

# **APPENDIX A**

## **Flexible Winter Power Operations Ice Best Management Practice**



## Ice Best Management Practice

### Flexible Winter Power Operations Albeni Falls Dam

Under certain meteorological conditions it is possible that releases from Albeni Falls Dam (AFD) could increase the risk of breaking up a downstream ice cover and causing ice jams, ice jam flooding and damage to structures and property along the Pend Oreille River downstream of AFD (Tuthill and Zabilansky 2011). These conditions might exist after a prolonged duration and severity of freezing conditions sufficient to create a relatively thick ice cover (greater than 4 inches) across the Pend Oreille River downstream of AFD. Under these conditions, it may be necessary to modify winter power operations to avoid elevating the risk of breaking up the ice. The best management practice (BMP) detailed below provides a method to 1) anticipate when potentially hazardous ice conditions exist, and 2) manage discharge from AFD to avoid breaking up the ice when these conditions exist. Monitoring is a key part of the BMP that will be used to confirm the ice conditions in the river.

The BMP tracks accumulated freezing degree days (AFDD) to predict ice conditions on the river. AFDD is a statistic that summarizes the number and severity of freezing days that have occurred over time. An ice prediction model was developed to correlate AFDD with the ice thickness on the river. This model will be used to determine if the river is sufficiently frozen to increase the risk of ice jam flooding. Ice conditions predicted by the model will be verified by monitoring. An ice thickness of about 4 inches across the river is the threshold for modifying project operations.

When the potential for creating an ice jam exists, the BMP decreases the rate of change in discharge from AFD based on predictions from a hydraulic model developed for the Pend Oreille River. The hourly ramp rate is reduced to 2 kcfs/hr. The daily ramp rate is reduced to 5 kcfs/24 hrs and 10 kcfs/48 hrs. This is coupled with a “rest” period of 24 hours after any total increase of 10 kcfs during hazardous ice conditions. The river is monitored to verify predictions of the hydraulic model to confirm that changes in flow do not increase the risk of breaking up the ice.

The BMP is meant to constrain power related operations when potentially hazardous ice conditions exist downstream. During periods of high inflow or floods, existing operations including the 0.5 foot ramping rate for Lake Pend Oreille take precedence.

#### 1. Parameters:

|                    |                                       |
|--------------------|---------------------------------------|
| $T_{w-afd}$        | Temperature of AFD outflow            |
| AFDD <sup>11</sup> | Accumulated freezing degree days (°F) |

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<sup>11</sup> A freezing degree day *FDD*, is calculated as  $32^\circ\text{F} - \text{daily average air temperature } T_a$ . For example, if  $T_a = 20^\circ\text{F}$ ,  $FDD = 32^\circ - 20^\circ = 12$ . An accumulated freezing degree day *AFDD* is the daily summation of *FDD*. Ice thickness  $t_i$  can be calculated from  $t_i = C\sqrt{AFDD}$  where  $C$  is a coefficient typically between 0.3 and 0.6. Based on regional  $T_a$  and

|              |  |
|--------------|--|
| $T_a$        | Daily average air temperature at nearest available station to Cusick.                        |
| $T_{a5}$     | Average of 5-day forecast $T_a$  |
| $Q_b$        | Average discharge from AFD 1 week prior to meeting thresholds for modified winter operations |
| $Q$          | AFD release discharge  |
| $\Delta Q$   | Increase in release discharge above base flow  |
| $\Delta Q/t$ | Ramping rate   |
| $Q_{max}$    | Maximum release flow   |

## 2. Open Water Conditions:

### Assumptions and constraints

- Relatively steady base flow  $Q_b$ : 4-17 Kcfs<sup>12</sup>
- Maximum ramping rate  $\Delta Q/t$ :  $\leq 5$  Kcfs/hr or  $\leq 10$  Kcfs/24 hr
- Maximum outflow  $Q_{max}$ :  $\leq 45$  Kcfs
- Maximum duration of elevated release:  $\leq 14$  days

## 3. Ice Hazard Conditions:

If  $AFDD \leq 100$  (4" of ice) and  $T_{a5} \geq 20$  °F maintain normal operations

If  $AFDD \leq 100$  and  $T_{a5} \leq 20$  °F or  $T_{w-afd} \leq 34$  °F monitor downstream river for the appearance of border ice or frazil ice and be prepared to transition to modified winter operations.

For  $AFDD \geq 100$ , transition to modified winter operations:

- Limit AFD outflow increase ( $\Delta Q$ ) to 10 Kcfs (AFD outflow  $Q \leq Q_b + 10$  Kcfs)
- Limit ramping rate  $\Delta Q/t = 2$  Kcfs/hour and  $\Delta Q/t = 5$  Kcfs/24 hours and  $\Delta Q/t = 10$  Kcfs/48 hours
- During ramp-up period monitor downstream for ice breakup, ice jams, and ice-related flooding
- While  $T_{a5} < 25$  °F hold at  $Q \leq Q_b + \Delta Q$

If after 24 hours no ice problems observed for  $\Delta Q = 10$  Kcfs and  $T_{a5} \geq 25$  °F:

- Limit  $\Delta Q$  to 20 Kcfs ( $Q \leq Q_b + 20$  Kcfs)

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limited  $t_i$  data, a  $C$  value of 0.4 is reasonable for this section of the Pend Oreille River. (EM 1110-2-1612) *Ice Engineering*, 2005) provides greater detail on AFDD and  $t_i$  calculation methods.

<sup>12</sup> Under current operating procedures the average AFD outflow during cold periods from 1980-2009 is has been relatively constant, averaging 16 Kcfs. When storing water in Lake Pend Oreille for later release, it is assumed that the AFD outflow will be lower, on the order of 4-10 Kcfs.

- Limit ramping rate  $\Delta Q/t = 2$  Kcfs/hour and  $\Delta Q/t = 5$  Kcfs/24 hours and  $\Delta Q/t = 10$  Kcfs/48 hours
- During ramp-up period monitor for ice breakup, breakup ice jams, and ice-related flooding
- While  $T_{a5} < 25^\circ\text{F}$  hold at  $Q \leq Q_b + \Delta Q$  (suspend the ramp-up, continue once  $T_{a5} \geq 25^\circ\text{F}$ )

If no ice problems observed at  $\Delta Q = 20$  Kcfs and  $T_{a5}$  remains  $\geq 25^\circ\text{F}$ :

- Limit  $\Delta Q$  to 30 Kcfs ( $Q \leq Q_b + 30$  Kcfs)
- Limit ramping rate  $\Delta Q/t = 2$  Kcfs/hour and  $\Delta Q/t = 5$  Kcfs/24 hours and  $\Delta Q/t = 10$  Kcfs/48 hours
- During ramp-up period monitor for ice breakup, breakup ice jams, and ice-related flooding
- While  $T_{a5} < 25^\circ\text{F}$  hold at  $Q \leq Q_b + \Delta Q$  (suspend the ramp-up, continue once  $T_{a5} \geq 25^\circ\text{F}$ )

If no ice problems observed at  $\Delta Q = 30$  Kcfs and  $T_{a5}$  remains  $\geq 25^\circ\text{F}$ :

- Allow increasing AFD outflow to maximum ( $Q \leq 44$  Kcfs)
- Limit ramping rate  $\Delta Q/t = 2$  Kcfs/hour and  $\Delta Q/t = 5$  Kcfs/24 hours and  $\Delta Q/t = 10$  Kcfs/48 hours
- During ramp-up period monitor for ice breakup, breakup ice jams, and ice-related flooding
- While  $T_{a5} < 25^\circ\text{F}$  hold at  $Q \leq Q_b + \Delta Q$  (suspend the ramp-up, continue once  $T_{a5} \geq 25^\circ\text{F}$ )

If river becomes clear of ice, restart AFDD summation. When AFDD exceeds 100, repeat above procedure.

