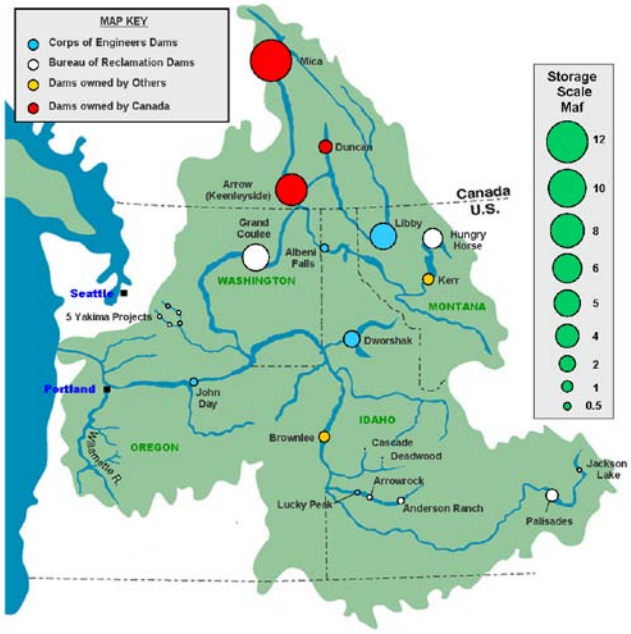
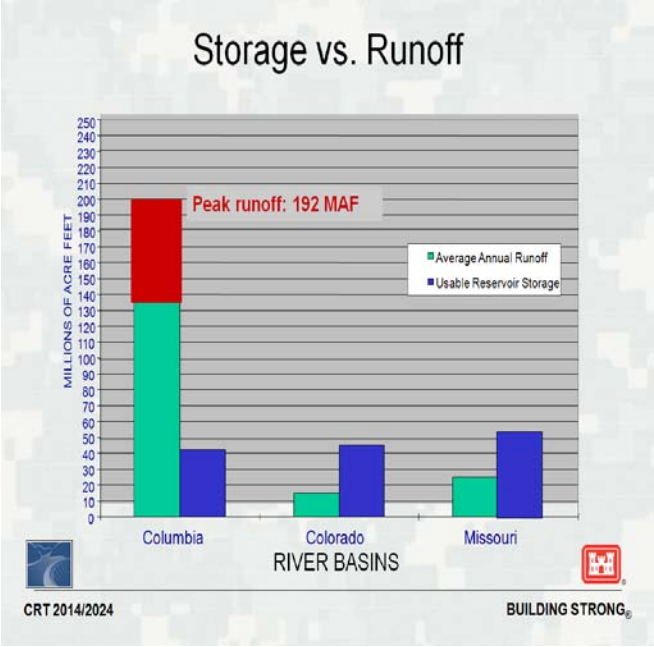
December 13, 2012 Presentation to SRT
Flood Risk Analysis – Iteration 2 Results
Slides and Supporting Notes

The Columbia River system is comprised of run-of-river and storage reservoirs authorized or licensed for multiple purposes, including power generation, flood risk management, navigation, irrigation, recreation and fish operations. Run-of-river reservoirs have very limited storage and therefore simply pass inflows through hydroelectric projects by generating power or spilling. Storage reservoirs can accommodate significant changes in inflow volume, which is used to modify the timing and quantity of runoff through the river system.

Typical water management practices store and release water to serve the multiple purposes of the dams and reservoirs. Over 50 percent of the basin's storage capacity comes from the upper basin's Treaty dams in Canada. U.S. dams provide about 20 million acre-feet (maf) of storage with the majority at Hungry Horse, Libby and Grand Coulee. Grand Coulee is the only large U.S. storage facility on the Columbia River downstream of the Canadian dams and reservoirs. Grand Coulee storage is approximately 25 percent of the storage used annually in Canada. This is an important consideration for water management as about 35 percent of the annual runoff comes from Canada, making Canada's water management practices critical to overall water management in the lower Columbia River.





Overall, our basin is storage poor. Over 130 maf of water moves through the Columbia River Basin each year. This is over 10 times the water in the Colorado River Basin and 5 times the water in the Missouri.

Each basin has almost identical storage potential but in contrast to these other basins, the Columbia has a small amount of storage compared to the amount of annual runoff.

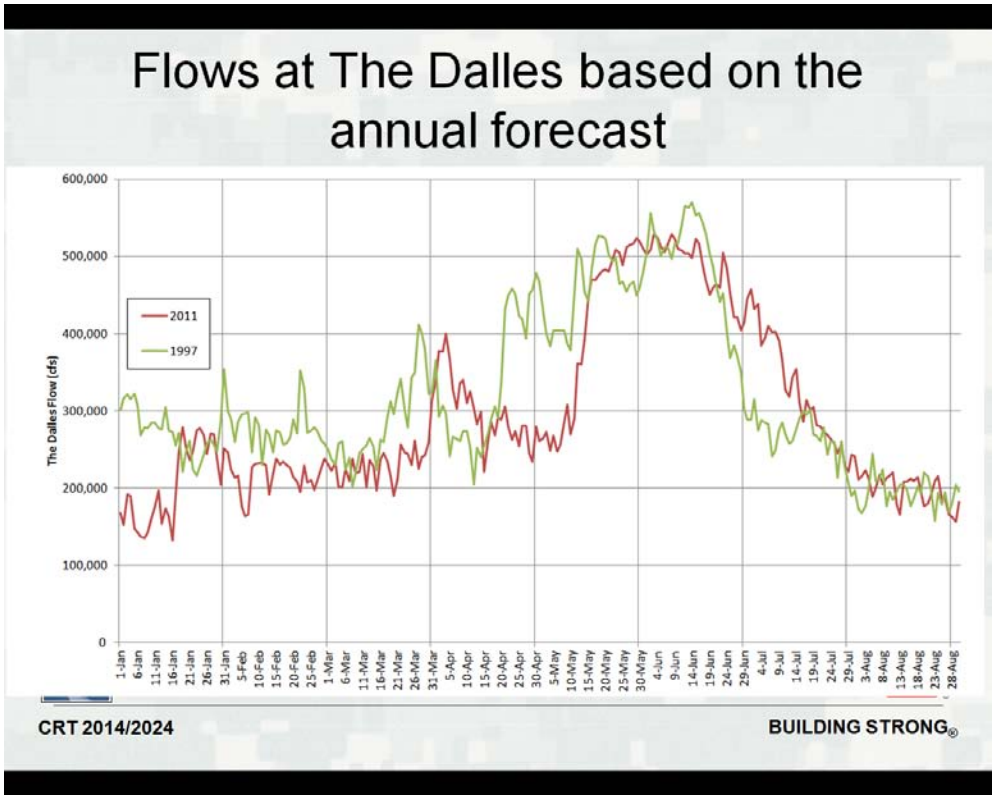
<u>Unpredictability</u>

Mother Nature controls the runoff and its variability. We do our best to forecast or predict the quantity and timing of runoff but there is large uncertainty about our ability to forecast the future.

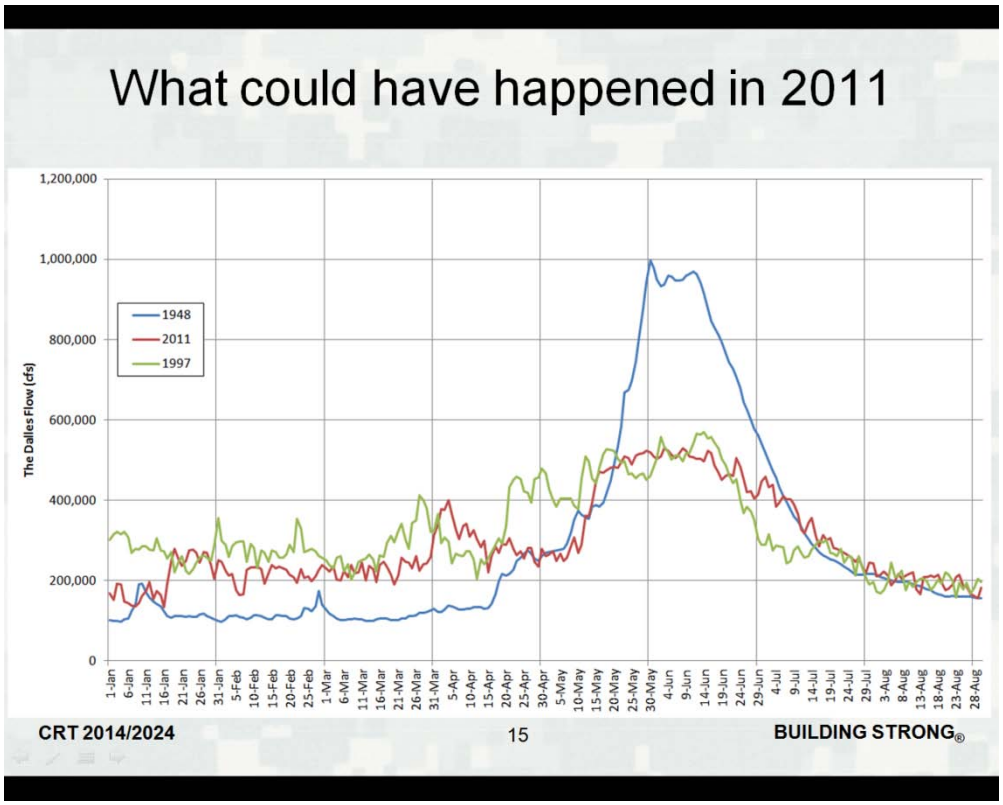
In 1948, early forecasts indicated a typical water year. Late spring rain combined with an aggressive snowmelt created a significant spike in flows (increase of over 300,000 cfs at The Dalles) that far exceeded our ability to effectively manage the event.

In 1997, we forecast a large snow pack along with a large but slow spring runoff. The management of this event required use of all of our storage space as well as a later refill period (started in June). Because we could anticipate this event, we used all of our resources to manage it to the fullest extent possible. Our water management practices greatly reduced the economic consequences.

In 2011, we encountered the opposite. We forecast a relatively small run-off in what one might almost consider a drought year. We started refilling reservoirs with the start of spring runoff. However, significant rain events throughout the basin occurred later. These rain events were very similar to what we saw in 1948.



Had either 1997 or 2011 had a combination of aggressive snowmelt on top of significant rain events like those in 1948, we could have seen devastating consequences similar to 1948. Once we set storage requirements for the year (based on the forecast) and start refill, our ability to adjust for unforecast events is very limited. This coupled with limited storage capacity in the U.S. makes water management even more important.



Flood Risk

Many factors contribute to the current level of flood risk. A sound approach to flood risk management considers economic, social and hydrologic factors to help determine an appropriate management configuration. A sound analysis includes contributions from regional stakeholders and partners to a recommended plan of action and cost sharing in its implementation.

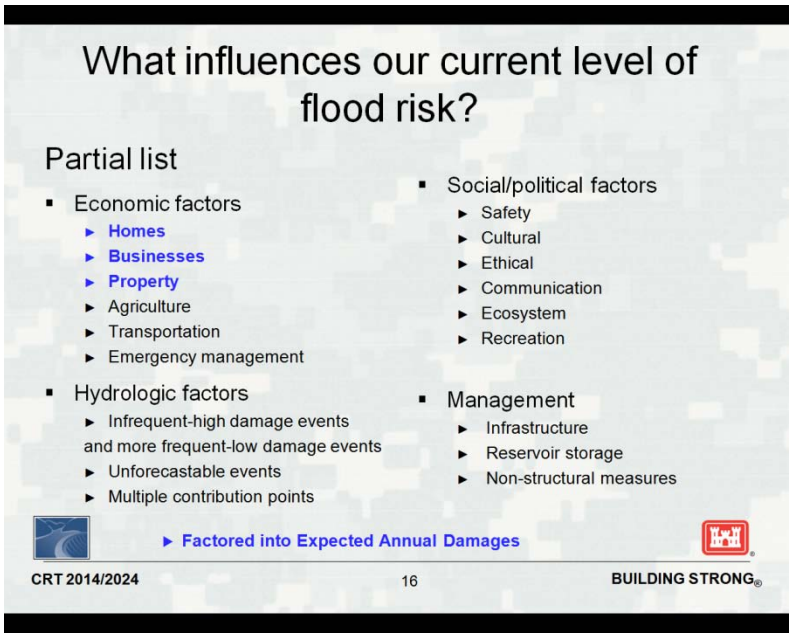
Treaty Review did not task the Corps to determine or challenge the established, current level of risk. It requires us to focus on how the post-2024 Treaty provision changes, from annual assured storage to Called Upon and effective use, influence this level of flood risk and to better understand our vulnerabilities under Treaty Terminates. The modeling assumptions about these changes only tells us part of the complex story behind our current risk.

Operating with Canadian storage will be different under Called Upon. It is unclear how we will operate U.S. dams to help compensate or accommodate changes in Canadian operations. It is our position to retain the current level of risk; how we do this will require changes in operations, and flows and timing may look different.

Risk = Consequences x Probability
Increased flood flow = Increased risk

Our focus, and the treaty nexus, should be on buckets of water we need to manage risk.
We cannot change where risk is, or where the people, homes and businesses are in our footprint.

Our ability to manage an event (consequences) and our uncertainty to forecast events (probability) drives our current level of risk. Storage is the big driver behind system management and access to Canadian storage is the largest known change post-2024.



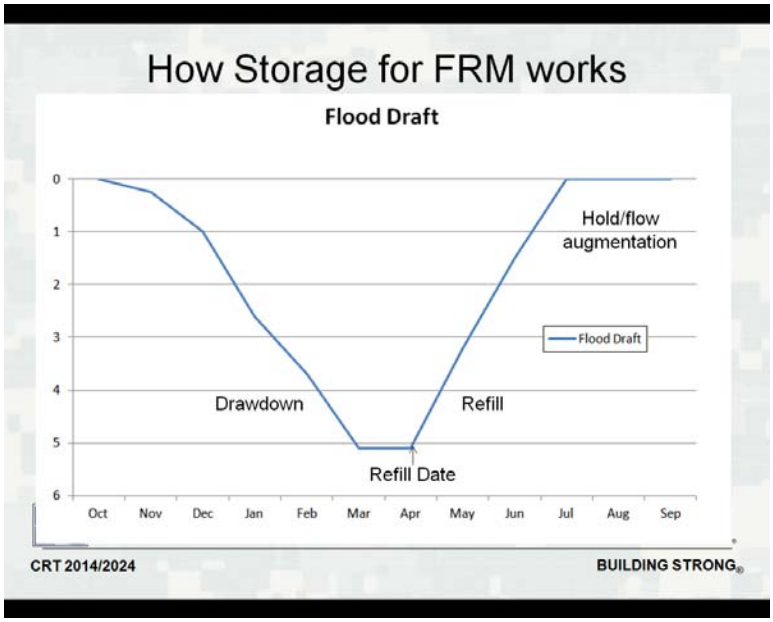
Flood Risk Management

Storage is an effective management solution to the variability of Mother Nature. We can modify storage based on what we predict or forecast for the upcoming flood season. Real time operations help balance system needs and focus on effective use of storage.

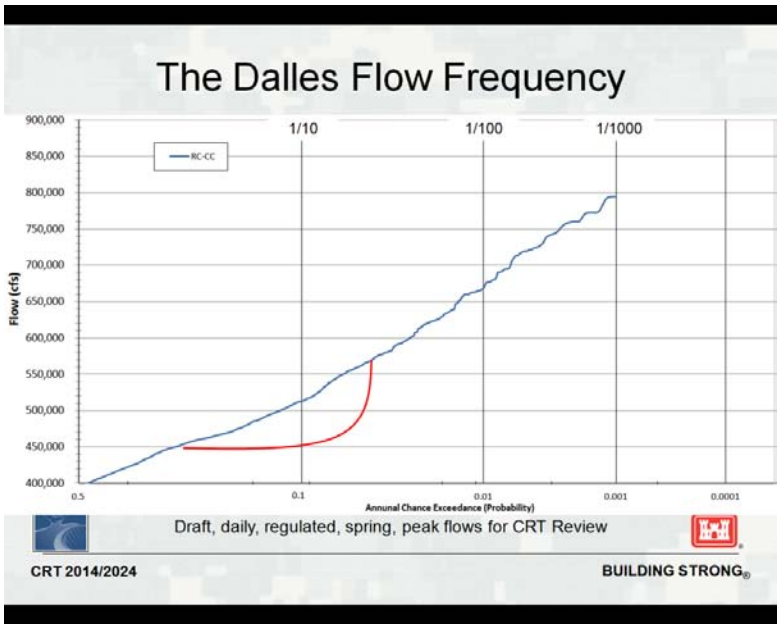
We have several reservoirs in the basin that aid in flood risk management but these reservoirs serve multiple purposes. To balance these purposes, we work to achieve effective use of that reservoir's space for flood risk. Effective use, in this case, means only drafting the volume of water from the reservoir that you will be able to refill in the spring. If a reservoir cannot refill, then we created too much reservoir space. Drafting a reservoir emptier than what we can refill during the flood season does not help with flood risk management because the contributing flood flows are not being generated by that basin. Therefore, refill is a critical part to effective flood risk management.

Once we draft reservoirs and refill has begun, the contribution to flood risk from that basin has been set. This is a risk of effective use. Again, our ability to react to an unforecast event is very limited. We do not have excess storage in the basin or infrastructure to further manage events.

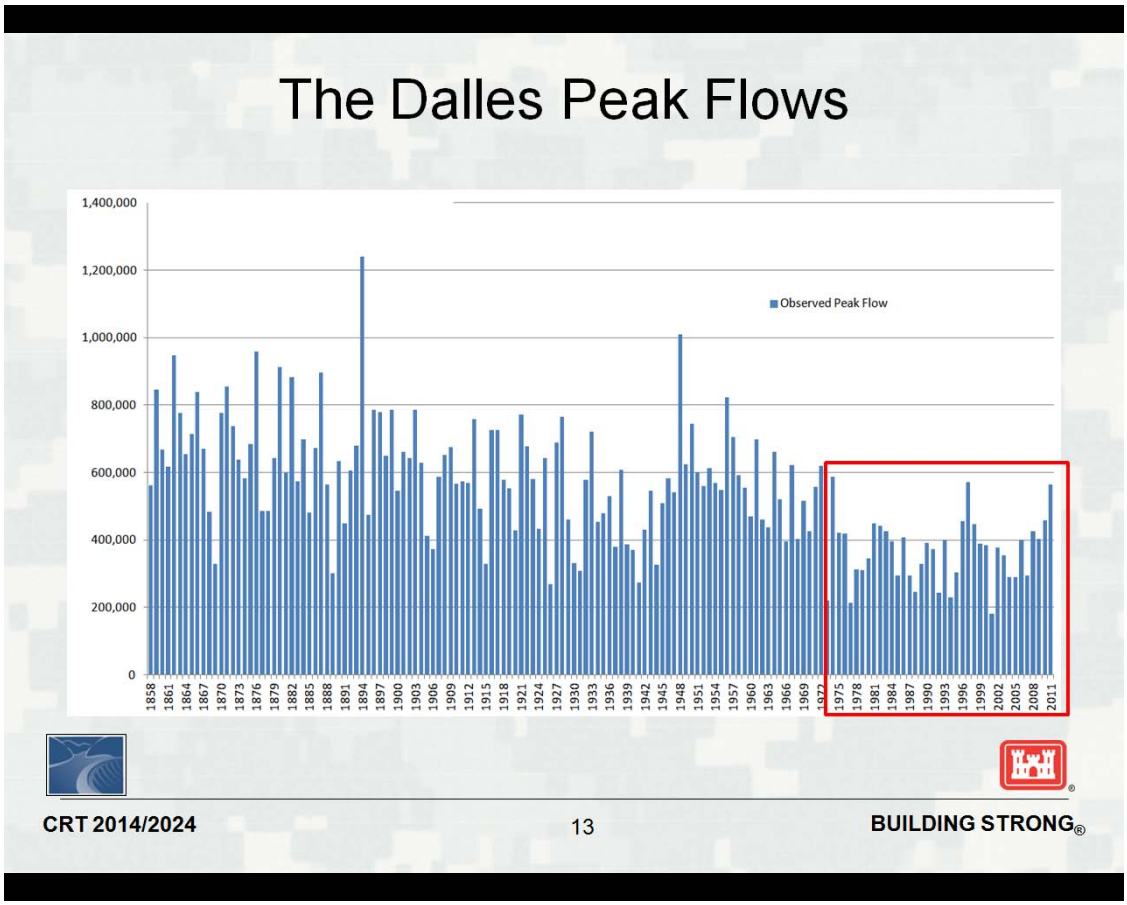
An example of our limited ability to manage an event after refill begins occurred at Libby in 2012. After determining effective use of Libby's storage and conducting refill as scheduled based on forecasts and the timing of runoff, a significant rain event occurred lasting days. The timing and amount of rain lead to flooding when just the week before there was concern about the ability to refill; once the rain started there was little we could do to alleviate the risk. If this event were determined to be a common occurrence for Libby then we would modify refill to leave more space for early summer rains.



Balancing the system to achieve multiple purposes means just that – we balance. If we choose hard and fast lines for flood risk management, you would see shifts in the blue line in the graph below (representing the annual peak flow at The Dalles for current conditions) to what is shown in red. The red line depicts operations where 450 kcfs is required. This shows that we would manage the system each year to 450 kcfs until exceeding our storage capacity and, therefore, more flow was passed through the system.



We could also achieve a red line if we had excess storage in the basin available to control flows. If flood risk management was our only priority and we had the storage-to-runoff ratio of the Missouri River Basin, the frequency curve would look more like the red line than the blue line, but we don't.

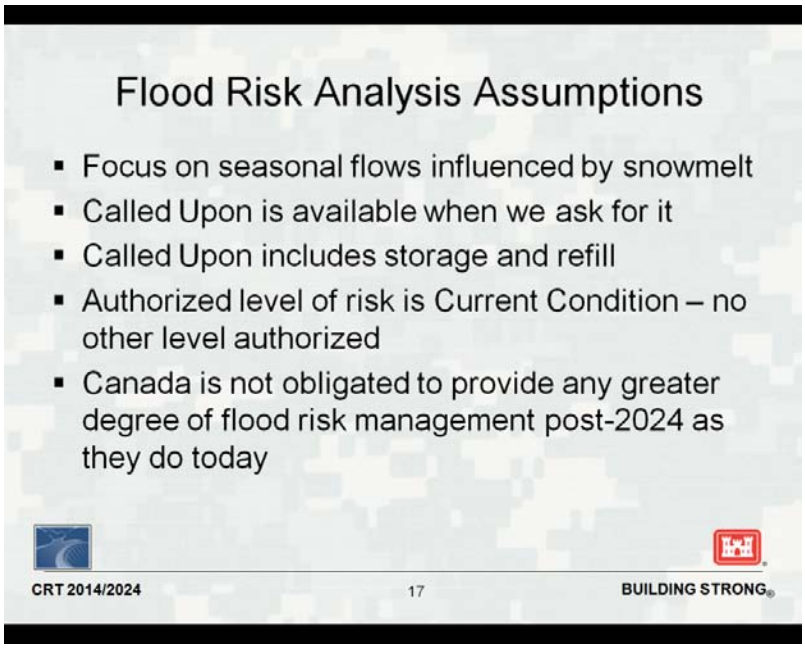


To illustrate our points on water management, the above graph shows the observed, instantaneous peak flow observed by the U.S. Geologic Survey at The Dalles, Oregon, dating back to 1858. As a reminder, The Dalles is the system operating control point and the forecast location where the need for effective use and called upon is determined.

The red box includes the years since 1973, when today's basic system of levees and dams were completed. 1974 and 1997 were two of the largest years on record but we were lucky that there was not significant rainfall or high temperatures during the snowmelt season.

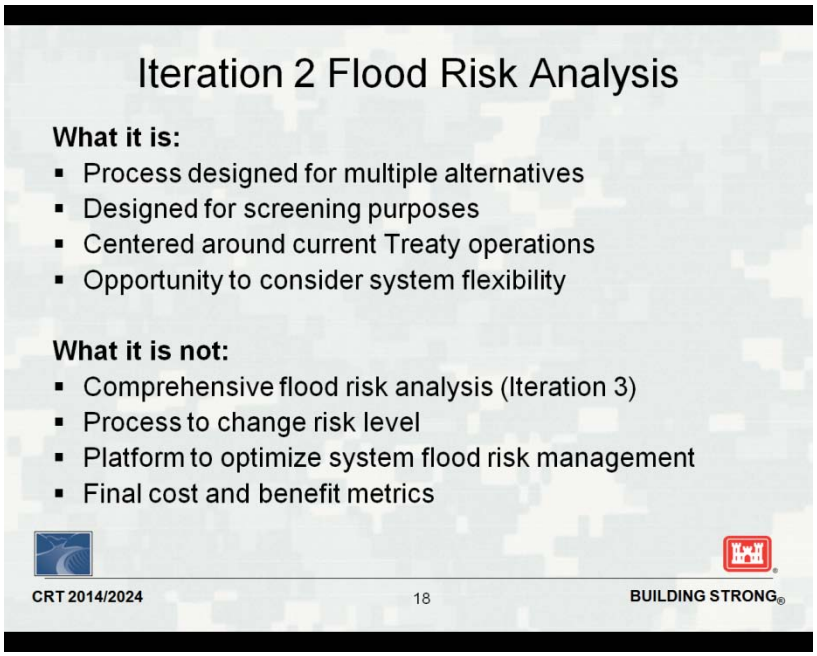
Our system is at risk and drastic changes in reservoir management could result in years like 1973, 1997 and 2011 turning into 1948.

<u>Iteration 2 - Flood Risk Analysis</u>



A risk analysis is a systematic, evidence-based approach for quantifying and describing the nature, likelihood and magnitude of risk associated with the current condition and the same values resulting from a changed condition due to some action.

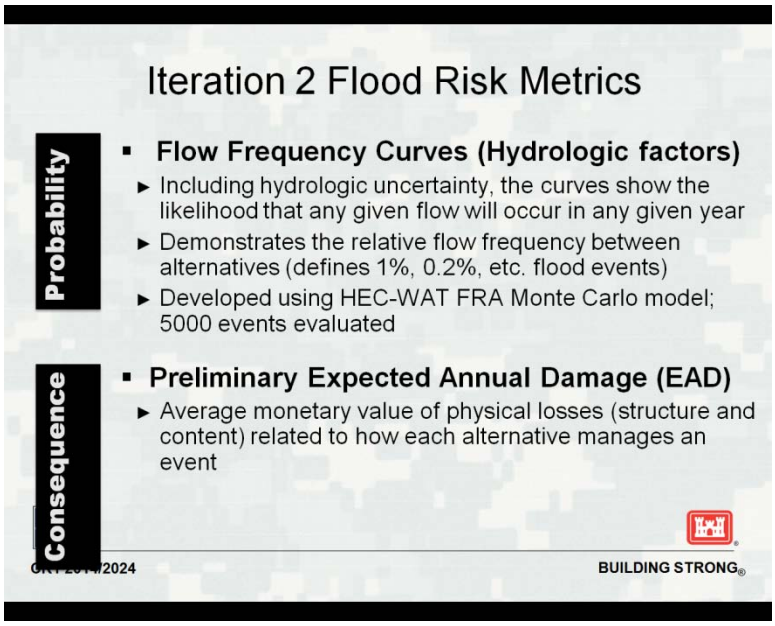
The Iteration 2 flood risk analysis was specifically designed for the Treaty Review process. We designed a process with hydrologic uncertainty (using event-based analyses) to evaluate and compare the flood risk of numerous Iteration 2 alternatives without completing a full risk and uncertainty analysis. Our focus remains on the Treaty nexus, which is why seasonal flows related to snowmelt, and changes based on modeling post-2024 Treaty provisions are a priority.



The Treaty Review process is not designed to be a comprehensive flood risk analysis that includes the full suite of uncertainty, costs and benefits and a recommended plan for implementation. Our downscaled Iteration 2 approach to flood risk analysis allows us to readily evaluate alternatives, and to understand the changes in risk between different alternatives without conducting a full risk analysis. It helps us move

forward on a Treaty recommendation. Further studies and efforts will be required to actually implement the Treaty decision.

We also are not authorized to study changes to the levels of flood risk although the Treaty Review process may spur this regional discussion.



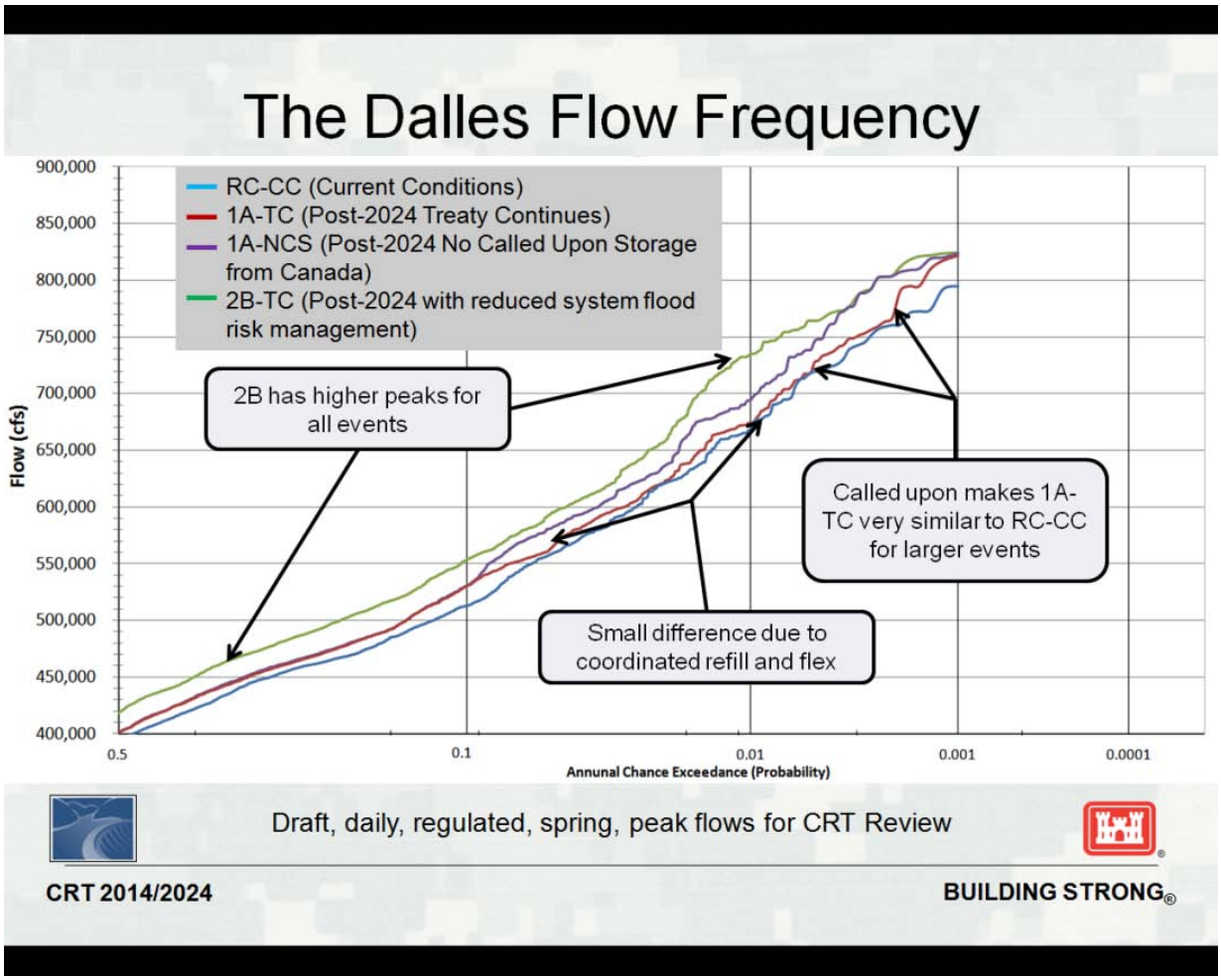
We generated flow frequency curves at various locations in the basin by sampling the 70-year historic record, 16 synthetic events, and our flood risk analysis set of forecasts. Using Monte Carlo sampling, we ran the reservoir simulation (ResSim) model through about 5000 realizations to determine the likelihood that any given flow will happen at any given year. This demonstrates the relative flow frequency changes between alternatives.

Preliminary expected annual damage (EAD) was also used as an Iteration 2 metric. The Corps' definition of EAD is the average annual damages realized based on the flood risk management in place. Preliminary EADs were generated for numerous locations throughout the basin to characterize the structure and content damages realized on an annual basis. While this is not the final EAD for the basin, it does represent the majority of damages we will see and, therefore, is appropriate for alternative comparisons. Again, we have over 70 dams and reservoirs in our modeling schematic and 130 levee systems. Levee systems for this modeling iteration included flood fighting in their performance criteria. Damages again include structure and content only, using a 2010 structural inventory.

<u>Iteration 2 – Flow Frequency</u>

This graph depicts the annual chance exceedance at The Dalles for four of the Iteration 2 components. The blue line representing Current Condition indicates the probability of an event based on how we manage the system today. It illustrates part of our current level of flood risk in the basin.

Again, annual chance exceedance shows the probability of an event occurring <u>in any one year</u>.



Notice that none of the flow frequency lines under the three other components mimic current conditions. For all events shown, there is an increased probability of seeing more water then what we see today. Increasing flows and their likelihood (frequency) without changing the management configuration increases risk.

For the component 2B, the flow of a 0.1 chance exceedance is an increase of 40,000 cfs over current conditions. Looking at the same component, the increase is 70,000 cfs for the 0.01 event. Taking a step further, the one out of every 50-year flow event for 2B equates to the one out of every 100-year flow for 1A and the one out of every 250-year flow for current conditions.

The likelihood of flows at or above 600 kcfs is approximately 2.8% for current conditions. This increases to 3.2% for 1A-TC and 5% from 2B-TC.

Probability of Flow @ The Dalles

	RC-CC	1A-TC	2B-TC
450 kcfs	28.9 %	31.8 %	39 %
600 kcfs	2.8 %	3.2 %	5.0 %
800 kcfs	Possible but unlikely (0.07 %)	Twice as likely as CC (0.15 %)	Four times as likely as CC (0.27 %)

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This increase in flows over current conditions occurs for a few reasons. First, under our post-2024 alternatives we do not have access to assured storage in Canada. Assured storage restricts operations at Arrow under current conditions and reduces flow from that dam. Second, 2B-TC was designed to reduce system flood risk management, which is shown by the overall increase in flows for all events.

<u>Flood frequency: percent chance of a flood occurring in any one year</u>
1-year flood = 100% (1.0) chance of occurring in any one year
2-year flood = 50% (0.5) chance of occurring in any one year
10-year flood = 10% (0.1) chance of occurring in any one year
25-year flood = 4% (0.04) chance of occurring in any one year
50-year flood = 2% (0.02) chance of occurring in any one year
100-year flood = 1% (0.01) chance of occurring in any one year
200-year flood = 0.5% (.005) chance of occurring in any one year
500-year flood = 0.2% (.002) chance of occurring in any one year

Preliminary EAD metric % change for Iteration 2 alternatives

	2A-TC	2B-TC	2A-TT	2F1	2F2
Total % increase from CC	2.3%	20.9%	4.0%	-12.4%	10.0%
Reach 1 % increase from CC	10%	93%	18%	-7.0%	45%

- Preliminary EAD (Expected Annual Damage) is a flood risk metric developed for iteration 2 to compare alternatives that incorporates flow probability and consequences.