RESEARCH PROJECT TECHNICAL COMPLETION REPORT

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OWRR Project No. A-011(CONN) OWRR Agreement No. 14-01-0001-001

Project Title Reduction of River Heat Pollution by Turbulence Stimulation

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Project Began (Mo. - Yr.) July 1965 Project Ended (Mo. - Yr.) June 1969

PROJECT OBJECTIVES:

A. To study experimentally the generation of turbulence from river-bottom roughnesses by means of air-flow models.

B. To study the influence of such turbulence on the diffusion at the interface of temperature stratified flows.

ACHIEVEMENT OF PROJECT OBJECTIVES:

A. It was discovered that typical dune-type roughnesses produce heavy turbulence immediately adjacent to the roughness, but that the general stream turbulence levels are not greatly affected by the bottom surface.

B. Local turbulence level produces a marked effect on diffusion coefficients. This shows up very strongly in air where gravitational influences are relatively weak. The diffusion coefficient was shown to vary approximately as the cube of the turbulence intensity.

RESEARCH PROCEDURES USED:

In both sets of experiments small low-turbulence wind tunnels were used as a flow source. For the tests on natural bottom roughness the test area was six feet long and of square cross-section, one foot on a side. The diffusion studies employed a wind tunnel which had a 15 foot long test area and a one foot by two foot cross-section.

Instrumentation and control was similar in both test arrangements. A variety of pitot impact and static probes was used to measure velocities and static pressures. Static pressure taps were set in the side walls to monitor velocity profiles along the tunnels. Both test areas had means provided to bleed air in order to maintain constant velocity flows. For turbulence measurements commercial hot-wire probes of the constant temperature type were employed. These could measure both mean and turbulent (r.m.s.) velocities. Air speed was controlled by varying the rotational speed of the blowers.

A. The "natural" river-bottom roughness was cut in wood to represent a typical bottom sand dune. Since the measuring station was fixed in longitudinal position, it was necessary to move the bottom in order to study specific positions on the individual dunes or waves. In all cases there were at least four complete sand waves ahead of the test point so that the flow pattern was fully developed.

B. The special features of the diffusion tests consisted of a grid which could heat the air in the upper part of the tunnel to provide a thermal stratification and two tunnel floors, one rough and one smooth. The rough floor used square bars transverse to the flow to produce a high turbulent intensity. The high level turbulence intercepted the thermal interface simply as a result of normal boundary layer growth.

RESULTS OR CONCLUSIONS:

A. The studies on the natural bottom roughness revealed that for dunes on which separated flow does not occur:

1. The skin friction on the sand wave is less than that on a smooth surface.

2. The form drag is quite high resulting in a total resistance about twice that due to a smooth surface.

3. The thickness of the highly turbulent layer is greatest at the trough and smallest at the crest of the dune.

4. The trough exhibits the greatest turbulent intensity and is the region which produces the conditions for sand movement to make the dunes travel along the river bottom.

5. The high level turbulence does not penetrate very far into the main stream so that natural roughnesses will have very little influence in mixing thermally stratified flows.

B. The studies on thermally stratified flows showed that the diffusion coefficient varies approximately as the cube of the turbulence intensity. Relationships were developed to evaluate the growth of the interface for thermally stratified flow. Because the turbulent intensity varied across the interface, these relations were only approximate.

It should be noted that by running the experiments with air rather than with water, an exaggerated picture of mixing of the thermal layers is obtained. In water, the gravitational field provides a stabilizing influence and suppresses the mixing of stratified layers.

LIST OF PUBLICATIONS:

Khanna, Sat Dev. Dissertation: "An Experimental Investigation of Turbulence Due to Forms of Bed-Roughness". University of Connecticut. June 1968 (Available from University Microfilms, Inc., Ann Arbor, Michigan.)

Prasuhn, Alan Lee. Dissertation: "A Study of the Mixing of Heat Stratified Flow under Varying Turbulence Conditions with Application to the Reduction of River Heat Pollution". University of Connecticut. June 1968 (Available from University Microfilms, Inc., Ann Arbor, Michigan.)

Prasuhn, A. L. and Scottron, V. E. "Reduction in River Heat Pollution by Turbulence Stimulation". University of Connecticut, Civil Engineering Department, Report No. 69-22, May 1969 (Reprinted from Proceedings of the Annual North Eastern Regional Antipollution Conference, July 22-24, 1968, University of Rhode Island.)

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ABSTRACT:

A. A wind tunnel study was made of a two-dimensional natural river bed model containing sand waves. Data were taken regarding mean velocity distribution angle of flow, static pressure distribution and longitudinal turbulence intensity along a typical wave. While valuable conclusions were obtained concerning the mechanism of bed-load transport, natural bottom roughness did not appear to assist in preventing thermal stratification.

B. A wind tunnel study was made of a two-dimensional heat-stratified flow. A mathematical model was developed and compared with measured temperature profiles for flow over both smooth and rough boundaries. Increased turbulence levels greatly accelerated the mixing rates.

KEYWORDS:

Pollution*
Turbulence*
Diffusion
Transport