DEPARTMENT OF THE ARMY
Office of the Chief of Engineers
DAEN-CWE-HD Washington, DC 20314

Engineer Technical
Letter No. 1110-2-239

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Engineering and Design
NITROGEN SUPERSATURATION

1. Purpose. The purpose of this letter is to provide guidance for the evaluation and identification of those projects with hydraulic structures having the potential to produce nitrogen supersaturation.

2. Applicability. This letter applies to all field operating agencies having responsibilities for the design of Civil Works projects.

3. References.

a. ER 1130-2-334

b. ER 15-2-11

4. Bibliography.

a. ER 1110-2-1402

b. EM 1110-2-1602

c. EM 1110-2-1603

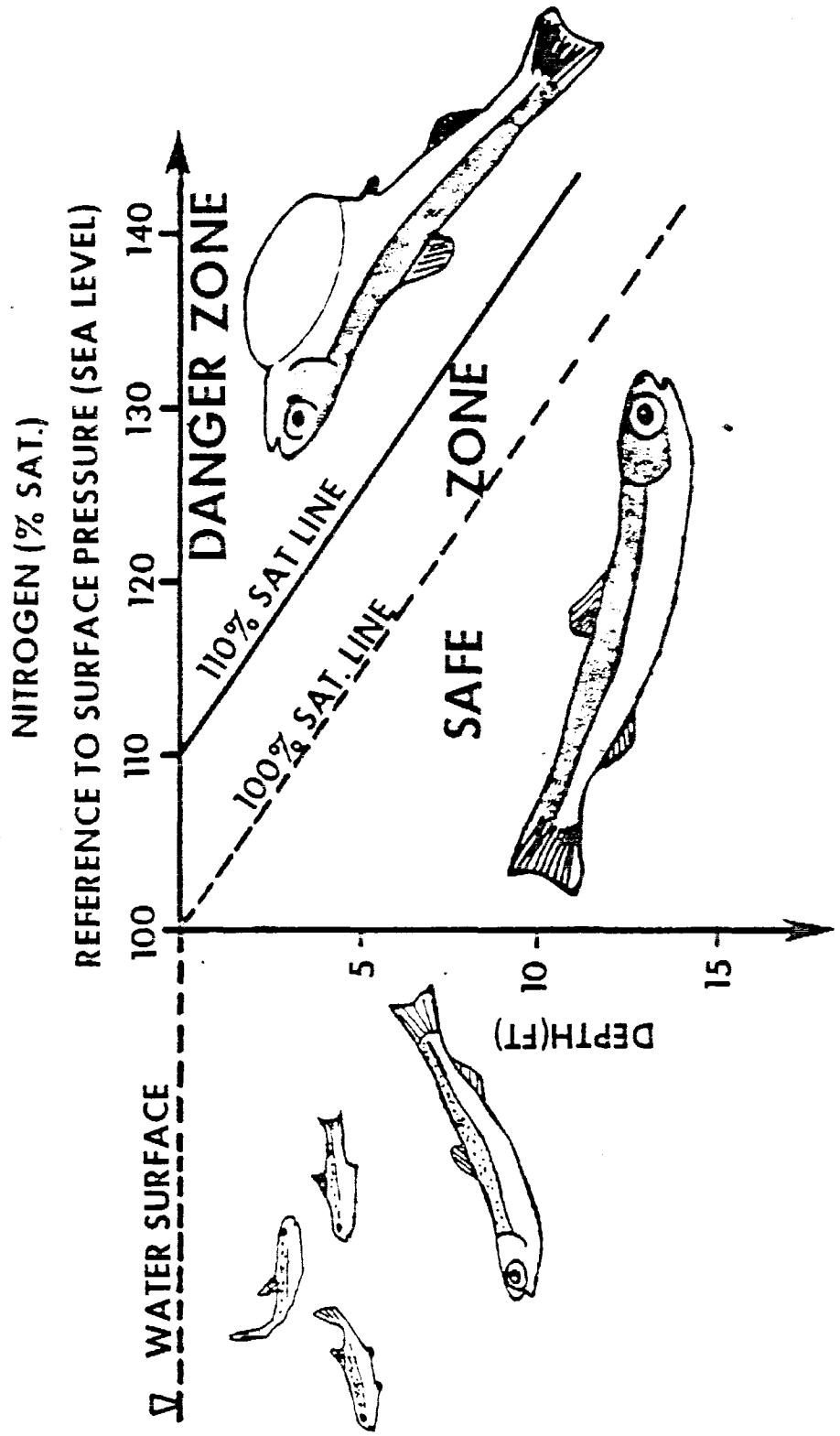
5. Discussion.

a. Nitrogen supersaturation and associated fish mortality due to gas bubble disease has occurred at Corps of Engineers projects on the Columbia River in the North Pacific Division (NPD) and more recently at the Harry S. Truman project in the Missouri River Division. Nitrogen supersaturation can result at any hydraulic structure from entrained air introduced by the spillway-stilling basin action. As the flow is subjected to hydrostatic pressure in the stilling basin, a portion of the entrained air is driven into solution before it has the opportunity to rise to the surface and escape into the atmosphere. A potential problem situation will exist if the characteristics of the flow within or downstream of the

stilling basin are such that the flow does not have the necessary turbulence to degas or purge itself of the excess dissolved nitrogen. Flow conditions below projects conducive to rapid equilibration with the atmosphere are shallow, turbulent streams. The reaeration and gas transfer characteristics of deep, slow moving rivers or downstream reservoirs are relatively small. Generally, fish will not suffer from gas bubble disease so long as they swim in depths below 15 feet. At those depths the external and internal gas pressures on fish are approximately equal. If the fish swim to the surface, however, the internal gas pressure exceeds the external gas pressure on the fish resulting in gas embolism or gas bubble disease. The tolerance of fish to levels of nitrogen supersaturation depends upon the time of exposure and the age and species of the fish; however, dissolved nitrogen levels referenced to surface pressure above 110 percent are generally considered to be harmful. (Figure 1.)

b. The phenomenon of nitrogen supersaturation below hydraulic structures is complex and depends upon a number of factors. Normally the problem of nitrogen supersaturation has been associated with aerated flows plunging into deep stilling basins with slow moving downstream flow conditions. If the hydraulic jump in the stilling basin is a free jump, sufficient turbulence should be present to degas the flow so that dissolved nitrogen levels referenced to surface pressure will not exceed 110 percent. If the hydraulic jump is submerged, the flow may plunge to the bottom of the basin. With submerged hydraulic jump flow conditions, the change in momentum of spillway or outlet works releases due to a typical 50 foot radius toe curve subjects the flow to a pressure about 1.16 times the hydrostatic pressure on the apron due to the downstream tailwater. The jump will become fully submerged when the tailwater depth is greater than approximately 125 percent of the theoretical d_2 value. It should be noted that roller bucket stilling basins are designed for tailwaters greater than 125 percent of d_2. In general, if for a given discharge the tailwater exceeds a depth of 25 feet and if the tailwater depth is greater than 110 percent of theoretical d_2 (partially submerged jump) and if flow conditions downstream of the project are not conducive for degassing the flow, the potential for nitrogen supersaturation exists and should be investigated.

c. Nitrogen levels can be determined by measuring total gas content with a gas saturometer and subtracting dissolved



THEORETICAL SAFE AND DANGER ZONES FOR FISH

FIGURE 1

oxygen content measured or by using a calibrated gas chromatograph. Techniques to estimate the percentage of nitrogen supersaturation below a hydraulic structure have been developed by NPD and by the U.S. Bureau of Reclamation (USBR). Inclosure 1 gives a summary of the development and evaluation procedure for the NPD method. Inclosure 2 gives a summary of the USBR method. The technique developed by NPD was based on projects in the Columbia River Basin. The spillways are all gate-controlled ogee crests and with the exception of The Dalles, they have similar stilling basin characteristics. The NPD method should be used to evaluate the effects of structures similar to those in the Columbia River Basin. The coefficients for this technique are based on these types of structures. The technique developed by the USBR is more general than the NPD technique and utilized data from a wider variety of hydraulic structures. The USBR technique should be used to evaluate the effects of structures other than the type found in NPD. Both techniques compute downstream nitrogen concentration values by considering such variables as upstream concentration, headwater and tailwater elevations, head loss, angle of the jet, residence time of the bubbles, and pressure conditions in the basin.

d. If measurements or estimates indicate that a potential for nitrogen supersaturation problems exists, then detailed model studies of the project may be necessary to develop alleviation measures. Assistance in the studies can be obtained from the Waterways Experiment Station. Also, technical assistance can be obtained from both the Federal Interagency Steering Committee on Reaeration Research and the Committee on Water Quality (reference 3b). Requests for the services of either of these committees should be coordinated through HQDA (DAEN-CWE-H) WASH DC 20314.

6. Action Required. Review all reservoir projects, following the procedures outlined in Inclosures 1 and 2, to determine potential for nitrogen supersaturation problems under all operating conditions including interim conditions during construction.

a. Existing Projects. Report results and proposed corrective measures in Annual Division Water Quality Reports (reference 3a).

b. Projects under Planning, Design or Construction. Report results and proposed alleviation measures if required in

appropriate portions of Survey-Feasibility Reports, Design Memoranda, Detailed Project Reports, etc.

FOR THE CHIEF OF ENGINEERS:

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