Subject: RE: Dungeness Reservoir - Seismic Reconnaissance
From: David Rice <drice@anchorqea.com>
Date: 6/30/2023, 11:17 AM
To: "Gray, Steve" <steve.gray@clallamcountywa.gov>, "Donisi, Joe" <joe.donisi@clallamcountywa.gov>, "McElroy, Patrick" <patrick.mcelroy@clallamcountywa.gov>
CC: Robert Montgomery <rmontgomery@anchorqea.com>, Stan Boyle <Stan.Boyle@shanwil.com>, Jennifer Mead <Jennifer.Mead@shanwil.com>, Chris Kemp <Chris.Kemp@shanwil.com>

Hi Steve, Joe, Pat,

As a follow up to our discussion on Wednesday and my email chain below, I asked Shannon & Wilson to provide clarification on some of the questions we discussed. I've included their feedback below. As discussed on Wednesday, I will be out of town next week. I'll have occasional email access and can respond to anything urgent. As you indicated during our call, we understand that the following need to take priority for this project before we push much further with design: 1) Determining the best path forward for dealing with the findings of the seismic reconnaissance, 2) Developing a framework for water rights with the DWUA and Washington Water Trust, and 3) Developing and framework for O&M roles and responsibilities and scheduling time to have a more detailed discussion about that with the Work Group.

Please let us know if you have any additional questions or need more clarification as we work through Item 1 above. We'll also get started on laying the basis for the O&M framework (Item 3) and can talk about that again the next time we check in (July 12).

Please also let me know if, after you have had a chance to review this information with Joe, you would like us to put a little more time into refining the configuration we generated with the reservoir pushed to the south, reach out to BPA to get feedback, and develop the concept to the level of detail we did for other alternative configurations so that we can estimate the cost impact.

Geotech Feedback on Seismic Questions
Here are the questions I forwarded to our geotech team and their responses (in RED).

- Would digging a fault trench (or trenches) likely confirm the presence of faults at the site?
  - Digging a fault trench would provide a high probability that we could put our finger on the fault and offset locations, it will be a matter of digging deep enough and extending the fault trench far enough.
    - The layered silt, clay, and sand soil and underlying glacial till below the surficial alluvial deposits would provide a high probability of observing offsets.
    - The length of trench required will depend on where digging starts and the inclination of the past movement (which is unknown) and post offset event surficial weathering and deposition (which mask past surface rupture adding uncertainty to the selection of exactly where to start digging.)

- Would digging a trench be likely to tell us more than just that there is a fault?
  - Excavating a trench would provide a high probability of seeing vertical offset. The magnitude of the vertical offset measured could be used to estimate fault horizontal offset by using ratios of horizontal to vertical movement that have been interpreted from the nearby Creek faults. With both measured vertical and estimated horizontal movement the total slip could be interpreted.
  - Low to very low probability of being able to measure horizontal slip in the trench.
  - Low to medium-low probability of finding recurrence information in a trench that is only excavated into the alluvium deposits at the site. Medium to high probability of finding recurrence information in a trench that extends down into the underlying till.
  - Excavating more than one trench, e.g., on site and off site, would increase the likelihood of obtaining recurrence information.

- If digging a trench (or trenches) is not likely to confirm displacement or recurrence interval, what is the value in digging a trench?
    - At a minimum, we would learn fundamental information about the fault:
        - minimum and possibly total width of the fault zone;
        - if there are secondary strands and where they are located;
        - if the slip is distributed over a broad zone or a narrow plane;
        - a range of dip angle(s) that fault movement would intersect the embankment.
    - Vertical displacement would be measured based on offsets exposed in the fault trench. Horizontal offset and total slip would be estimated as discussed above. Thus, excavating the trench would provide an estimate of displacement to consider for reservoir and embankment design.

- Based on what we know right now, do you think that trying to design the embankment so that it can be built across a fault will lead to a less complicated/better outcome than if we put our effort into shifting the reservoir further to the south or elsewhere so that it doesn't overlap with the fault? Or, asked it this way too…if we had known what we know now from the seismic reconnaissance and believed there were potential faults on the site when we started the 30% design, would we have tried to locate/design the reservoir so that there was no overlap with a potential fault, or would we have designed the reservoir as we did with the expectation that we would be able to design it to handle the displacement, etc.?
    - Avoidance of the fault zone and areas indicating past fault movement is the best option.
        - If during 30% design we had known what we know now regarding the presence of active (post-glacial) faulting at the site we would have tried to locate/design the reservoir so that there was no overlap with a potential fault.
        - If during 30% design we had known what we know now regarding the presence of active (post-glacial) faulting at the site it is unlikely that we would have recommended going forward with a design and with an expectation that we would be able to design the reservoir to handle fault displacement since we would not have known how practical that might have been without further information about the fault.
        - The stability berm on the north side of the reservoir embankment (if incorporated in final design of a southerly shifted reservoir) may not need to be south of the fault zone depending on its configuration, dimensions, etc.
    - Based on what we know now, we would expect an extended review and design modification/development period to complete reservoir and embankment design documents for a reservoir built across an active fault.
        - The downstream population, rate of potential erosion/breach of the embankment should fault offset greater than that selected for reservoir/embankment design, and uncertainty would need to be addressed in the reservoir / embankment design.
        - The process would include us developing a design and providing DSO with exploration data and engineering analyses to support our choices (both of which we would provide for any reservoir and embankment design). Because there may be some subjective decisions to be made as part of selecting some of the reservoir and embankment feature dimensions, we would expect multiple discussions and iterations on the design.
            - The dam design must have a very low probability of failure.
            - Depending on the quality of the information we base our design on and uncertainties in the information and in the design elements, it may be prudent for the project to engage an independent third party to conduct a peer review at various stages of design development. Multiple expertise might be needed for a peer review.
                - Peer reviews are common on complicated, critical, and non-routine projects.
                - DSO may request an independent peer review by a qualified third party engineer be conducted since designing and constructing an embankment across an active fault is not routine.

Note from Dave Rice: We do have experts on our consultant team who have been brought on to

provide peer review of our design work. HDR will provide one of their dam experts to peer review our work and we also have a construction cost estimating firm (Ott-Sakai) to provide constructability review and help with our cost estimates. Our hope/intent is that those folks would provide the peer review needed, but they would not be truly independent of the design team.

- If the reservoir footprint stays essentially where it currently is, lowering the top of reservoir water surface elevation such that it is mostly below the ground surface would be the second choice.
  - …, or constructing so the reservoir is mostly below the surface of a raised ground surface, i.e., where the area around the reservoir is essentially raised by placing excavated material for a wide area beyond the reservoir such that the "embankment" around the reservoir is really wide, fairly flat exterior slope, and not too high above the existing ground surface
    - By doing this it would not look like an embankment and would take longer to erode. A longer time to erode if overtopped or if fractured due to fault offset would change the risk of catastrophic flooding by extending the time overwhich water is releasede from the reservoir.
  - Freeboard should be included around the reservoir to accommodate water displaced by upward ground displacement and seiches.
  - The aerial footprint and excavation volume of a reservoir with sufficient storage would be larger than for the current configuration.

- Are we reasonably confident that there are no faults south of the furthest south line that Chris mapped?
  - Yes.

Thanks,

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From: David Rice
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Subject: Dungeness Reservoir - Seismic Reconnaissance

Hi Steve, Joe, Pat,

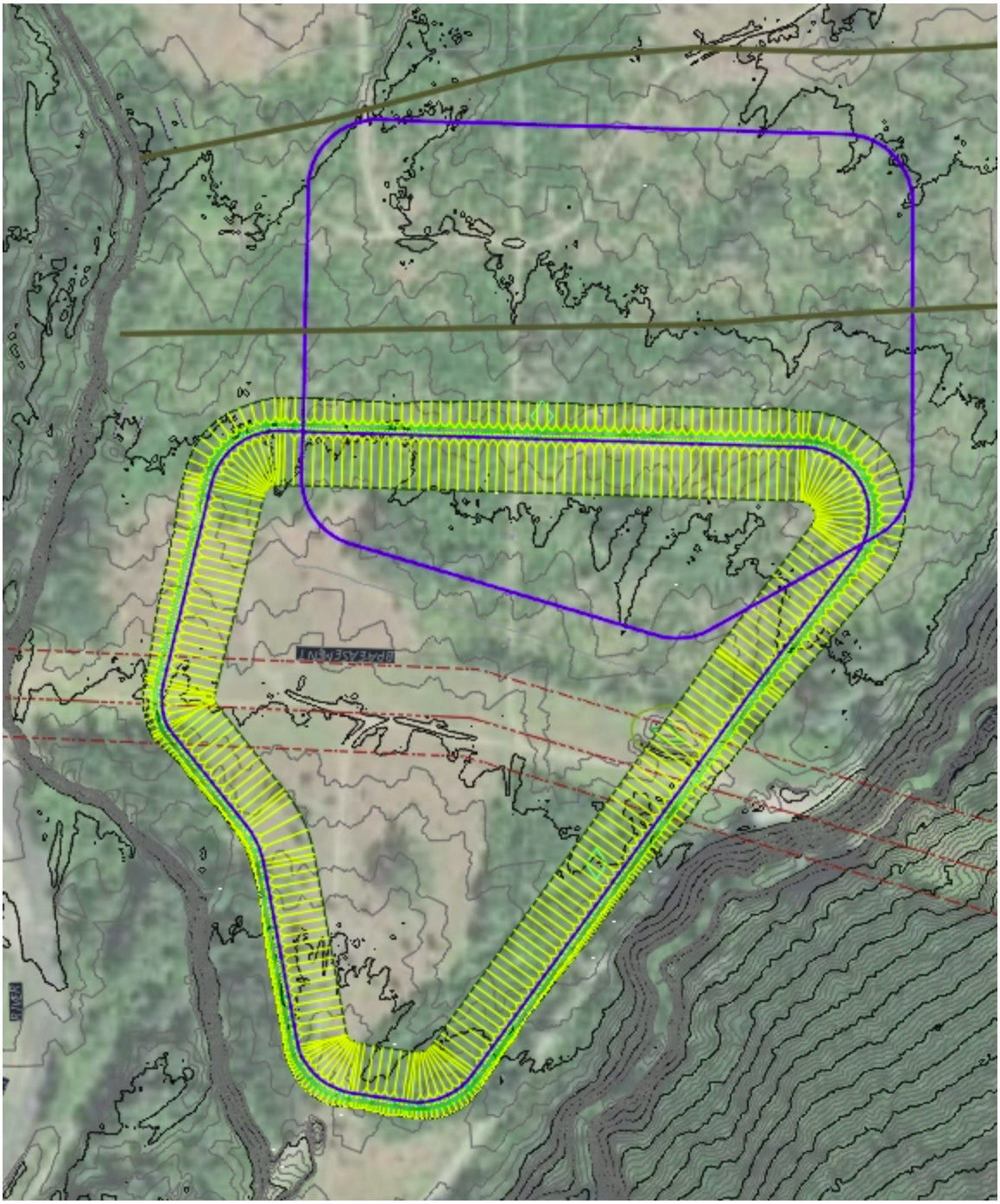
Here's a brief update with some additional thoughts on our path forward toward dealing with the information generated by the seismic-geologic reconnaissance completed by Shannon & Wilson. I've included time to discuss this during our weekly check-in meeting with you this morning.

Is there potential for pushing the reservoir to the south to avoid any of the features that are showing up on the seismic reconnaissance as potential fault zones?

We took an initial look at this by modeling a reservoir in AutoCAD Civil 3D with the reservoir completely south of the furthest south potential fault line that was mapped by Shannon & Wilson's geologist, Chris. The clip below shows the outcome of this exercise. The yellow represents the embankment, but does not include the toe berm (that would need to be added through refinement). The blue line over the yellow area represents the full water surface. The other blue line represents the full water surface of the reservoir included in our preliminary design. Here are a few things to note:

- The volume of the reservoir modeled was just under 1,700 acre-feet. So, we could refine it a little to reduce the volume to 1,600 acre-feet.
- We kept the top of the embankment at 438 feet and the full water surface elevation at 435 feet, which are equal to the numbers we used for preliminary design.
- We also kept the bottom of the reservoir at a similar elevation to what was included in the preliminary design.
- The embankment height and extent are smaller than what we had in the preliminary design because the ground elevation is higher toward the south end of the site. The ground elevation is about 10-12 feet higher at the north end of the reservoir under this configuration that for the preliminary design configuration, which means that the embankment would be about 10-12 feet shorter.
- The excavation volume would be greater than the excavation required for the preliminary design configuration. We have not refined this enough to look at costs yet, but given the trend we've seen with the other configurations we've looked at, I would anticipate the cost to be greater based on the increased excavation volume.
- This configuration does not consider the BPA easement or infrastructure as a constraint. We would need to confirm with BPA whether this was even possible or not. They may have limited ability to restrict what we do on the property their infrastructure crosses if it is truly an easement and not a right-of-way or fee-owned property. We reviewed the documents we have on file for the BPA easement. Based on our read, we think the property is an easement rather than a right-of-way or fee-owned property. Their documents refer to the corridor on which their infrastructure is built as either easements or fee-owned properties, but they refer to both of them as right-of-way, which is kind of confusing. I this case, based on the descriptions provided, we believe their infrastructure is on an easement through the reservoir property. They would likely still require access to their infrastructure for maintenance. There are at least two sets of power poles within the footprint of the reservoir shown in this configuration. Those would probably need to be protected or replaced. So, there would definitely be some work to do to confirm what could and couldn't be done through their easement and the reservoir would need to be configured to meet those constraints, which could reduce the footprint and volume.
- The configuration does not consider the Type 1 Wetland found in the pit near the entrance to the site as a constraint. The impact to that wetland should be something we can mitigate. I'm not sure what the mitigation would look like, but I don't think it would be a big deal.
- We tried to maintain space between the reservoir and the shoreline buffer and between the reservoir and the road to the east.
- I believe most of the cleanup site is still south of the reservoir footprint in this configuration.

If you would like, we can refine this and bring it to the level of detail provided for the other reservoir configurations we've looked at recently (enough detail to plug volumes into our cost spreadsheet and generate a rough cost for it).



What would it take to look at fault displacement and recurrence intervals from nearby faults and determine how those values would impact the embankment design at our site, if we left the reservoir in the same location as shown on the preliminary design?

Shannon & Wilson has already put some effort into this. They have started to research fault offsets of nearby faults and initiated a literature review to try and determine the standards for embankment design in a fault zone. There is still plenty of work left to do on that front, so I asked them to pause until we've had a chance to discuss it further with you. Additional work that could be done to better understand how fault displacement would impact the reservoir design could include:

- Additional research of fault offsets for nearby faults and estimate fault offsets based on desktop correlations with fault dimensions.
- Completion of literature review on embankment dam design for fault offset.
- Develop sketch(es) of a possible revised embankment zone configuration to accommodate estimated fault

offset.
- Develop approximate costs, schedule, and description for a fault trenching exploration at the Project site.
- Model the possible revised embankment zone configurations in Civil 3D to estimate volumes of materials needed.
- Plug the volumes into our cost spreadsheet to determine the impact to cost for the possible revised embankment zone configurations.

About $18-20K worth of time has already been spent beyond the initial presentation of seismic reconnaissance results trying to understand the impacts, coordinating on this issue, researching nearby faults, reviewing literature, etc. Completing these steps would likely take another $35K-$40K. Shannon & Wilson also offered a couple of things to note relative to this work:

1. Cumulative and per-event fault offset cannot be reasonably estimated at this time based on information available. The estimates for fault offset we come up with will be based on interpretations of fault offset from nearby faults, and use of rough desktop correlations developed for other faults. We have no way of knowing if these estimates will be "conservative" or not.
2. We will not be performing any engineering analysis to support the embankment zoning configuration for fault offset. All embankment zoning configurations provided will be very conceptual and subject to change. Changes could be needed based on: future seepage and stability analyses, future seismic deformation analyses, future filter designs and material availability, additional fault information, erodibility considerations, input from DSO, etc. The possible embankment zoning configuration will be provided using hand-drawn sketches. (i.e., Our proposed effort does not include performing drafting. We have assumed we would provide sketches to AnchorQEA for subsequent drafting and inclusion in the reservoir CAD model).
3. After the County and Design Team has developed a plan to propose to DSO, early and frequent communication with DSO will be critical for Project success. It is possible that multiple design concept iterations or additional conversations and coordination with DSO will be necessary to develop a reservoir design concept acceptable to the DSO for the case that a fault is (assumed to be) present at the reservoir site. It is also possible DSO may not accept a reservoir overlapping the fault location.
4. Estimated costs to conduct fault trenching will be very approximate, based on the information we have available now and current labor/equipment rates. We plan to provide approximate costs, schedule, and trenching descriptions in an email format and with hand-drawn sketches (i.e., at this time we will not be developing a formal scope of work and proposal with detailed cost breakdown, or performing drafting).

I'll walk through this during our call this morning.

Thanks,

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