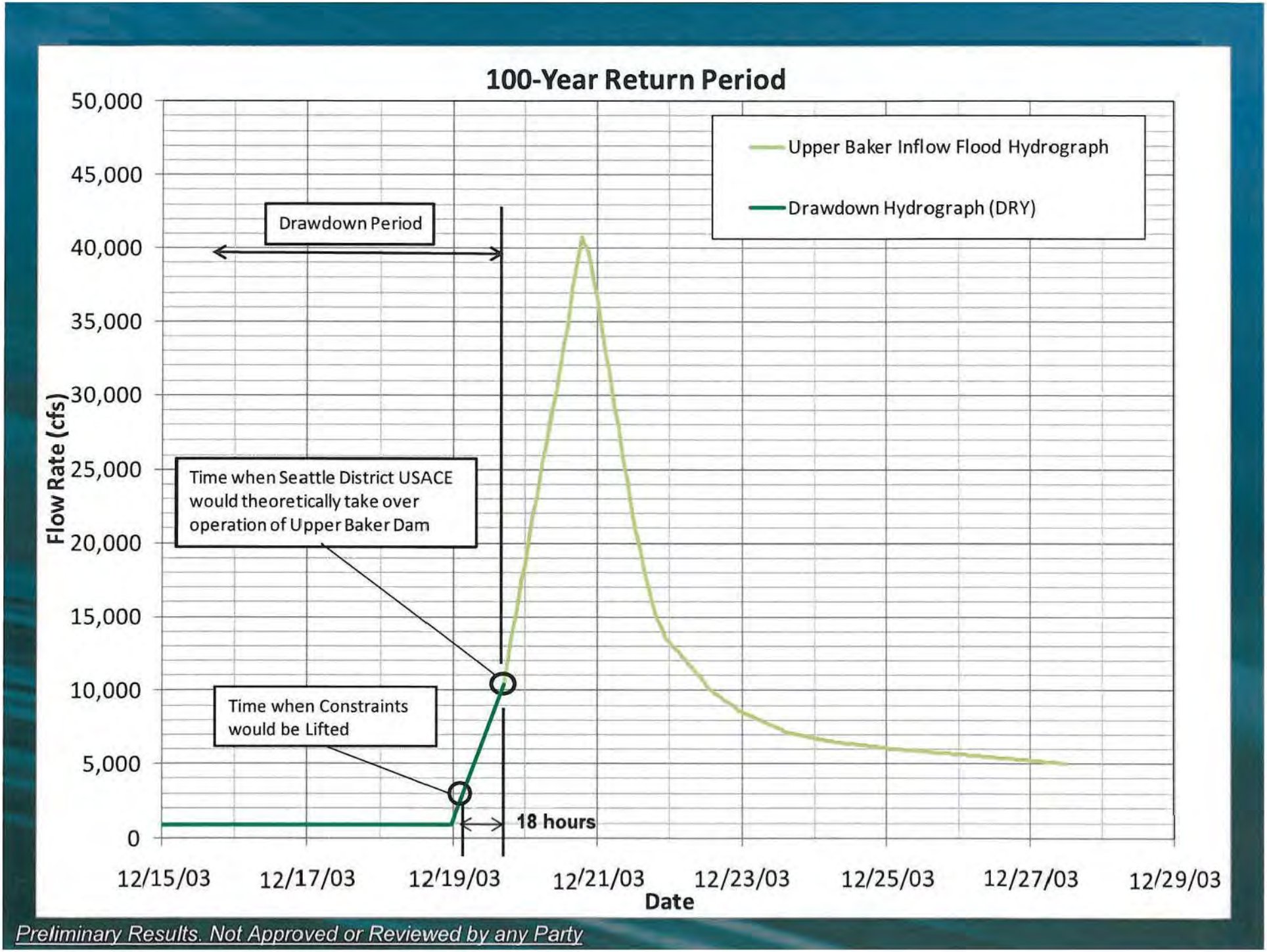
No minimum flow requirements.
No maximum instream flow constraint.
No downramping limitations for environmental interests.

[4] Daily reservoir elevations between October 1, November 1, and November 15 shall be at or below straight lines drawn between 727.77 and 724.47 and between 724.47 and 711.56 for those respective dates with a gradual refill after March 1.

NOTE: All elevations are referenced to NAVD 88. Operations in effect for all years (no special dry year conditions)

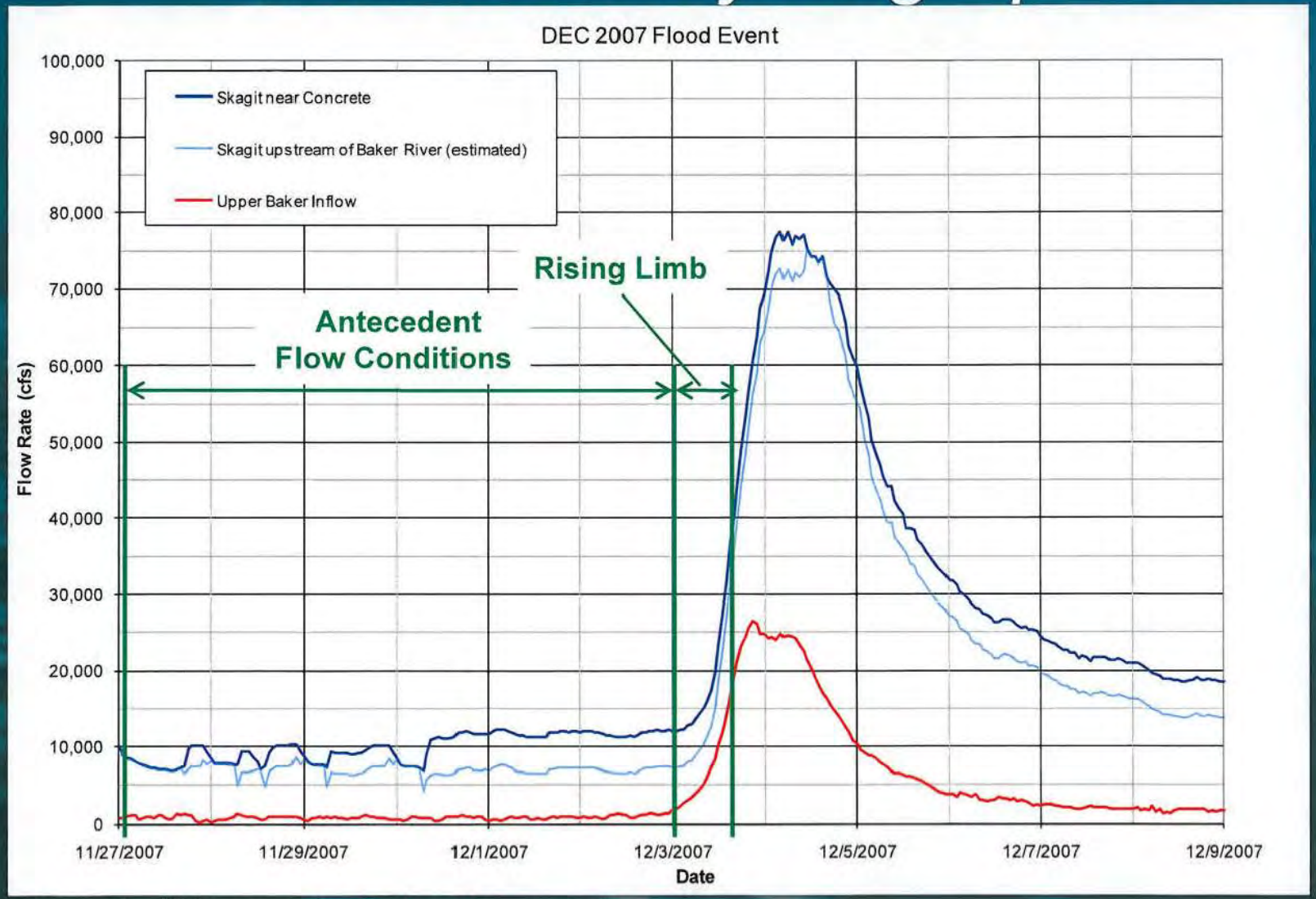
Outflow Needed

- Precedent conditions for every situation will differ. Often, the dams will already provide more flood storage than required (Nov 2006)
- Rule of thumb: 1 cfs net outflow will provide 2 AF of storage in 24 hours
- Typical Baker inflows prior to an incoming flood event will be 2,000 – 5,000 cfs and then the hydrograph will go vertical
- The nature of our floods dictates drawdown must be accomplished in the days before the system hits, not hours before



Preliminary Results. Not Approved or Reviewed by any Party

Procedure - Drawdown Hydrographs



Preliminary Results. Not Approved or Reviewed by any Party

Question

Is it better to increase Baker outflow incrementally, thoughtfully and in consideration of all environmental and flood factors specific to the situation, or determine project outflow according to pre-established blind triggers and constraints?

Discussion

- For imminent flood reservoir drawdown to work, outflow constraints must be temporarily modified
- Some license articles (106(i); 305; 107(c); seem to indicate imminent flood drawdown is OK
- Some license articles (106(L); Aquatics Table 1; seem to indicated imminent flood drawdown is severely constrained
- We believe we can set up a responsive and collaborative process to make the imminent drawdown decisions

Path Forward

- Proposed process:
  - Designate a 107(c) standing committee composed of ARG, BRCC, or members; Weather Service, Corps, and Skagit County Emergency Management
    - Convene conference call upon weather alert
    - Decide what the outflow should be for the next 24 hours
    - Re-convene 24 hours later and set outflow for the next 24 hours
    - And so on

Example Process #1

1. November 14: Weather Service sees potential atmospheric river event 6 days out; notifies Skagit County Emergency Management; initial thought is that flood potential is 50-year event
   - Upper Baker at 75,000 AF
   - Lower Baker at 15,000 AF
2. Skagit DEM notifies PSE/BRCC/ARG; convenes phone conference for the next morning
3. November 15: Committee looks at precedent environmental conditions and reservoir levels; weighs impact of additional release; immediate environmental concern is with spawning chum salmon; however, environmental managers decide it is OK to release some extra water given the circumstances. Committee decides to increase release to 8,000 cfs for the next 24 hours, which is about 5,000 cfs above inflow and exceeds Article 106 outflow by 4,400 cfs

Example Process #1 (cont.)

4. November 16: Committee reconvenes. Conditions have not changed so Committee leaves outflows in place.
5. November 17: Committee reconvenes. Reservoirs are down 20,000 acre-feet since November 15. Weather system is now developing and is 3 days out. Appears main energy will go a bit north. Given forecast change, and given flood storage already in place (110,000 AF), Committee decides to back off on outflow to Article 106 specified outflow, 3,600 cfs, which is close to inflow.
6. November 18: Committee reconvenes. Weather forecasters are confident main storm energy will be about 50 - 100 miles north. Committee makes no change to outflow regime.
7. November 19: Baker inflow rises as Skagit also comes up. Skagit natural flow exceeds 90,000 cfs trigger for Corps to take over operation of UB Dam. UB inflow exceeds 25,000 cfs for a 12-hour period.

Example Process #1 (cont.)

8. November 20: As hydrographs recede, UB has filled about 30,000 AF, to a level providing 65,000 AF of flood storage. Lower Baker passed inflow during this flood event except near the Skagit flood peak, and still has 5,000 AF of storage available. This operation reduced the Skagit flood peak by 10,000 cfs, to a regulated flow of 93,000 cfs which is estimated to increase egg-to-migrant survival by 15%.
9. November 21-22: PSE reduces UB back to flood pool. Note that pool refilled even though the main energy of the storm missed the basin.

Example Process #2

1. November 14: Weather Service sees potential atmospheric river event 6 days out; notifies Skagit County Emergency Management; initial thought is that flood potential is 50-year event
   - Upper Baker at 75,000 AF
   - Lower Baker at 15,000 AF
2. Skagit DEM notifies PSE/BRCC/ARG; convenes phone conference for the next morning
3. November 15: Committee looks at precedent environmental conditions and reservoir levels; weighs impact of additional release; immediate environmental concern is with spawning chum salmon; however, environmental managers decide it is OK to release some extra water given the circumstances. Committee decides to increase release to 8,000 cfs for the next 24 hours, which is about 5,000 cfs above inflow and exceeds Article 106 outflow by 4,400 cfs

Example Process #2 (cont.)

4. November 16: Committee reconvenes. Indications are the flood potential is not decreasing but much uncertainty still exists. Committee leaves outflows in place.

5. November 17: Committee reconvenes. Reservoirs are down 20,000 acre-feet since November 15. Weather system continues to develop and is 72 hours out. Weather service is very concerned the storm represents significant flood potential for the Skagit basin. Committee decides to bump up outflow to 12,000 cfs for the next 24 hours, resulting in net outflow of 9,000 cfs

Example Process #2 (cont.)

6. November 18: Committee reconvenes. Weather forecast looks grim. Reservoir storage:
   - Upper Baker at 105,000 AF
   - Lower Baker at 23,000 AF
   - Total 128,000 AF

   Committee decides to go to max project outflow from both dams until the Skagit passes through 60,000 cfs at Concrete, then reduce Project outflow to 4,300 cfs. Given relatively low reservoir elevations, max Lower Baker outflow is about 11,000 cfs.

7. November 19: Baker inflow rises as Skagit also comes up. Skagit natural flow exceeds 90,000 cfs trigger for Corps to take over operation of UB Dam. Ingoing reservoir storage:
   - Upper Baker at 117,000 AF
   - Lower Baker at 33,000 AF

Example Process #2 (cont.)

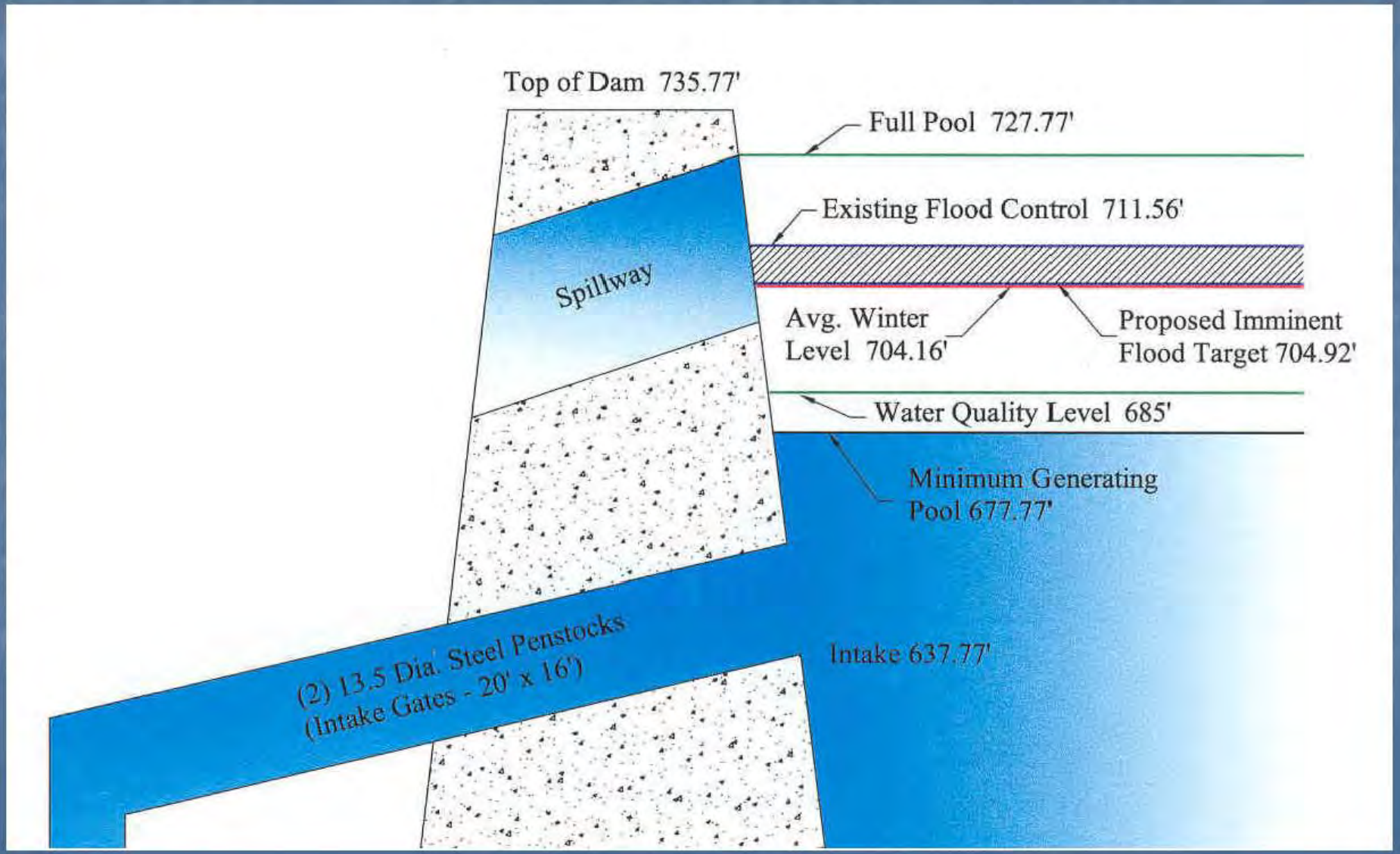
8. Nov 19-20: UB inflow exceeds 60,000 cfs for a 6-hour period, and exceeds 45,000 cfs for a 24-hour period. Lower Baker inflow exceeds 15,000 cfs for a 24-hour period. Upstream gages begin to recede, indicating a Skagit River flood peak at Concrete in the early hours of November 20. PSE, in consultation with the Corps and the Skagit County Unified Command, requests shutting down generation at UB to reserve space in LB to reduce project outflow to zero beginning 10 hours prior to the Skagit flood peak at Concrete.

9. November 20: As hydrographs recede on the 20th, UB has filled to within 15,000 AF of full pool. LB is very near full pool.

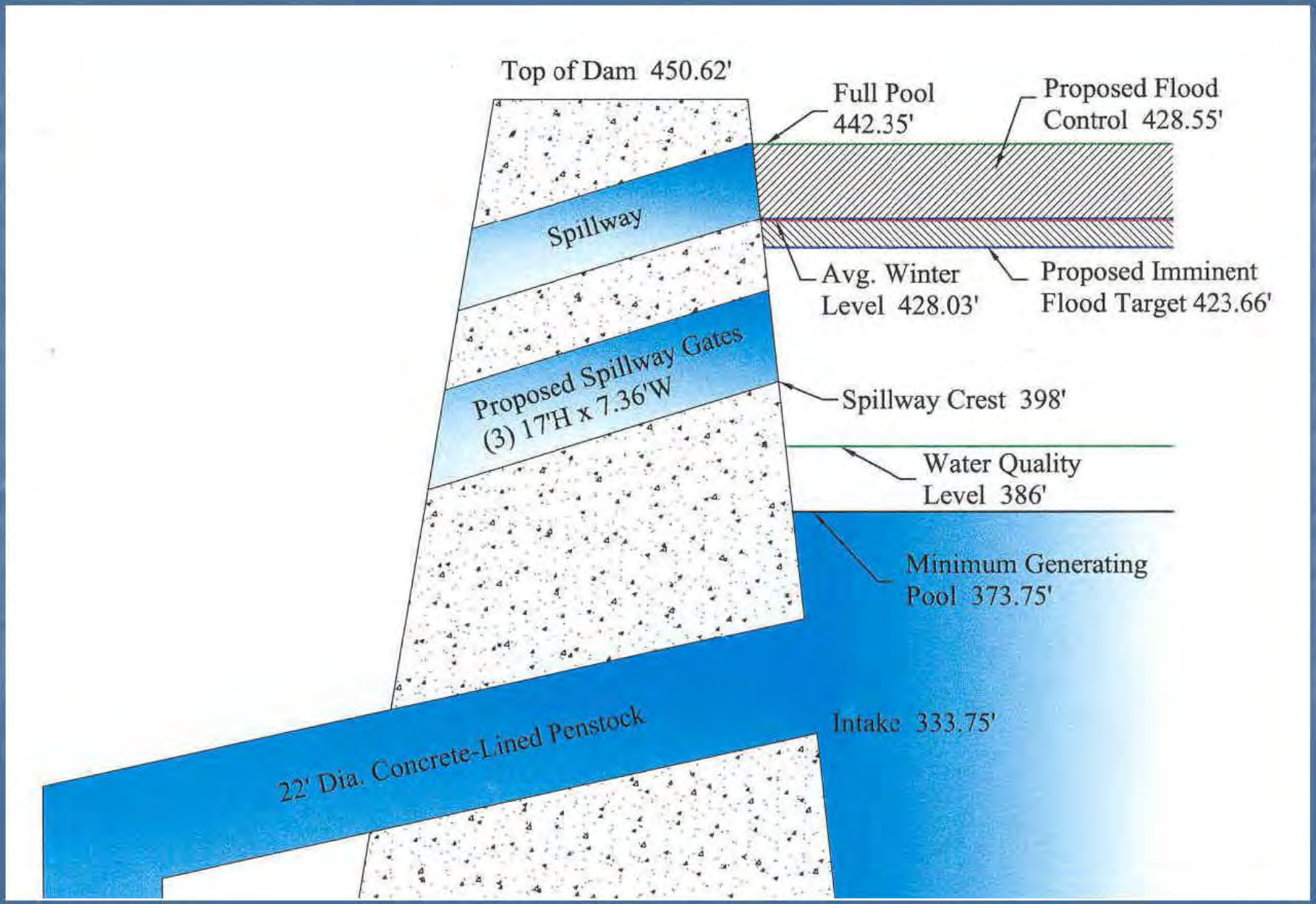
10. November 21: Pre-flood reservoir management by the 107(c) committee resulted in a conservatively-estimated 2.5 feet of water surface elevation reduction in the Skagit River system downstream of Sedro-Woolley. As the Skagit recedes, Baker outflow is increased, and the reservoir flood pools are re-attained within a few days.

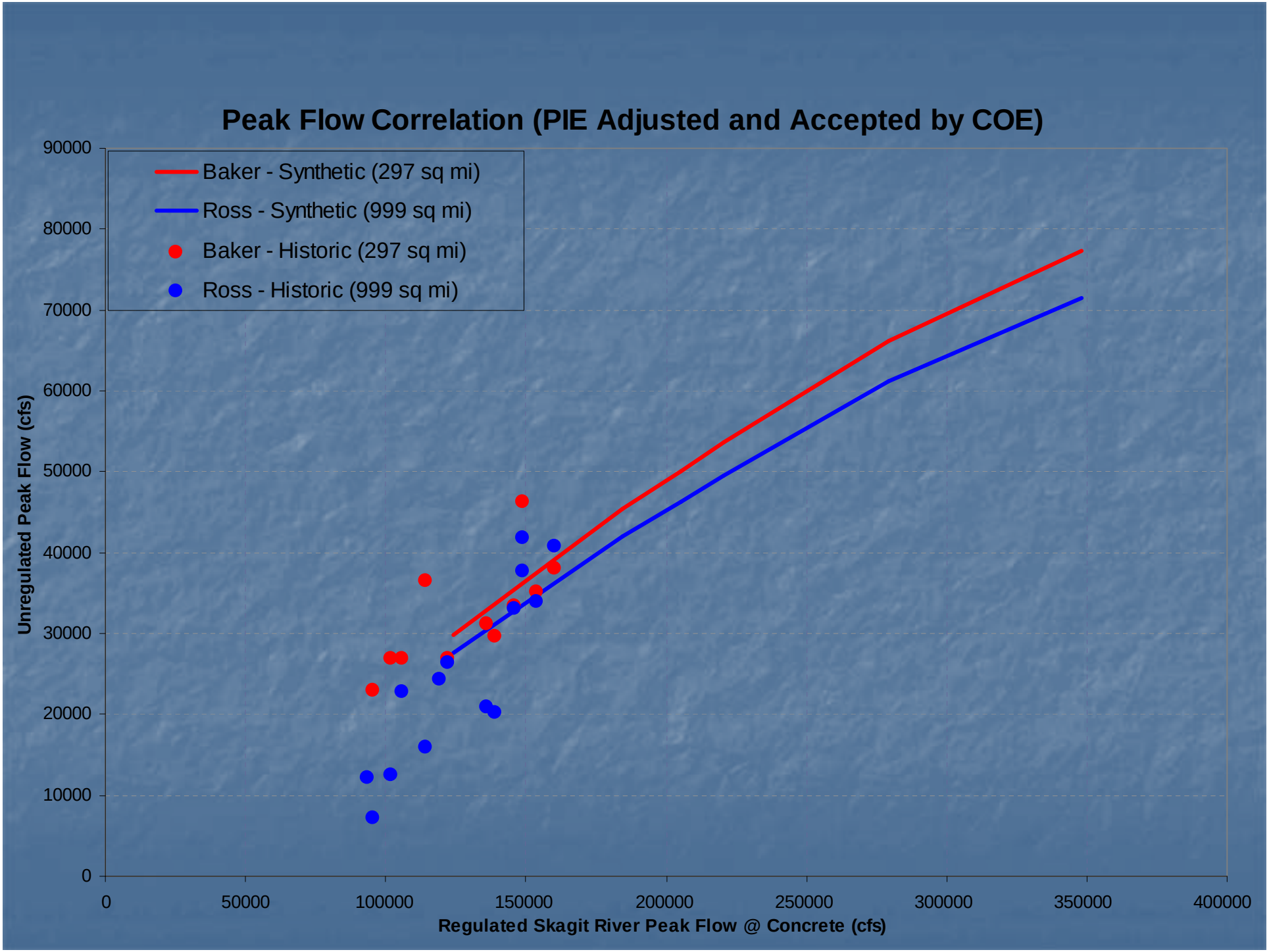

Questions / Discussion

Upper Baker Dam



Lower Baker Dam




Peak Flow Correlation (PIE Adjusted and Accepted by COE)
Baker - Synthetic (297 sq mi)
Ross - Synthetic (999 sq mi)
Baker - Historic (297 sq mi)
Ross - Historic (999 sq mi)
Unregulated Peak Flow (cfs)
Regulated Skagit River Peak Flow @ Concrete (cfs)
0
10000
20000
30000
40000
50000
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Ross Dam
22 October 2003