ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
POSITION PAPER
FISHERIES ISSUE F-2.4

EXECUTIVE SUMMARY

Issue

Significance of potential changes in dissolved gas on salmon and resident fish habitats and populations downstream of the dams.

Position

It is the position of the Power Authority that both the mitigation measures and the operational procedures proposed for the Susitna Project will maintain dissolved gas concentrations at or below existing levels in areas downstream of the Project. This, in turn, will result in no detectable effect on aquatic resources.

Present Knowledge

Dissolved gas supersaturation resulting in "gas bubble disease" in fish occurs downstream of some hydroelectric facilities and can cause sublethal stress or death in aquatic organisms. Gas supersaturation occurs when water, carrying entrained air, enters a receiving stream. Nitrogen and other gases in the entrained air dissolve into the water as the depth and pressure increase. The resulting dissolved gas concentration at depth becomes greater than surface water saturation at atmospheric pressure. Fish or other aquatic organisms exposed to this supersaturated water may then develop gas bubble disease.

Supersaturation of atmospheric gases occurs naturally in Devil Canyon, presumably due to the extreme turbulence encountered there (ADF&G 1982). A linear relationship has been found to exist between the level of gas supersaturation measured below Devil Canyon and rates of discharge between 10,000 and 32,500 cfs. The highest level of gas supersaturation observed to date was 116 percen. of saturation at a flow of 32,500 cfs. Levels exceeding 116 percent probably occur naturally, since flows exceeding 32,500 cfs are frequent. The mean annual flood, or the flood exceeded on the average every two years, is 50,000 cfs.

Alaska state water quality standards specify that the concentration of total dissolved gas shall not exceed 110 percent of saturation at any point of sample collection. Although total gas concentrations in excess of that standard have been documented to occur at the downstream end of Devil Canyon, no detrimental biological effects of supersaturation have been observed.

The Susitna Hydroelectric Project will be designed and operated to minimize gas supersaturation. Expected dissolved gas concentrations downstream of the dams should be less than 110 percent during normal project operations. Water used to generate power, which is expected to be at or below saturation levels in the reservoirs, will be discharged through turbines and into tailwater below the dams without entraining air. Turbine releases, therefore, will not contribute to gas supersaturation. Environmental flow requirements in excess of power flows will be released through fixed cone valves. Floods having recurrent intervals of 50 years or less will be stored in the Watana reservoir and released through the powerhouse and cone valves. In the two-dam scenario the relative amounts of water to be released through the cone valves and turbines will depend upon electrical energy demand and available storage capacity in the reservoirs. Water released through the cone valves is not expected to result in levels of dissolved gas that would cause impact on the downstream aquatic resources, because the valves disperse the release so that it enters the river as a spray spread over a large area. The spray will not plunge to a depth that would result in significant amounts of additional gas being forced into solution. Therefore, high levels of gas supersaturation are not expected to result from normal project operations.

Floods with recurrence intervals of greater than 50 years will be released through the turbines, cone valves and spillways. The spillways will not be operated until the flood storage pool (between El 2,185 and El 2,193) is filled and the release capacity of the cone valves, in combination with the powerhouse discharges, is exceeded. Water released over the spillways will not be dispersed as much as releases through the cone valves. Therefore, it is anticipated that these flows will entrain air and carry this air/water mixture to sufficient depth to result in levels of gas concentration exceeding levels resulting from cone valve operation. However, dissolved gas concentrations under high flow conditions with the project are expected to be no higher than those which may occur under natural flood conditions without the project, and they will occur much less frequently than is currently the case.

The proposed manner of operating Watana prior to the construction of the Devil Canyon Dam will limit the maximum streamflow to approximately 30,000 cfs for floods with recurrence intervals of less than 50 years. Since the mean annual flood with the Project will be 15,000 cfs as compared to 50,000 cfs under natural conditions, there will be an overall decrease in the frequency of occurrence and maximum levels of gas supersaturation which occur in Devil Canyon. When Devil Canyon Dam begins operation, a large portion of the Devil Canyon rapids, which at present can cause high dissolved gas concentrations, will be bypassed (via the powerhouse tailrace discharges which will be returned to the mainstem river flow downstream of some of the most turbulent rapids) or inundated, reducing supersaturation when compared to naturally occurring levels.

Mitigation Measures Endorsed by Alaska Power Authority

Mitigation measures proposed by the Power Authority include the use of a flood storage pool and fixed cone valves to store or discharge water in excess of powerhouse flows. The absence of air entrainment in powerhouse flows, the use of fixed cone valves, and flow regulation by the reservoirs will result in reduced dissolved gas concentration levels compared to natural conditions (APA 1983).

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INTRODUCTION

Issue

Significance of potential changes in dissolved gas on salmon and resident fish habitats and populations downstream of the dams.

Position

It is the position of the Power Authority that both the mitigation measures and the operational procedures proposed for the Susitna Project will maintain dissolved gas concentrations at or below existing levels in areas downstream of the Project. This, in turn, will result in no significant impact on the aquatic resources from excessive gas supersaturation.

DISCUSSION

Present Knowledge

The absolute quantity of dissolved gas that water can hold is a function of water temperature and pressure. The capacity of water to hold gas in solution (dissolved) increases with increasing pressure and decreases with increasing temperature. Dissolved gas supersaturation occurs when either the temperature or pressure of water with a given amount of dissolved gas concentration changes to the extent that it exceeds saturated levels at the new conditions.

Gas supersaturation can affect the biochemistry, physiology, and behavior of aquatic organisms by causing gas bubble disease. When fish encounter water having dissolved gas concentrations in excess of saturation, the gas in the water diffuses through the gills, tending towards equilibrium within the fish at the supersaturated level. Then, when the fish leaves the zone of supersaturated water, gases in the blood and other body fluids begin to come out of solution, forming bubbles inside the fish. The bubbles can cause circulation blockages and disruption of tissues. The overall effects on an organism can vary from sublethal stress to death (Fickeison and Schneider 1976).

Causes of Supersaturation. Supersaturated dissolved gas concentrations may occur at dams and hydroelectric facilities by any of the following mechanisms:

1. Spillway discharges entering the receiving stream can cause entrainment of air bubbles to depth where the change in hydrostatic pressure results in higher dissolved gas concentrations.

2. Leakage of air into powerhouse turbines, where sufficient pressures may exist to force excess gas concentrations into solution. In some hydroelectric facilities air is "bled" into turbines to prevent cavitation damage to turbine runners.

3. Withdrawal of nitrogen saturated water from depth in a body of water, such as the cold hypolimnion layers of a reservoir, and to warmer temperatures and lower pressures, which may then result in a temporary condition of gas supersaturation, until aquatic gas concentrations can equilibrate with the atmosphere. This stiuation does not have any turbulence associated with it; turbulence would result in more rapid equilibration to ambient conditions.

Gas supersaturation has not been observed in the Susitna River upstream of Devil Canyon (e.g. upstream of river mile 150-163). Gold Creek, located below Devil Canyon, enters the Susitna mainstem at approximately 100 percent gas saturation. It is presumed that other rapidly flowing tributaries also enter the mainstem Susitna with approximately 100 percent gas saturation levels. Gas supersaturaion is apparently produced in the mainstem Susitna, under natural conditions, within Devil Canyon rapids. Gas supersaturated water appears to be caused by the entrainment of air in the rapids and pressurization of the water in plunge pools. The measured levels of gas concentration appear to be directly related to river discharge rates flowing through the canyon, within the discharge ranges observed to date (i.e. 10,000-32,500 cfs) (ADF&G 1982; APA 1983, Fig. E-2-85). Although gas concentrations of 115 to 116 percent have been observed at the mouth of Devil Canyon, neither fish embolisms nor evidence of gas bubble disease have been observed in the Susitna River to date (ADF&G 1982). Alaska water quality standards specify maximum allowable total dissolved gas levels of 110 percent of saturation at any point of sample collection (18 Alaska Administrative Code 70.020).

An additional concern regarding gas supersaturation is the rate at which supersaturated gas in flowing river water returns to equilibrium through contact with the atmosphere. The rate at which gas will come out of solution is dependent on the water temperature and the exposure of the water to lower gas pressures. Gas supersaturated water has been observed to persist for long downstream distances where adequate opportunities did not exist for the dissolved gases to equilibrate with the atmosphere (Boyer 1974; Fickeison and Schneider 1976).

Measurements of total gas concentration in several reaches downstream of Devil Canyon at 16,000 cfs and 32,500 cfs have been used to study the rate of dissipation of gas supersaturation in the Susitna. Analysis of the data indicates that the dissipation rate can be modeled by an exponential decay function and that the amount of supersaturation is reduced by approximately 50 percent in the first 20 miles downstream. The dissipation rates have not been modeled further than 20 miles downstream, but any supersaturated conditions would be expected to decrease further due to shallower channel depths, more water surface area in contact with the atmosphere, and dilution of mainstem waters by tributary influent (ADF&G 1982).

<u>Biological Effects</u>. The potential biological effects of excessive gas supersaturation below Devil Canyon rapids, should the situation occur, would depend on several factors, including:

1. The seasonal timing of supersaturation.

2. The level of supersaturation.

3. The downstream extent of supersaturated water.

4. The amount of time that the organisms are exposed to the condition.

5. The biological characteristics of the organisms in question.

Large controlled releases are most likely to occur during middle to late summer or early fall when the reservoir(s) are full, under most conditions, according to proposed operational schemes (APA 1983, APA 1984). At this time, adult salmon will be using the Middle River mainstem channel as a migratory route to spawning habitats. The mainstem channel and peripheral habitats will also be utilized for rearing by juvenile salmon and resident fish during this period. Under with-project conditions, and without any mitigation measures, potential biological effects of excessive gas supersaturation might involve disruptions of adult salmon inmigration to spawning areas, and/or detrimental effects on rearing juvenile salmon or resident fish. The effects of gas supersaturation are often less severe and less prolonged on smaller organisms, like benthic invertebrates and relatively small fish (Fickeison and Schneider 1976; Dawley et al. 1975). Consequently, impacts on small fish might be less than for inmigrant adult salmon. In addition, high levels of gas supersaturation will most likely coincide with high volume flow events of relatively short duration. During high flow events, mobile aquatic organisms such as juvenile fish will likely seek the slower velocities and better water quality conditions in the more shallow, peripheral habitats. In any case, high flow events will be shorter in duration and will occur less frequently with the Project in place as compared to natural conditions.

MITIGATION

Mitigation Measures to Avoid Negative Biological Impact

Project design and operations have been proposed to minimize the potential for impacts on downstream fisheries due to excessive gas supersaturation. For normal powerhouse discharges, and for all floods with recurrence intervals of less than 50 years, the Project is not expected to cause excessive concentrations of supersaturated gas. The operational plans would usually result in gas saturation levels which are equal to or less than naturally existing levels, primarily because the frequency and magnitude of high flows through Devil Canyon would be diminished.

Watana Operations. The proposed design for Watana Dam includes multilevel intakes for water withdrawal from the upper 120 feet of Watana Reservoir. Powerhouse flows will be discharged below tailwater elevations near the downstream toe of the dam in order to prevent entrainment of air into the flows. This also will serve to maximize power production efficiency. Discharges that will be withdrawn for environmental flow requirements or to pass flood flows would be routed through the six fixed cone valves which will have a combined capacity of 24,000 cfs. The fixed cone valves will disperse their releases in the form of a spray spread over a large area of impact and this will prevent plunging of releases to a depth sufficient to cause significant additional amounts of dissolved gas.

Releases from Watana Dam and Reservoir (with no Devil Canyon Dam) could still cause gas supersaturation in the Middle River reach by flowing through lower Devil Canyon rapids, as under natural conditions. Therefore, until Devil Canyon Dam and Reservoir are operational, the total downstream releases from Watana Dam, for all flows less than the 50-year flood recurrence level, will be limited to a maximum of 30,000 cfs. By using Watana to control maximum flows through Devil Canyon rapids, the Project should be able to maintain any naturally caused gas supersaturation within acceptable levels.

Devil Canyon Operations. Devil Canyon Dam will involve withdrawing water for its turbines from the upper 50 feet of the reservoir. Each of the four powerhouse turbines will have a rated capacity of 3,680 cfs. Powerhouse flows will be discharged through a 6,000-foot-long tailrace tunnel and will bypass the lower Devil Canyon rapids. These flows will be released below tailwater levels near the downstream end of Devil Canyon, in order to prevent air entrainment in the flows and to maximize plant efficiency. Devil Canyon Dam will have seven fixed cone valves for releasing environmental and flood flows while minimizing gas concentrations downstream.

Total discharges from the powerhouse and cone valves of Devil Canyon Dam under proposed project operations will be no greater than 38,500 cfs for flood flows with recurrence intervals less than 50 years. Flows greater than the 50-year flood will be released through a combination of cone valves, turbine discharges and spillways.

For all flows less than the 50-year flood, the proposed Project, with Devil Canyon Dam, will discharge less than the natural mean annual flood (50,000 cfs) through a short section of Devil Canyon rapids. Therefore, dissolved gas concentrations will be reduced from naturally occurring levels and any biological effects due to gas supersaturation will be eliminated or reduced.

Mitigation Measures Endorsed by Alaska Power Authority

Mitigation measures proposed by the Power Authority include the use of a flood storage pool and fixed cone valves to store or discharge water in excess of powerhouse flows for all conditions up to and including the 50-year flood. The absence of air entrainment in powerhouse flows, use of fixed cone valves and flow regulation by the reservoir will result in reduced dissolved gas concentration levels compared to natural conditions (APA 1983).

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