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Hydrothermal Modeling of the Cooling Water Discharge from the Vermont Yankee Power Plant to the Connecticut River

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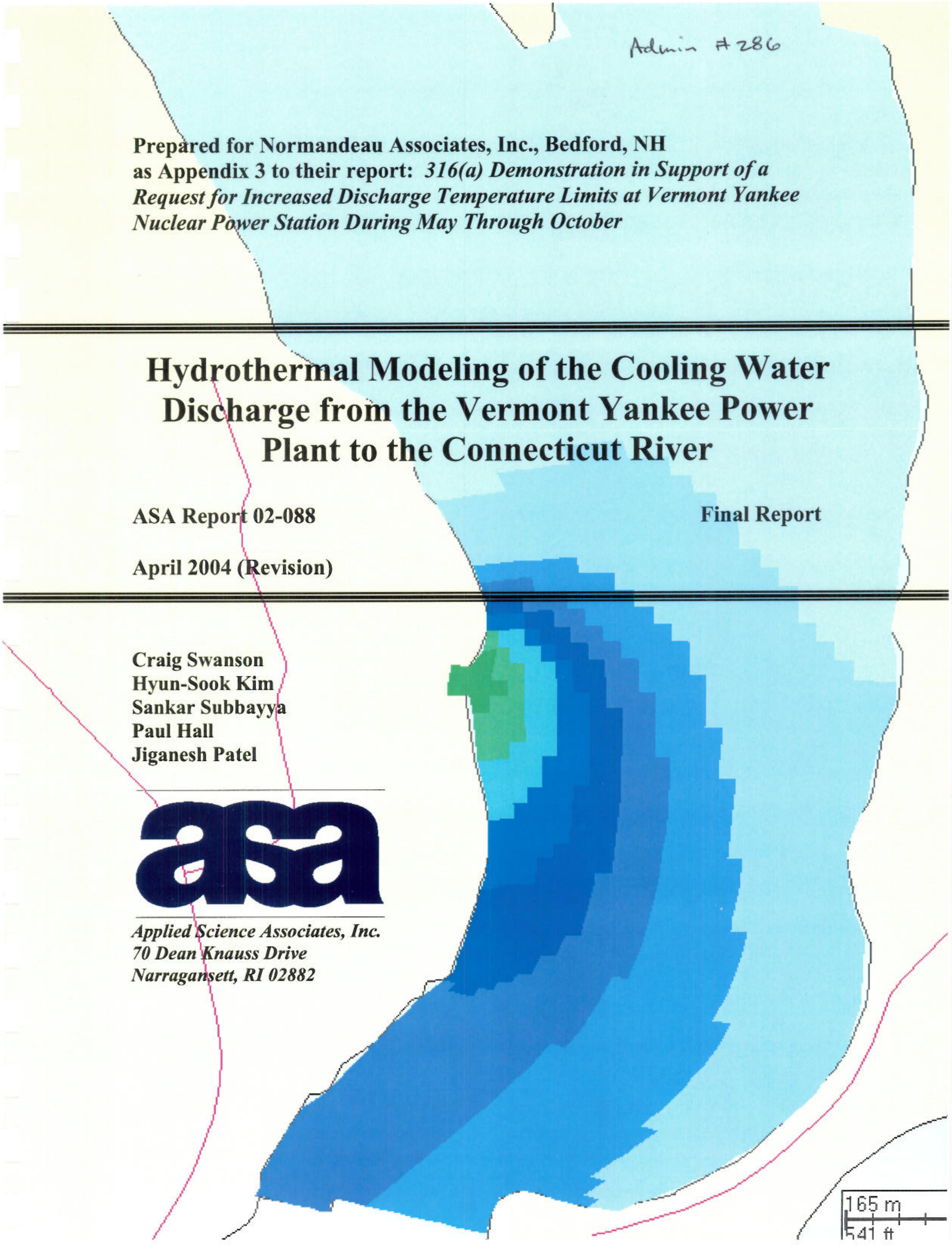

Executive Summary

The Vermont Yankee Nuclear Power Station (Vermont Yankee), an electric-generating station, is located on the Connecticut River in Vermont above the Vernon Dam. Vermont Yankee uses a sophisticated cooling system that varies from an open cycle, once-through cooling water configuration to a closed cycle, cooling tower configuration that recirculates the cooling water. In support of a request to increase discharge temperature limits during the summer period pursuant to a 316(a) of the Clean Water Act, Applied Science Associates, Inc. (ASA) was contracted to assess the thermal discharge from the plant and its effects on the River using a state-of-the-art, boundary fitted computer simulation model accepted by the United States Environmental Protection Agency and numerous state regulators.

The model was calibrated and confirmed to data collected from a set of continuous monitoring thermistors as part of a field program from May through October 2002. The data also included river flows and water temperatures obtained from permanently deployed instruments used in Vermont Yankee's operations. The model calibration and confirmation exercises used data sets acquired in August and June – July 2002, respectively. The August calibration period was chosen to be representative of warm river temperatures and low river flows. The June – July confirmation period was chosen to include warm river temperatures occurring during fishway operations.

Results of the calibration and confirmation indicated that the model predicted both flows and temperatures well. The flow predictions for the calibration and confirmation periods were very successful, exhibiting RME and ECV values less than 3% and 4%, respectively, which were smaller (better) than U. S. EPA guidance levels (30% and 10%, respectively). Correlations between the prediction and observations were excellent, with r^2 values of 0.92 and 0.98 for the calibration and confirmation periods, respectively, which were larger (better) than the guidance level of 0.88.

The calibration results indicated that temperature predictions were also good. Best results were obtained at the upper layer, but they became somewhat reduced with depth. Squared correlation coefficients at the surface were usually larger (better) than the U. S. EPA guidance level of 0.71, and the correlations became smaller with depth. However, RME and ECV for all three layers ranged between 0 and 5.6%, showing that they were smaller (better) than the EPA guidance levels (25% and 45%, respectively) and suggesting that the predictions throughout the water column were acceptable.

The confirmation results indicated that the model performed excellently in simulating the thermal conditions of June – July 2002. The surface temperature predictions showed RME values ranging between 0.6% to 3.0% compared to the guidance level of 25%, ECV values between 2.6% and 8.1% compared to the guidance level of 45%, and r^2 greater than 0.66 compared to the guidance level of 0.71. Similar variations in model error statistics were found at the middle and bottom layers. Based on the successful calibration and confirmation, the model could then be used for predictions under selected plant and river conditions.

Two sets of scenario simulations were performed for the August and June – July periods separately, to investigate the effect of proposed new temperature limits within the portion of the lower Vernon Pool affected by the Vermont Yankee discharge during the summer permit compliance period and during the period of fishway operation, respectively. For the August period, a 1°F (0.6°C) increase from 2°F (1.1°C) to 3°F (1.7°C) resulted in a marginal increase in the temperature of the water column or on the bottom. For worst conditions occurring only 1% of the time, 30% of the bottom area increased by at least 0.3°C (0.5°F) and 20% increased by a maximum of 0.4°C (0.7°F). For typical conditions occurring 50% of the time, 30% of the bottom area increased by at least 0.1°C (0.2°F), 20% increased by at least 0.2°C (0.4°F) and 10% increased by a maximum of 0.6°C (1.1°F). Similar results were obtained for changes in water column volume.

Temperature predictions during June and July when the fishway was operating with warmest river temperatures indicated that a 1°F increase in temperature rise generally resulted in similar increases (0.4°C) [0.7°F] in water temperature regardless of whether conditions were worst (1% of the time), infrequent (10% of the time) or typical (50% of the time). There was a slight increase in effects under typical conditions of higher river flow and therefore higher plant flow. Results also indicated that the ambient water temperature primarily influenced the temperature in the fishway rather than Vermont Yankee's rejected heat.

Based on the hydrothermal modeling results, a 1°F (0.6°C) increase in the permit limit from 2°F (1.1°C) to 3°F (1.7°C) resulted in *de minimus* changes in the thermal structure of the Vernon Pool.

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1. Introduction

Entergy Nuclear Vermont Yankee, LLC (Entergy VY) owns the Vermont Yankee Nuclear Power Station (Vermont Yankee), an electric-generating station located in Vermont, on the Connecticut River (River) above the Vernon Dam, a hydroelectric facility owned by PG&E National Energy Group. Vermont Yankee uses a sophisticated cooling system that varies from an open cycle, once-through cooling water configuration to a closed cycle, cooling tower configuration that recirculates the cooling water. In support of a request to increase discharge temperature limits during the summer period pursuant to a 316(a) of the Clean Water Act, Applied Science Associates, Inc. (ASA) was contracted through Normandeau Associates, Inc. to assess the thermal discharge from the plant and its effects on the River using a state-of-the-art, boundary fitted computer simulation model accepted by the United States Environmental Protection Agency and numerous state regulators.

The purpose of this study was to determine what effects, if any, the increased Vermont Yankee thermal discharge would have on the thermal structure of the River, particularly during the late summer period of low River flow and warm River temperatures. The study included a field program (i.e., collection) component to characterize the physical thermal regime in the Vernon Pool. A hydrothermal modeling study designed to characterize the circulation and temperature distribution in the River followed. The modeling study was designed to evaluate the potential effects of Vermont Yankee's proposed increase on the temperature distribution in the River under expected and worst-case conditions.

This report documents the hydrothermal model application, calibration and confirmation, which then provided predictions of the thermal regime in the Vernon Pool under relevant scenarios. Section 1 provides an introduction to the study, including background and purpose, and structure of the report. Section 2 describes the study area, the Vernon Pool, on the Connecticut River above the Vernon Dam and the relevant information about dam and plant operations and layout. Section 3 describes the thermal plume mapping and other field studies and data used in the modeling study. Section 4 describes the hydrothermal model (BFHYDRO) and the Water Quality Mapping and Analysis Package (WQMAP) system, of which the model is a part. This section also describes the application of the model to the Vernon Pool and the results of the calibration and confirmation procedures. Section 5 presents the thermal plume simulations for a series of selected environmental and plant operating conditions. Section 6 presents a summary and conclusions. Section 7 lists references. Presentations of the environmental, dam and plant data during selected periods are included as appendices as are descriptions of the BFHYDRO model and the WQMAP system.