DEPARTMENT OF THE ARMY
NEW ENGLAND DISTRICT, CORPS OF ENGINEERS
696 VIRGINIA ROAD
CONCORD, MASSACHUSETTS 01742-2751

REPLY TO
ATTENTION OF

July 19, 2007

Engineering/Planning Division
Geo-Environmental Engineering Branch

SUBJECT: Simulated Hydrologic Responses to the Removal of Two Dams on the Woonasquetucket River, North Providence, Rhode Island.

Anna Krasko
U.S. EPA, New England Region
1 Congress Street, Suite 1100 (HBO)
Boston, Massachusetts 02114-2023

Dear Ms. Krasko:

Enclosed is a description of a numerical model that was constructed by USACE personnel to assess possible hydrologic responses to the removal of the Allendale and Lyman Mill Pond dams along the Woonasquetucket River in North Providence, Rhode Island. The expressed concerns were the possible effects of dam removal on water levels and ground-water flow patterns near the "Oxbow" wetland between the two reservoirs. The model results indicate that the wetland receives much of its water from precipitation and runoff from adjoining upland areas and that water levels and flow patterns near the wetland would be minimally affected by dam removal. This is a limited study, additional model runs can be made to provide insights on the effects of uncertainties, such as aquifer hydraulic properties, on model results.

Thank you for the opportunity to perform this analysis. Please contact Forest Lyford (978) 318-8046 or Mike Kulbersh (978) 318-8088 if you have questions about the model and results.

Sincerely,

H. Farrell McMillan

H. Farrell McMillan, P. E.
Chief, Engineering/Planning Division

Enclosures

Copy Furnish:
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U.S. EPA, New England Region
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Boston, Massachusetts 02114-2023

Simulated Hydrologic Responses to the Removal of Two Dams on the Woonasquetucket River, North Providence, Rhode Island

July 2007

Introduction

The removal of the Allendale and Lyman Mill Dams on the Woonasquetucket River in North Providence, Rhode Island, is being considered as part of a sediment-restoration project. Concern has been expressed about the effects that dam removal might have on water levels and sustained viability of a wetland (also known as the Oxbow Wetland) between the two reservoirs and on groundwater flow patterns that might cause contaminants to move from the area of the Centredale Manor Restoration Project Superfund Site to the wetland.

At EPA's request, the U.S. Army Corps of Engineers, New England District, developed an approach to address these concerns. A numerical modeling approach was used to take into account many interacting physical features and hydrologic conditions that could not be assessed using analytical methods. A simple representation of the hydrologic system was selected to provide insights on possible responses and to provide a basis for follow-on comprehensive investigations, if needed. Two figures show simulated flow patterns before and after dam removal and groundwater-level declines that might result from dam removal (see attached).

Model Design

The valley-fill aquifer system was conceptualized as a transmissive valley-fill aquifer bounded on each side by less transmissive till and bedrock in uplands. The valley-fill aquifer receives water principally by infiltration of precipitation and runoff from uplands. The reservoirs along the Woonasquetucket also are potential recharge sources, particularly in downstream reaches. Some water in upland areas discharges to intermittent streams, and water in the valley drains to the river, reservoirs, and the wetland.

The USGS software, MODFLOW and MODPATH, were used for this model analysis. The flow model was designed with one layer to simulate the valley fill. The layer was extended into the adjoining uplands to account for runoff (surface and groundwater) that is available for recharge to valley-fill sediments. This limited study did not accurately simulate ground-water flow in upland areas. The model area extended to topographic divides to account for all the water in the watershed. The area of particle tracks shown in the attached figure approximates the extent of the model area. The boundary arbitrarily crossed a large tributary stream on the west side, assuming that the water balance in the valley-fill aquifer was independent of flow in the tributary watershed. The upstream end of the model was placed at the base of a small upstream reservoir, and the downstream end was placed several hundred feet downstream of the Lyman Mill Dam. A constant head cell was assigned at the upstream and downstream ends of the river to account for inflow and outflow to and from the model area. The steady-state option was selected to simulate average conditions.

A uniform cell width of 100 feet by 100 feet was selected for the finite-difference grid. A uniform thickness of 50 feet was selected to approximate the thickness of the valley fill. The thickness in some hilltop areas was increased by several feet during initial model runs to maintain active model cells. The upland area thickness, however, was not critical for simulating groundwater flow in the valley. The bottom of the aquifer was calculated by subtracting 50 feet from a land surface array, which was constructed from a Rhode Island GIS elevation data base.

A uniform hydraulic conductivity of 40 ft/d (0.014 cm/sec) was assumed to approximate an aquifer transmissivity of about 2,000 ft^2/d (square feet per day), which is representative for aquifers in this setting (Kontis and others, 2004). A lower upland hydraulic conductivity value of 4 ft/day (0.0014 cm/sec) was selected to simulate upland transmissivity but was minimally important for achieving the goals of this model. The dams were simulated using the wall barrier option in MODFLOW; the wall was assigned a hydraulic conductivity of 0.01 ft/d (3.5E-6 cm/sec).

Streams that appear on the state data base, excluding the Woonasquetucket River and reservoirs, were simulated as drains. The model drains are groundwater sinks when the water level rises above the drain level, in this case the land surface, but are not sources of water. A uniform drain width of 5 feet was assumed, and a high drain hydraulic conductivity of 100 ft/d was selected so the drain conductance did not constrain flow out of the model.

Drains also were used to simulate wetlands. The drains had the dimensions of the drain cells, and an arbitrarily high hydraulic conductivity of 100 ft/d was assigned.

The Woonasquetucket River and reservoirs were simulated as rivers that served as sources of water when aquifer head was below the river level or as sinks when aquifer head was above river level. A uniform width of 50 feet was assumed for the river, and a width of 100 feet, the cell width, was applied in reservoir areas. A riverbed thickness of 1 ft was assumed for both areas. A hydraulic conductivity of 1 ft/d was assumed for river areas (Kontis and others, 2004), and a hydraulic conductivity of 0.1 ft/d was assumed for the reservoir. Average reservoir elevations of 93.5 ft for the Allendale Pond and 77 ft for the Lyman Mill Pond were from maps prepared for the U.S. Army Corps of Engineers by Battelle (written commun., 2007). River levels were from digital elevation data.

To simulate the effect of removing two dams, the reservoir river cells were removed and uniform river cells were placed along the preexisting channel. A uniform river slope was assumed from the upstream end of the reservoir to the downstream side of the dam. Other river properties were assigned as discussed above.

A uniform recharge rate of 24 in/yr (0.0055 ft/d) was assigned throughout the model area to account for all the water available for recharge, including upland runoff. This rate represents the average difference between precipitation and evapotranspiration for the region (Randall, 1996). Steady-state groundwater flow paths were simulated by tracking particles. One particle was assigned to each model cell. Particles were specified to stop at weak sinks, which are cells where not all water entering the cell discharges and some passes to adjoining model cells.

Model Results

The attached figure shows flow paths for conditions where the reservoirs are in place and for conditions after the two reservoirs are removed. Particle path lines are colored depending on the type of sink at which flow discharges: drain (green representing the wetland and two tributary streams), river (blue), or constant head (yellow). The condition "with dams" shows that most flow paths to the wetland drains are from upland sources, including uplands east of the river. Wetland drains also receive water from precipitation, which is not apparent because the flow paths are short and water immediately discharges to drains that receive the precipitation recharge. The north end of the wetland also receives flow from Allendale Pond, but this flow component is not observed for the "without dam" condition. Simulated water levels at the north end of wetland are lowered as much as two feet, but declines are generally less than 0.25 ft in the wetland area. Conceptually, the water balance in the wetland is not altered appreciably by removing the dams, but the wetland water balance for the two conditions was not included in this analysis. The largest water-level declines of approximately 6 ft are near the downstream ends of the reservoirs where heads were lowered the most by removal of the dams.

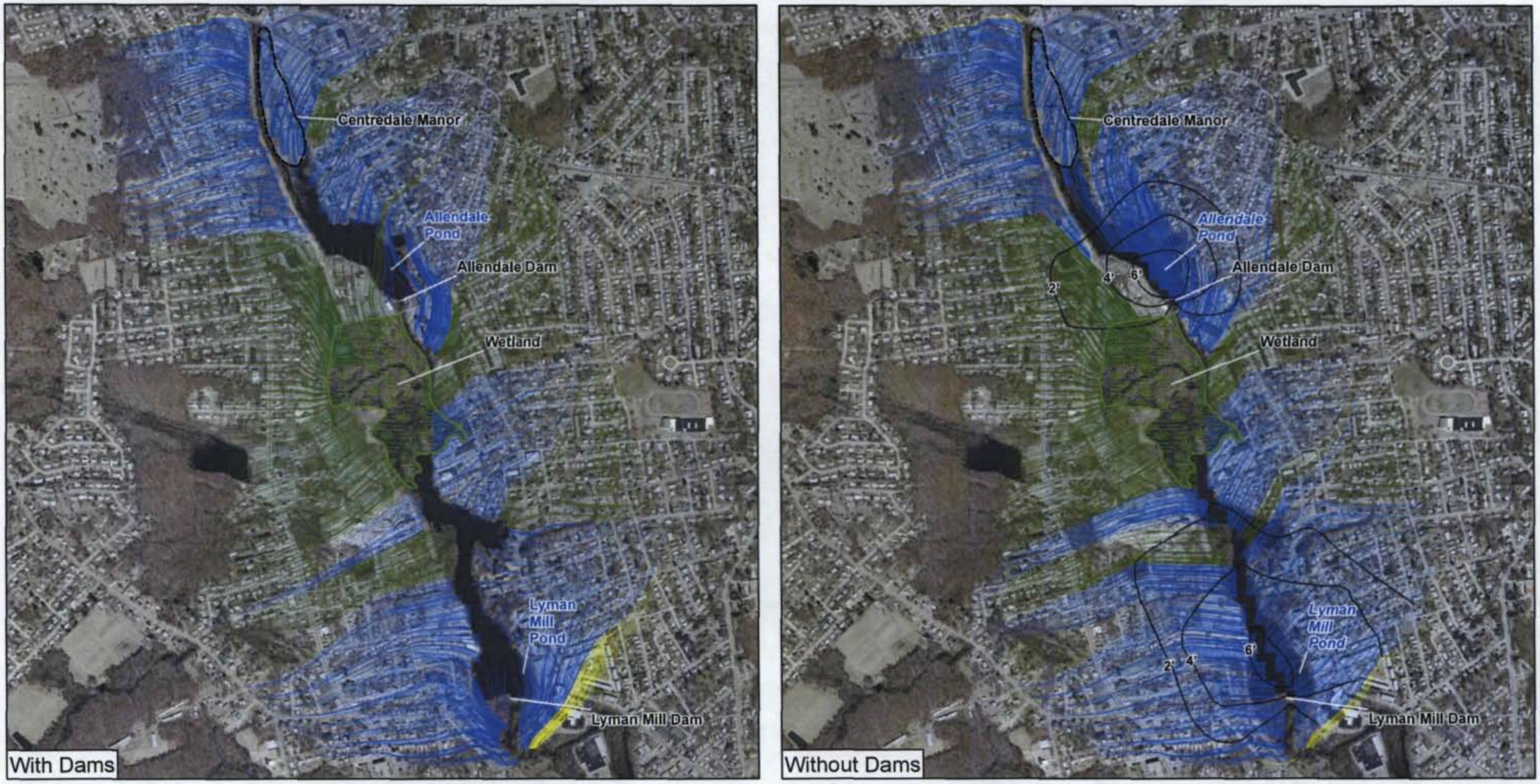
The Centredale Manor area did not appear to be a source of water to the wetland for either condition. Flow paths from that area, however, appear to extend farther down the valley after removal of the dams.

This simplified model representation of the aquifer system along the Woonasquetucket River has provided useful insights on possible hydrologic responses to removing the two dams. An uncertainty analysis may be useful to determine if the flow patterns change with plausible variations in uncertain model properties such as aquifer hydraulic conductivity, wall barrier hydraulic conductivity, recharge rates, and river properties. A wetland water balance for the two scenarios and plausible variations might also be useful for assessing impacts caused by the removal of dams.

References Cited

Kontis, Angelo L.; Randall, Allan D.; Mazzaferro, David L., 2004, Regional hydrology and simulation of flow of stratified-drift aquifers in the glaciated northeastern United States: U.S. Geological Survey Professional Paper 1415-C, 156 p.

Randall, A.D., 1996, Mean annual runoff, precipitation, and evapotranspiration in the glaciated northeastern United States, 1951-80: U.S. Geological Survey Open-File Report 96-395, 2 plates.



US Army Corps of Engineers
New England District

Legend

- Wetland

Particle Tracks

- Constant Head
- Rivers
- Drains
- Drawdown Without Dams

N

0 1,000 Feet

Centredale Manor
North Providence, RI
Particle Tracks with and without Dams
and Associated Drawdown

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July 5, 2007 DWN: MTW CHKD: MRK FPL