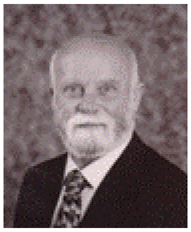
HYDRAULIC ANALYSIS: THE EFFECT OF WIND ON WATER

By Thomas J. Moran, PE



Wind passing across the surface of a small pond or lake can produce an alteration in the water levels. This effect is known as **setup**, which is used to describe how high the water level will rise on the upwind side of the water body.

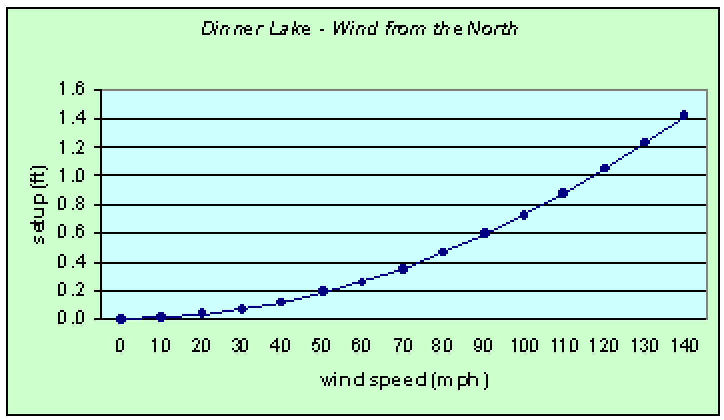
There are five factors that are used to estimate the setup in a water body:

- fetch – the distance (measured in feet) across the water that the wind travels;
- depth – the average depth (measured in feet) of the water body;
- gravity = 32.2 feet per second squared;
- wind speed (measured in feet per second); and
- the "K" factor = 2.025×10^{-6}.

Setup is then calculated as follows:
Setup = (K x (wind speed)^2 x fetch) / (gravity x depth)

For example, Dinner Lake, located in Highlands County, Florida, has an average depth of 9.8 feet, and the maximum width is 1 mile. Presuming the wind travels across the widest portion of the lake, the following table illustrates the setup as a function of wind speed.

Wind Speed (mph)	Setup (ft)
0	0.0
20	0.0
40	0.1
60	0.3
70	0.4
80	0.5
90	0.6
100	0.7
110	0.9
120	1.0
130	1.2
140	1.4



As you can see; a category 1 hurricane (with winds of approximately 80 MPH) will produce a setup of approximately 0.5 feet.

Another effect caused by the interaction of water and wind is **runup**. This term describes how far, in a vertical direction, a wave will travel up a slope. The determination of runup involves a fairly complex mathematical equation.

The significant wave height (H_s) for an 80 MPH storm across Dinner Lake (1 mile) is 3.6 feet. The wind must blow for 15 minutes to achieve this height.

The wave height (H) that will be exceeded in height by only 2% of the waves is 1.40 x H_s which equals 1.40 x 3.6 = 5.04 feet.

The wave length (L) is then $0.159gT^2$

Where T is the wave period, in seconds, and is calculated as $T = 0.429U^{0.44}F^{0.28} / g^{0.72}$ where

U = wind velocity in feet per second
g = gravitational force = 32.2 ft / s ^{2} and
F = distance = 1 mile = 5,280 feet

Thus, in this case,
$T = 0.429 \times 177.3^{0.44} \times 5{,}280^{0.28} / 32.2^{0.72}$
T = 3.79 seconds

and wave length $L = 0.159 \times 32.2 \times 3.79^{2}$
L = 73.5 feet

The bank of Dinner Lake has an average slope of one foot vertical for every six feet horizontal (1:6) and has a relatively smooth slope.

The wave height (H) divided by the wave length (L) = 5.04 / 73.5 = 0.68. Using published data tables, it is estimated that the ratio of runup (R) to the wave height (H) = R/H = 0.66.

Thus, the runup is calculated as follows:
R = 0.66 x 5.04 = 3.33 feet.

Adding the runup and setup then provides an indication of how far the water could rise on the upwind side of the lake.

In this case runup + setup = 3.83 feet indicating that, with a category 1 hurricane, the water level on the upwind side of Dinner Lake could theoretically rise 3.83 feet. This does not include any settlement of the bank caused by wind and wave action or contingencies.

If an individual intends to purchase and develop property adjacent to a lake, they should investigate the potential rise in water level before constructing any buildings. The wind and water action shown in this article can also be useful in evaluating the required freeboard on stormwater retention ponds necessary to prevent overflow. Water, misunderstood and uncontrolled, can be an extremely destructive force.

Roberson, Cassidy and Chaudhry, *Hydraulic Engineering, 2nd ed.* (John Wiley & Sons Inc., 1998) 331-38

Water Tidbits

A cubic foot of water weighs 62.4 pounds
A cubic yard of water (3 ft x 3ft x 3 ft) weighs 1,685 pounds
The water that would fill an office space that is 10 feet x 10 feet x 8 feet would weigh about 25 tons.

When you hear about a wall of water racing down a canyon at 25 miles per hour and the canyon is 50 feet wide and the water is 10 feet high; try to imagine the weight of the flood coming at you.

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