

The Effects of Global Warming on Leaf Drop Timing as Determined by River Level Step Jumps

Aviva Berezin and Dr. Michael Vorwerk

Environmental Science Program, Westfield State College, Westfield, MA 01086

Introduction:

Every fall, the leaves drop off the trees. When this happens, transpiration stops, so water that would have been utilized by the trees for transpiration is then available for runoff, groundwater infiltration, etc. This increase in the amount of available water causes an increase in river flow, which can be seen as a step jump on stage and flow graphs. Climate change is having a great effect on plant's physiological processes, such as dropping leaves, budding, and blooming (Project BudBurst, 2009). My hypothesis is that due to global warming, one change will be that these step jumps will occur later in the year. My reasoning is that because the warm part of the fall season is longer, the leaves will drop later. I also test the hypotheses that there will be an increase in the maximum river flows, e.g. larger flood events later in history and a greater variation in flows later in history. More specifically, my hypotheses are:

- Hypothesis 1: Over the study period, step jumps occur later in the year.
- Hypothesis 2: Over the study period, the maximum yearly river flows increase.
- Hypothesis 3: Over the study period, the yearly standard deviation in flow increases.

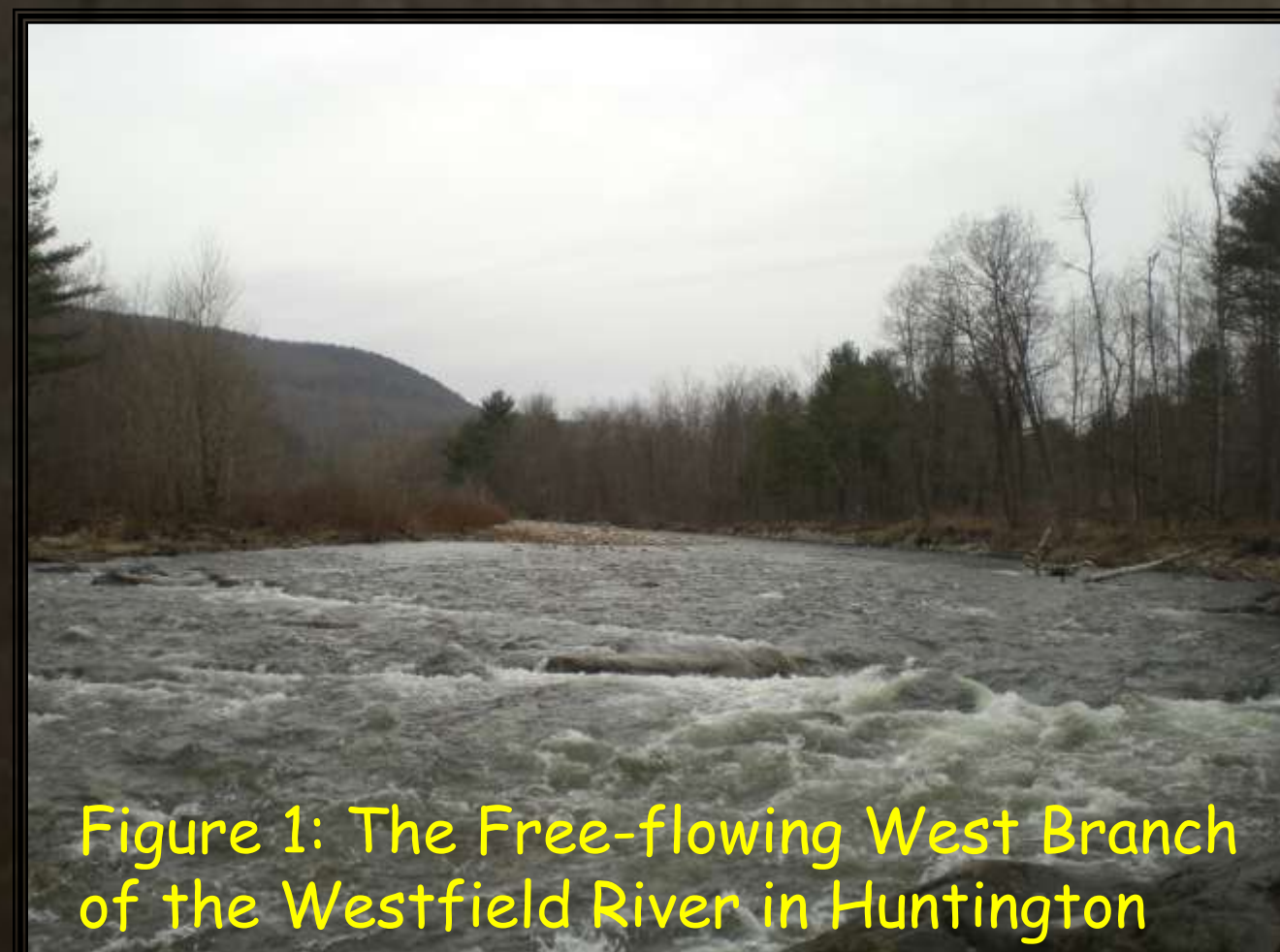


Figure 1: The free-flowing West Branch of the Westfield River in Huntington

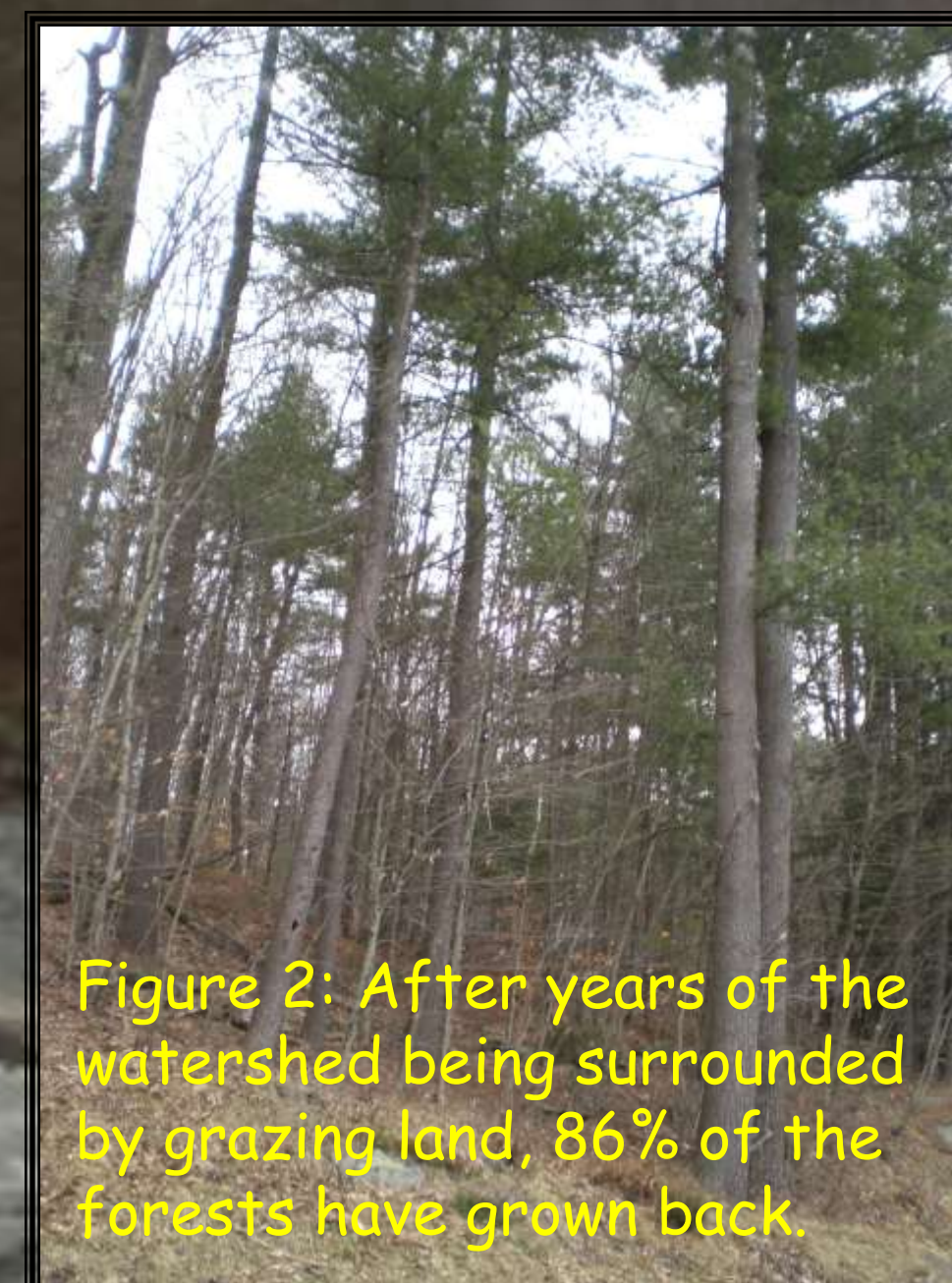


Figure 2: After years of the watershed being surrounded by grazing land, 86% of the forests have grown back.

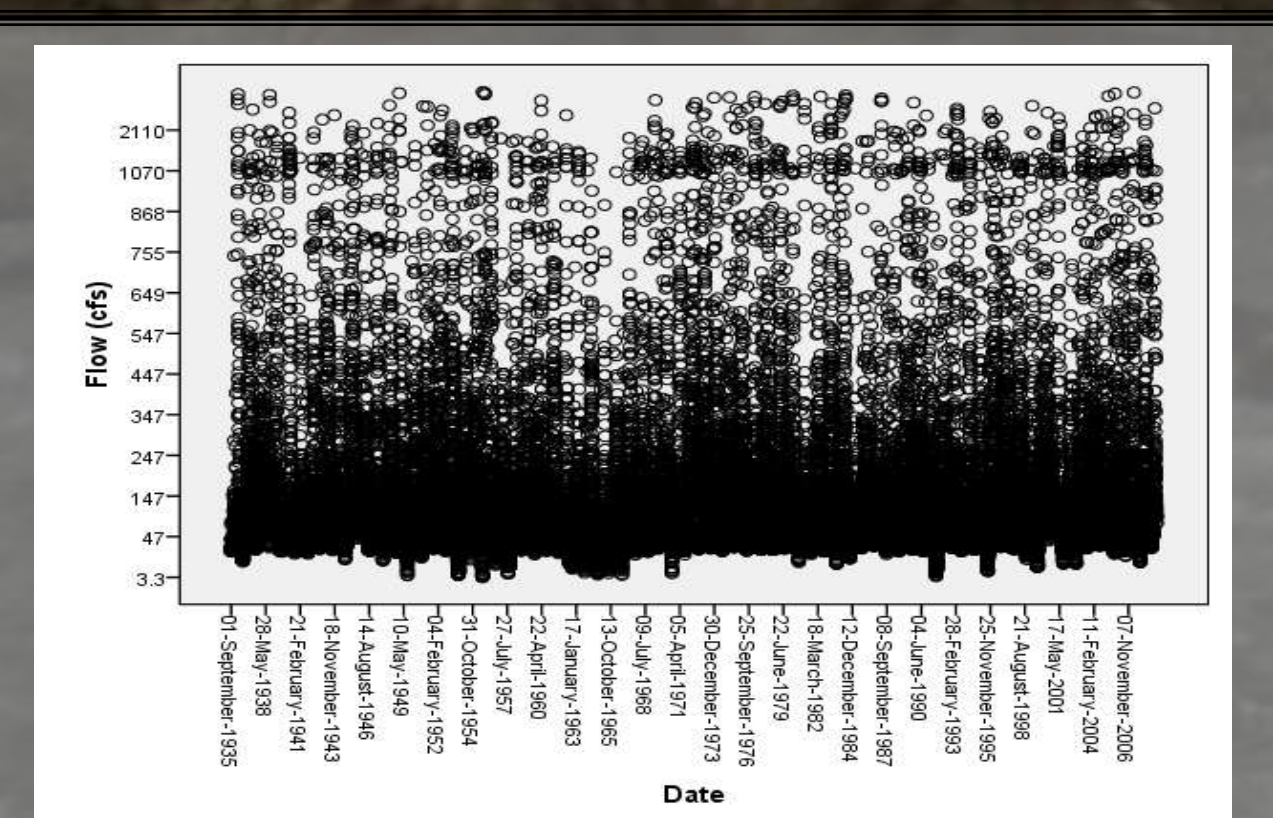


Figure 4: All flow data on record from September 1935 - January 2009.

Background:

Scientists predict many various environmental impacts due to global warming. For instance, scientists predict that plant physiology will change, causing trees to retain their leaves longer. Some research shows that shrubs will have greater leaf longevity (Suzuki & Kudo, 2006, Japan). Other research predicts more intense storms and increases in extremes of precipitation. This will result in more frequent flooding and droughts (Pew Center on Global Climate Change, 2008). In a study by the USGS, scientists found that the probability of a 100 year flood increased from once every hundred years to three to six times every hundred years (Mayell, 2002)

For my research, I used flow data from the West Branch of the Westfield River, Huntington, MA. The West Branch is a free-flowing branch, 33.8 kilometers in length (Figure 1). The drainage area is 242 km² - 243 km² (Schumann, 2007, USGS, 2009). In the 1800's the land surrounding the area was grazing land. Now, 86% of the land is forested with growth approximately a hundred years old (Figure 2), (USGS, 2009). The free-flowing part of the river has no dams or other man-made structures affecting the flow levels, so the data I obtained reflect the natural river levels in a relatively unimpacted, forested watershed.

Methods and Analyses:

I used the USGS river flow data from the West Branch of the Westfield River gauging station (Figure 3). The record contains the average daily flow for the West Branch of the Westfield River since September 1935 (Figure 4).

Methods for Hypothesis 1: I separated out the October daily averages for all the years (Figure 5). I then examined the graphs for each year to determine when step jumps, if any, occurred. I defined an increase of ten cfs or more in river levels that did not immediately drop back down to constitute a step jump, somewhat following the method of Schumann, 2007. Finally, I created a graph of the date of the step jump versus the year. A discussion of this follows in my analysis.

Methods for Hypothesis 2 and 3: I calculated the maximum average flow and the standard deviation of flow for each year since 1935. I next created graphs for each of these data sets to see if the maximum flow and/or standard deviation increased over time. Discussions follow in my analysis.

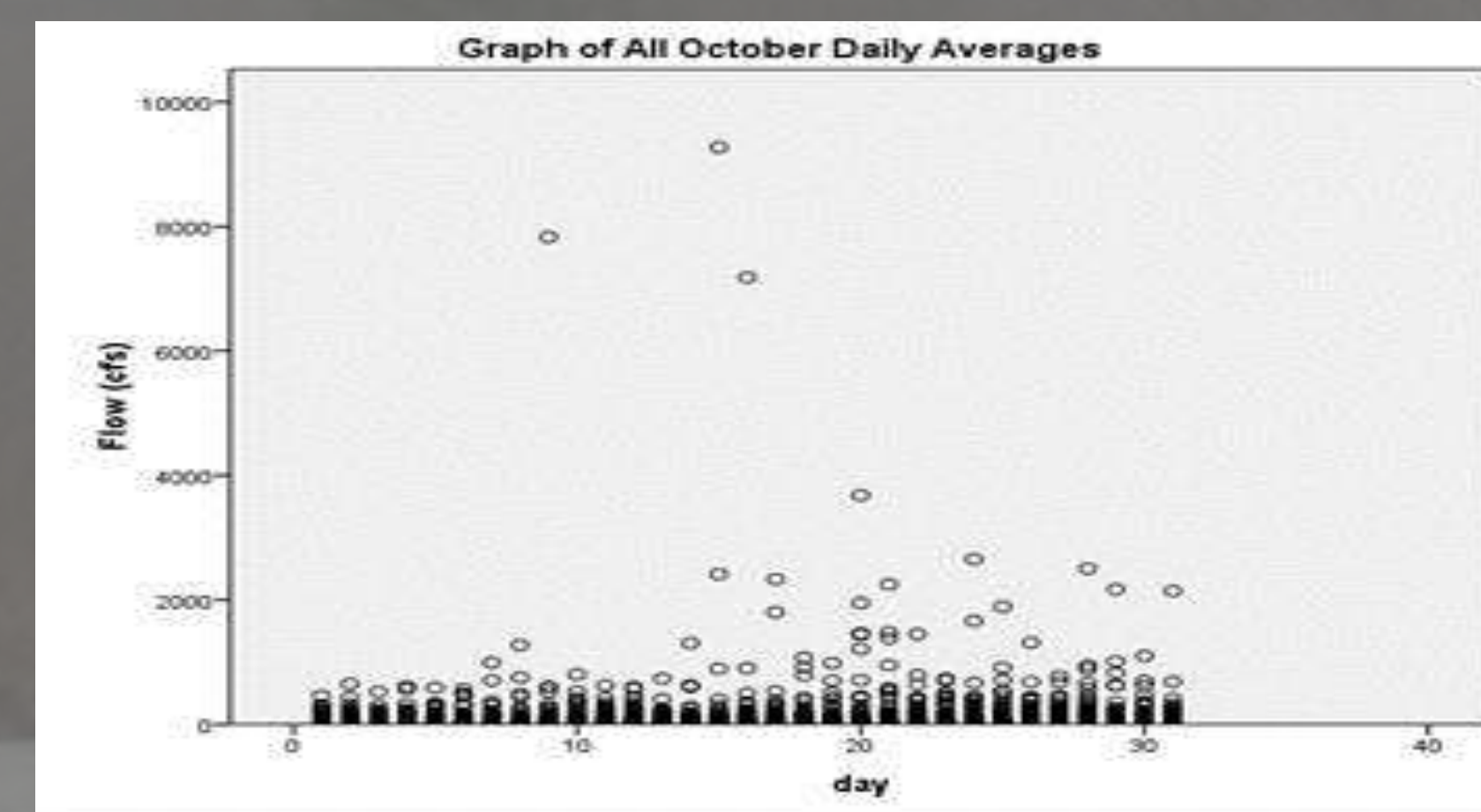


Figure 5: This is a graph of the average daily flow for every October day from all the years.

Hypothesis 1: I hypothesized that the step jumps would occur later in the season, because of global warming resulting in later falls. I graphed the dates of the step jumps and examined a trend line fitted to the data (Figure 6). The equation of my trend line was

$$\text{date} = -0.0128 \times \text{year} + 40.383 \quad \text{equation (1)}$$

Note that my slope is negative, refuting the hypothesis that the jumps occur later in the season. Additionally, statistics show that the slope is not significantly different than zero ($p = 0.785$). Upon further literature review, I found that leaf drop date is closely related to length of daylight (Dickie, 2001). Thus, it is possible that global warming will not affect when leaves drop off trees.

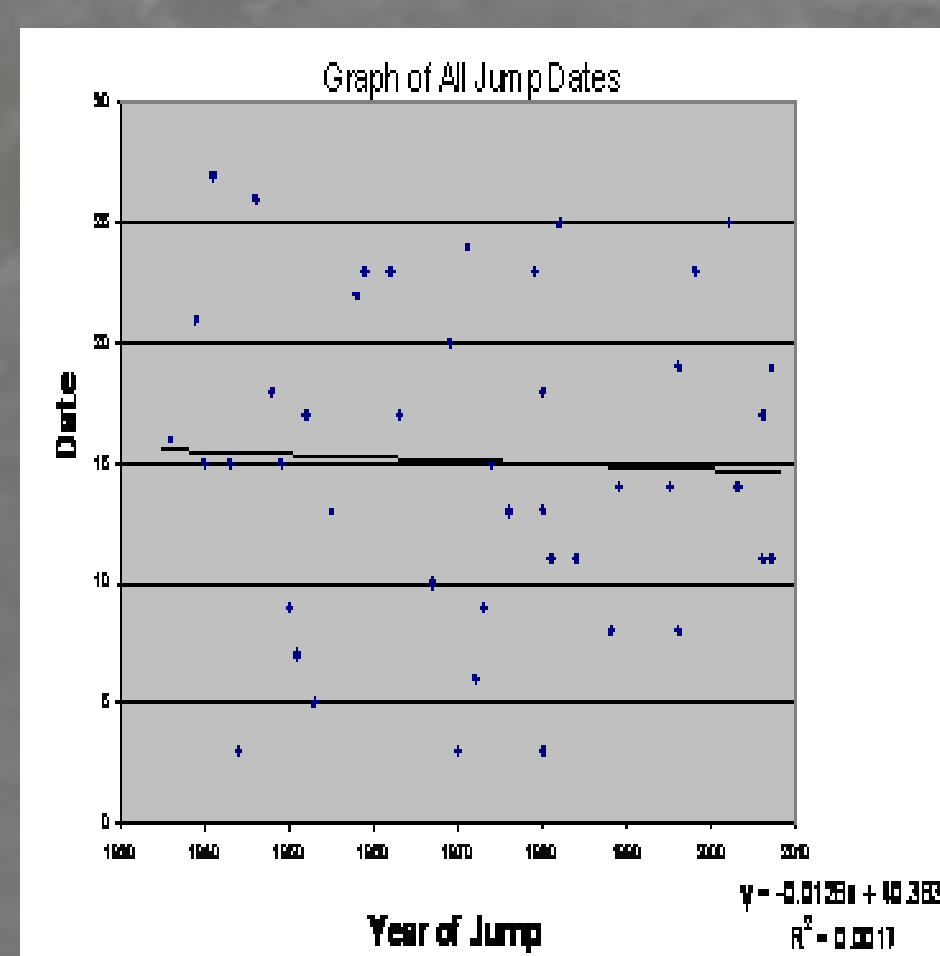


Figure 6: Graph of the date(s) of the step jump each October for all years. Its negative slope refutes my hypothesis of step jumps occurring later in the season.

Hypothesis 3: I hypothesized that the standard deviation in flows would increase as the years went on. I graphed the standard deviation for each year and examined a trend line fitted to the data (Figure 7). The equation of my trend line was:

$$\text{std} = 0.4054 \times \text{year} - 489.08 \quad \text{equation (4)}$$

Note that my slope is positive, however the r^2 value is 0.0044, suggesting that there is no correlation between standard deviation and year. Additionally, statistics show that the slope is not significantly different than zero ($p = 0.570$). Thus, my hypothesis was not supported by the data.

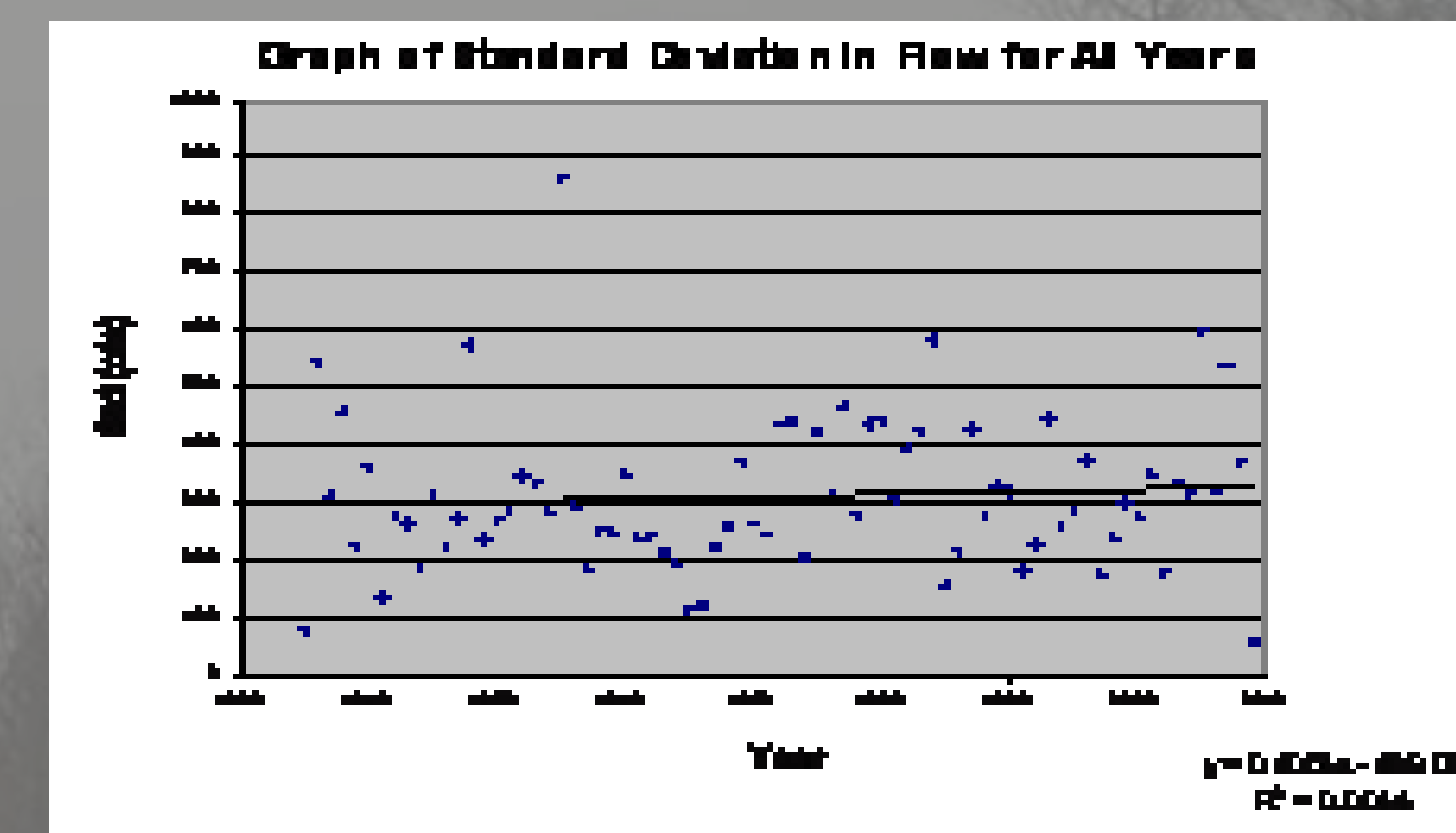


Figure 7: The small r^2 value of the graph, along with the p value does not support my hypothesis that the standard deviation will increase along with the years.

Hypothesis 2: I hypothesized that flood events would be greater in magnitude, following numerous predictions by scientists about increasing intensity of rain events and high water levels. I graphed the maximum yearly flows and examined a trend line fitted to the data (Figure 8). The equation of my trend line is:

$$\text{maxflow} = .783 \times \text{year} + 1566.8 \quad \text{equation (2)}$$

Note that my slope is positive, however the r^2 value is 0.00005, suggesting that there is no correlation between maximum flows and year. Additionally, the slope is not significantly different than zero ($p = 0.943$). Examination of the graph shows high flow events early in the record and late in the record causing a saddle shape in the data. One possible explanation is that the beginning large flows were more likely a result of increased runoff due to the deforested land, while the latter ones are a result of global warming. However, I have no analysis to support this.

If the early years are removed from the analysis i.e. starting from 1960 after the region was again heavily forested, the flows do appear to be increasing (Figure 9). A trend line fit to these data shows a positive slope. The equation of my trend line was:

$$\text{maxflow} = 24.738 \times \text{year} - 45984 \quad \text{equation (3)}$$

Note that my slope is positive, however the r^2 value is 0.04, suggesting that there is no correlation between maximum flow and year. Additionally, the slope is not significantly different than zero ($p = 0.167$). Thus, my hypothesis was not supported by the data.

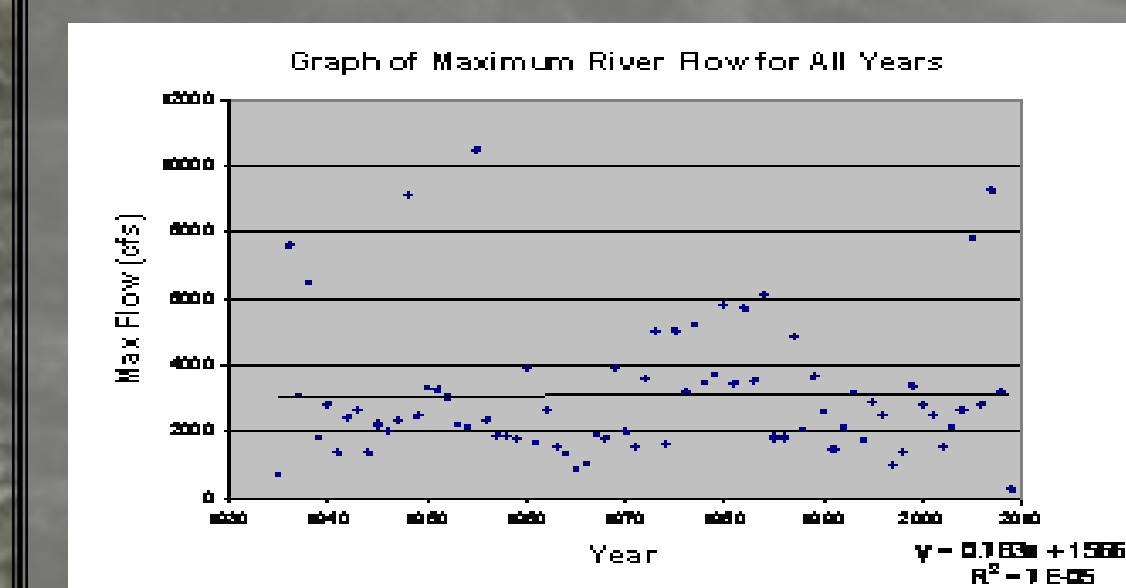


Figure 8: Graph of the maximum river flow for all years. Its r^2 value is extremely close to zero and shows no correlation between later years and larger, more frequent flood events.

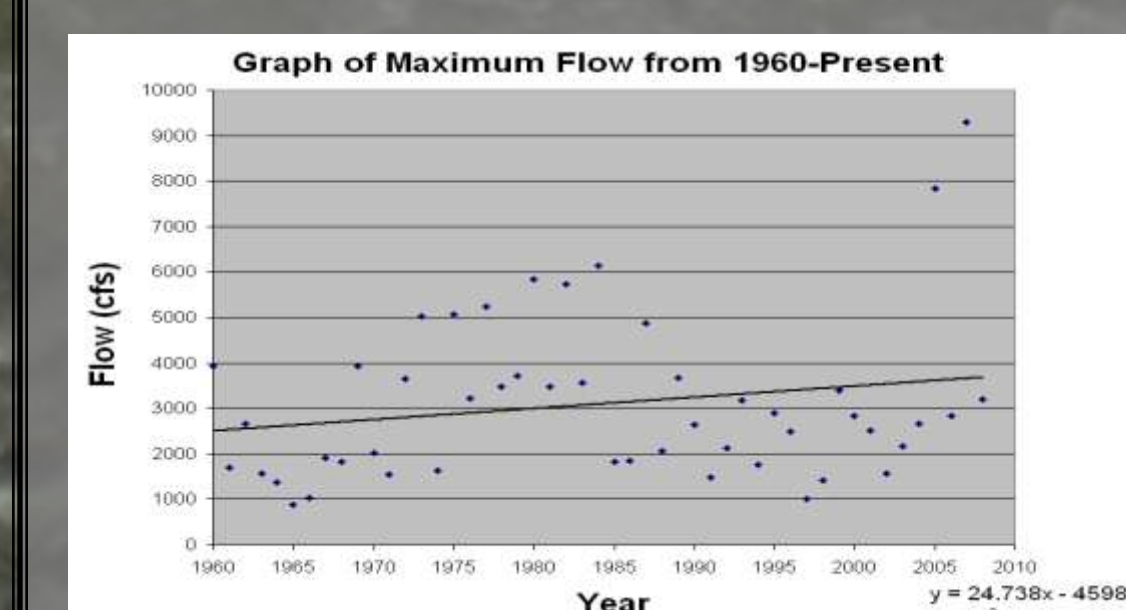


Figure 9: Graph of maximum flow from 1960-present shows a positive slope, but one that is not significantly different from zero.

Conclusions:

None of my hypotheses were supported. My analyses do not show that the step jump in river levels is occurring later in the Fall. This does not support the literature prediction that leaf phenology, such as leaf drop dates, has been affected by global warming. Also, the predicted increase in magnitude of floods and increasing variation in flow were not supported by these data.

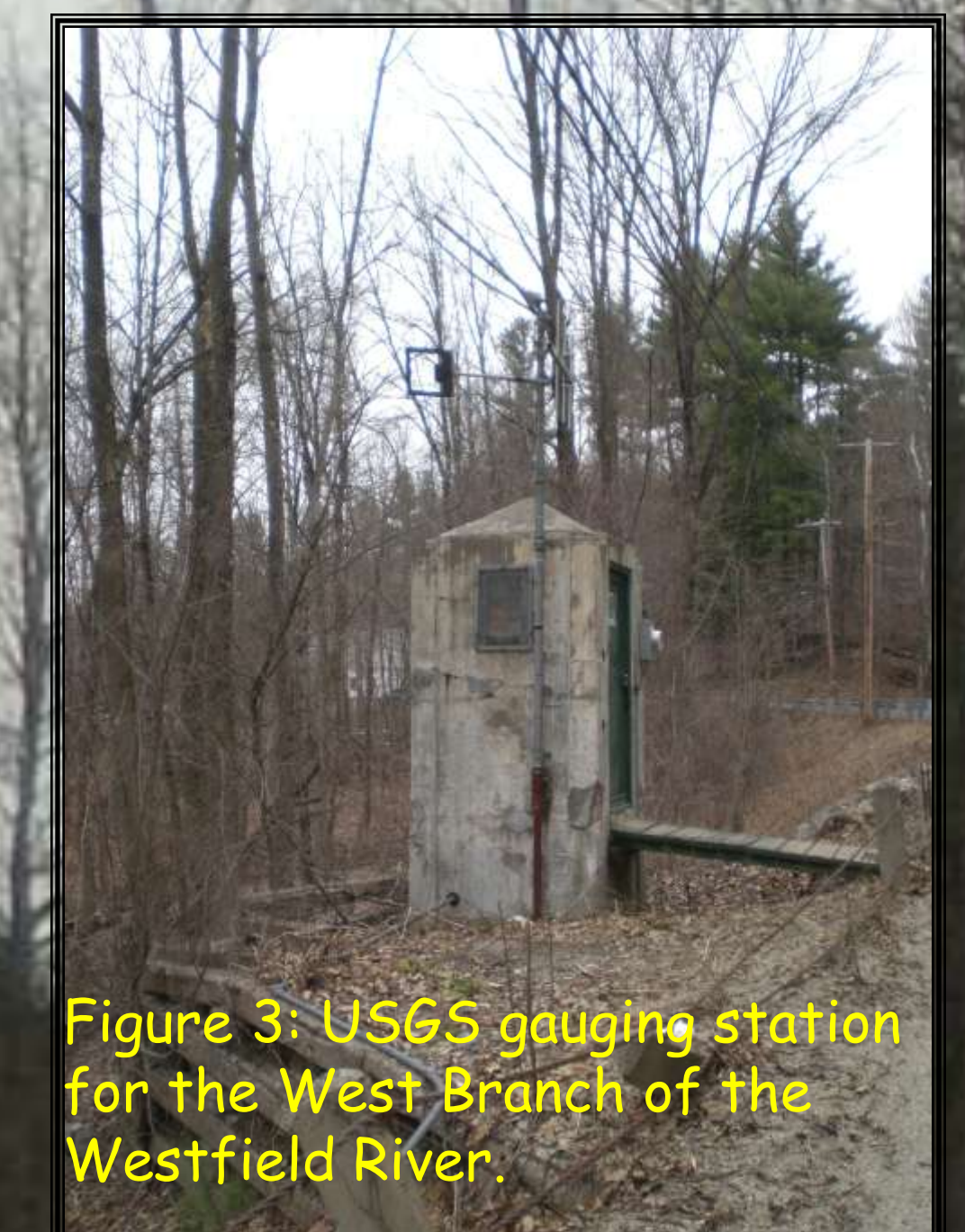


Figure 3: USGS gauging station for the West Branch of the Westfield River.

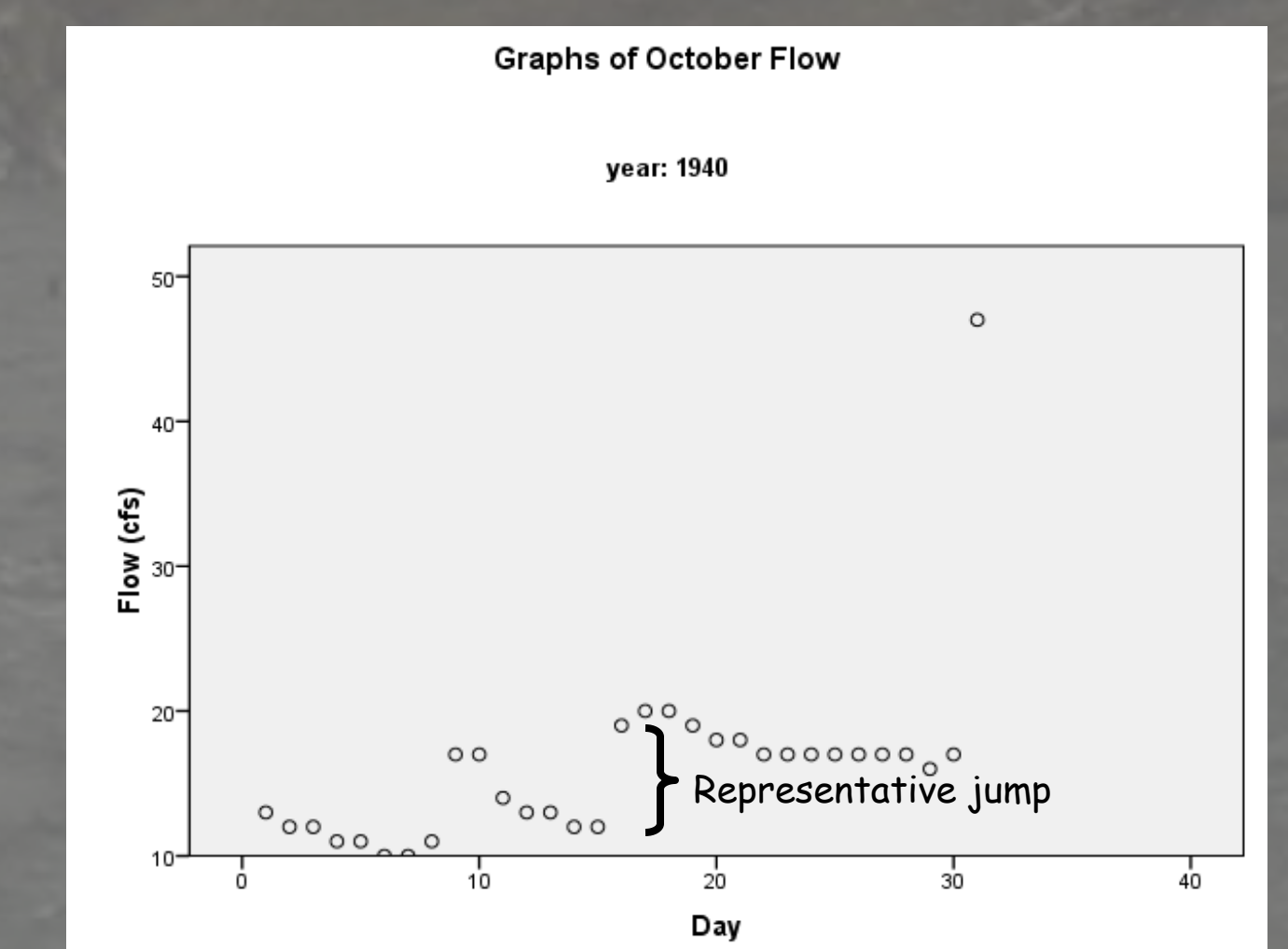


Figure 10: This graph is a good example of a step jump. Notice how the flow is at one level and after the jump it stays at the new level.

References:

- Dickie, Steve. "Deciduous Plants." *Plant Sciences*. 2001. *Encyclopedia.com*. 4 Apr. 2009 <<http://www.encyclopedia.com>>
- Pew Center on Global Climate Change. "Is Global Warming Generating Other Types of Severe Weather?" 12 May 2008. 1 Apr. 2009 <<http://www.pewclimate.org/hurricanes.cfm>>
- Mayell, Hillary. "Climate Studies Point to More Floods in This Century." *National Geographic* 30 Jan. 2002.
- Project BudBurst. "Phenology and Climate Change." 11 Mar. 2009. 25 Mar. 2009.
- Schumann, Jared. Westfield State College. 15 Feb. 2009.
- Suzuki, S., and G. Kudo. Short-term effects of simulated environmental change on phenology: leaf traits and shoot growth of alpine plants on a temperate mountain, Hokkaido University. 17 Dec. 2003. Graduate School of Environmental Earth Science. 1 Apr. 2009. <<http://www3.interscience.wiley.com/journal/119162968/abstract?CRETRY=1&SRETRY=0>>
- USGS. 2009 "West Branch of the Westfield River." Welcome to the USGS - U.S. Geological Survey. 01 Apr. 2009. 01 Apr. 2009 <<http://www.usgs.gov/>>