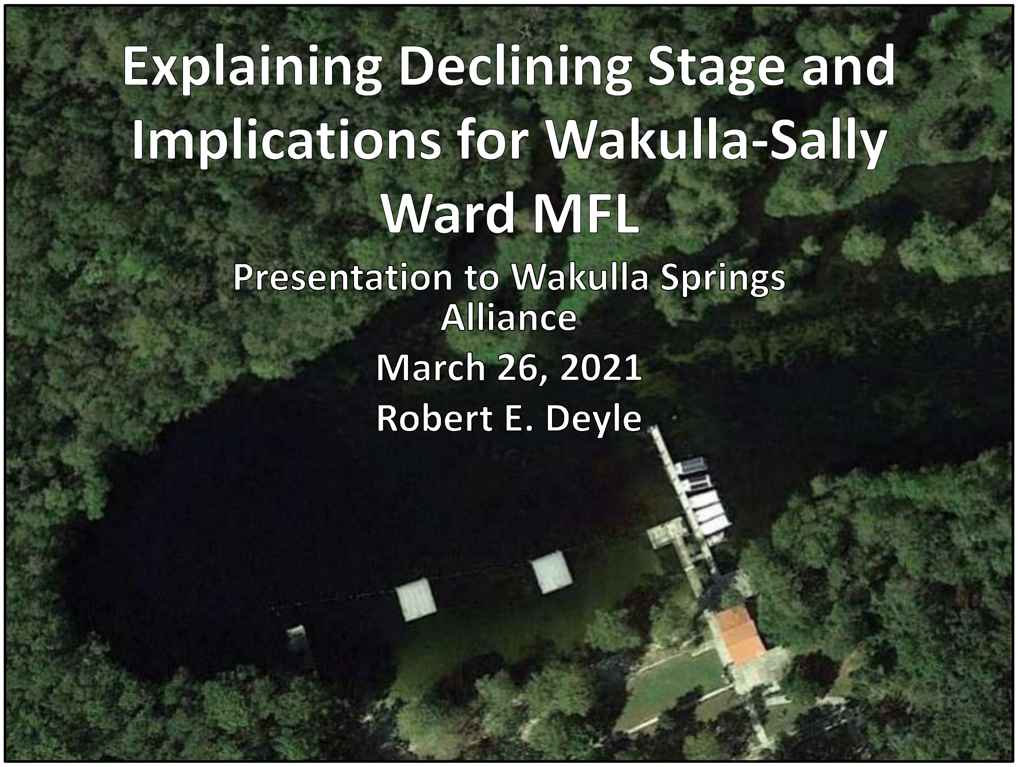
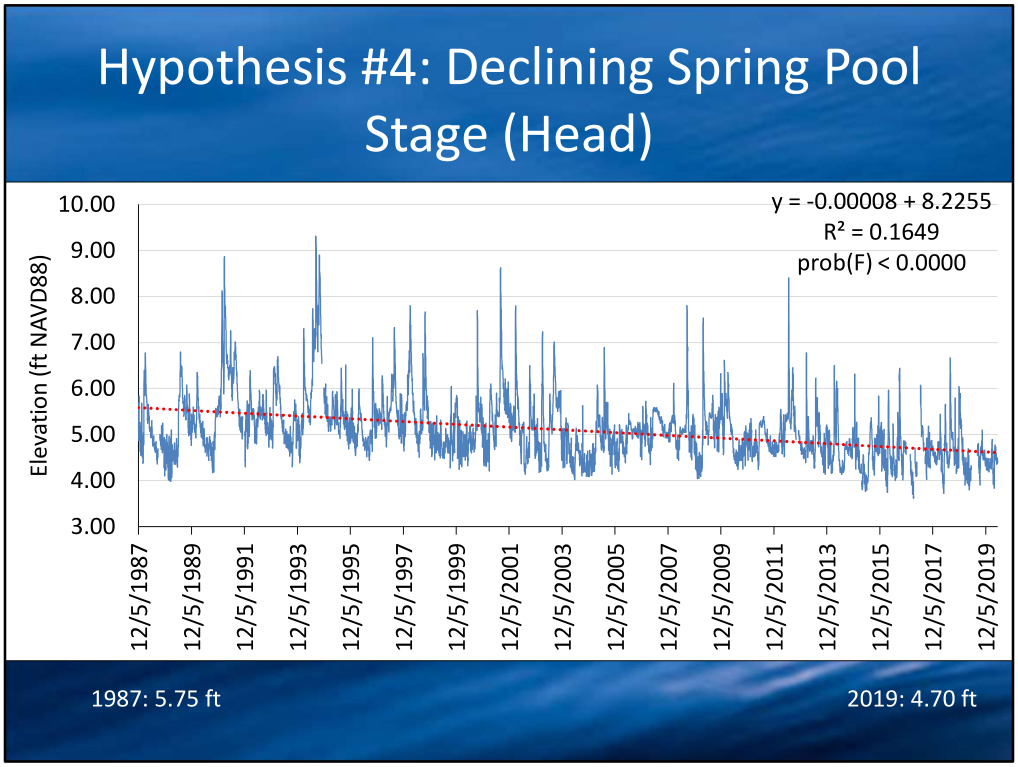



• This is the final presentation in a four-part series sharing what I believe we now know about why the water in the spring is “dark” so much more often than in the past, resulting in the almost complete cessation of glass-bottom boat tours and contributing to the decline of the submerged aquatic vegetation that forms the foundation of the spring food web
• This presentation wraps up an exploration of hypotheses about what has changed in the Wakulla Spring springshed and ecosystem that might explain why we have low visibility dark water conditions nearly all the time by considering possible explanations for the observed trend of declining spring pool and upper river stage

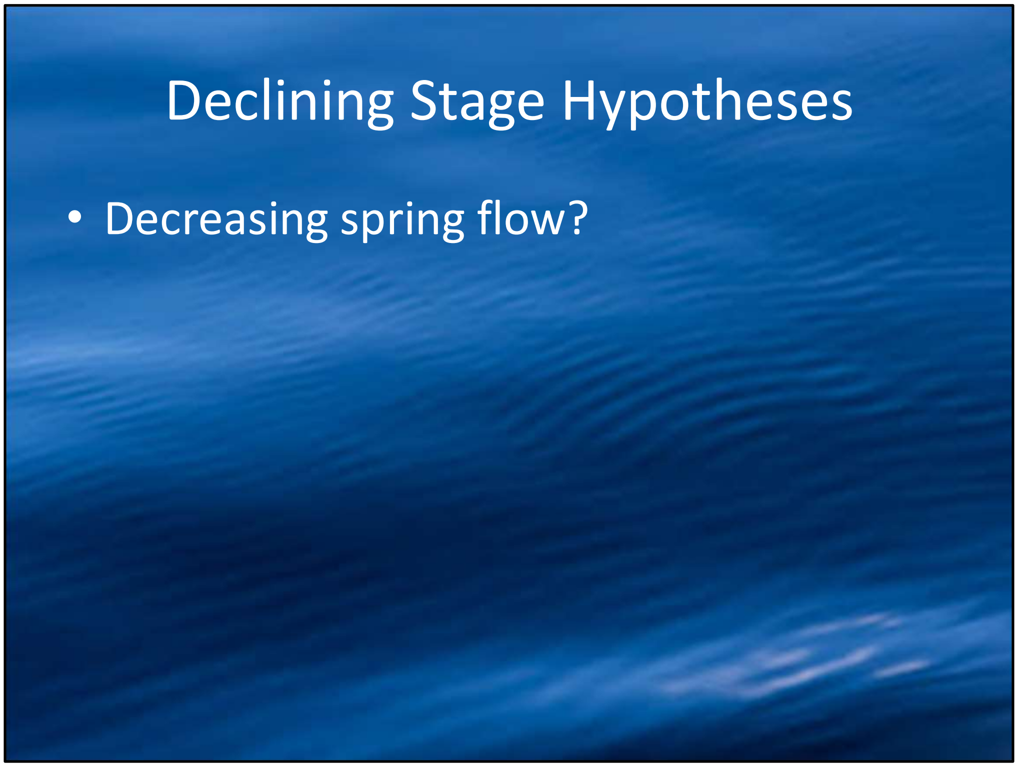
## Hypotheses

1. More Frequent Lost Creek Flows to Wakulla Spring
2. Accelerating sea level rise and head gradients
3. Changes in rainfall patterns
4. Declining spring pool stage (head)

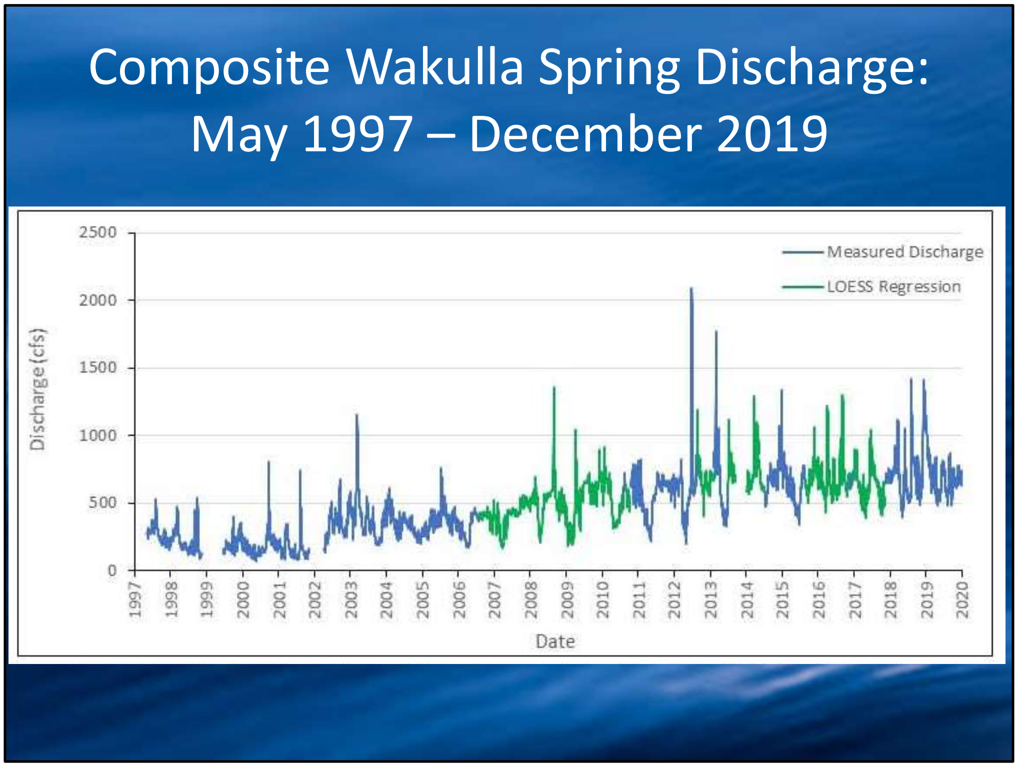
- In February I shared hypotheses about four forcing functions that may be contributing to the increased frequency and duration of dark water conditions observed at Wakulla Spring.



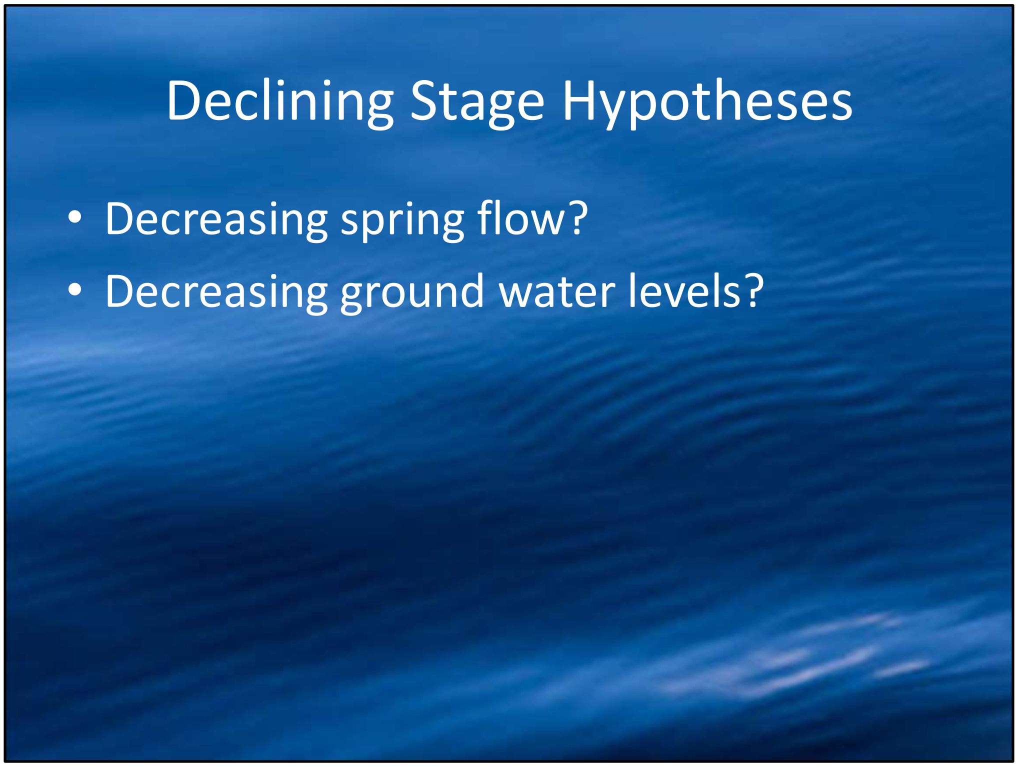

- The fourth hypothesis concerned the observed trend of declining spring pool stage or head as measured by the WMD for the period December 1987 through May 2020 at their gauge at the boat tram about 0.57 mile downstream from the spring boil.
- Comparing the end points of the trend line shown here, pool stage has decreased from a predicted value of about
    - **[click]** 5.75 ft North American Vertical Datum 88 (NAVD88) in 1987 to
    - **[click]** 4.70 ft NAVD88 in 2019
- [The elevation of the USGS gauge at Spring Creek is 0 ft NAVD88]
- What remains to be explained is why the spring pool and river stage is decreasing.



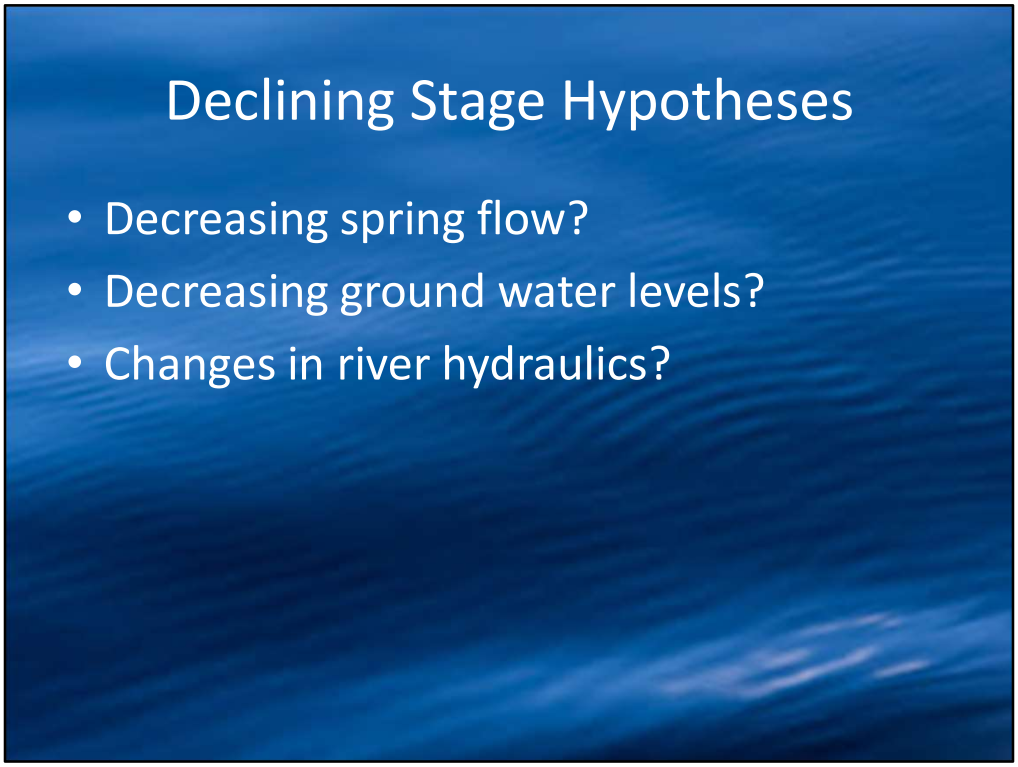

- **[click]** One straightforward explanation would be that spring flow or discharge is decreasing, but in fact, that is not the case **[next slide]**




- Overall, it has increased over the period 1997 through 2019 with a levelling off since about 2012 (Technical Assessment, p. 75)
- Meanwhile stage has been decreasing



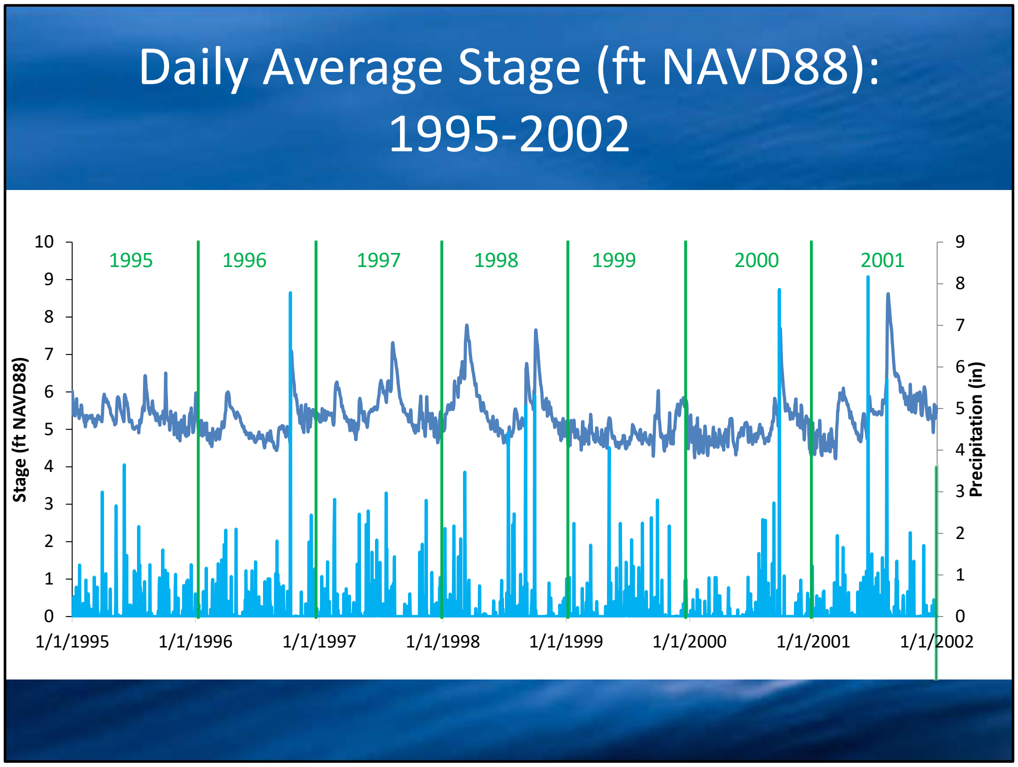

- **[click]** Another hypothesis that may help to explain the observed trend of declining spring pool and upper river stage
    - is that a long-term trend in declining ground water elevation in the springshed north of Wakulla Spring may be contributing to and/or primarily responsible for the observed decline
- The hydrogeologists at the Water Management District as well as Hal Davis have advised me that this is not plausible given the observed increasing discharge
- Declining ground water levels would only result in lower stage if the direct effect of the ground water level decline were a reduction in flow
- Furthermore, the WMD's draft Technical Assessment maintains that the available data indicate that ground water levels at wells nearest Wakulla Spring have been stable since 2000
    - The well data are limited, however, and not entirely convincing.
    - Reportedly, the finalized Technical Assessment, which is to be released soon, provides more robust evidence to support this conclusion.
- Nevertheless, the bottom line regarding stage decline is that changes in ground water elevation are not a likely forcing function



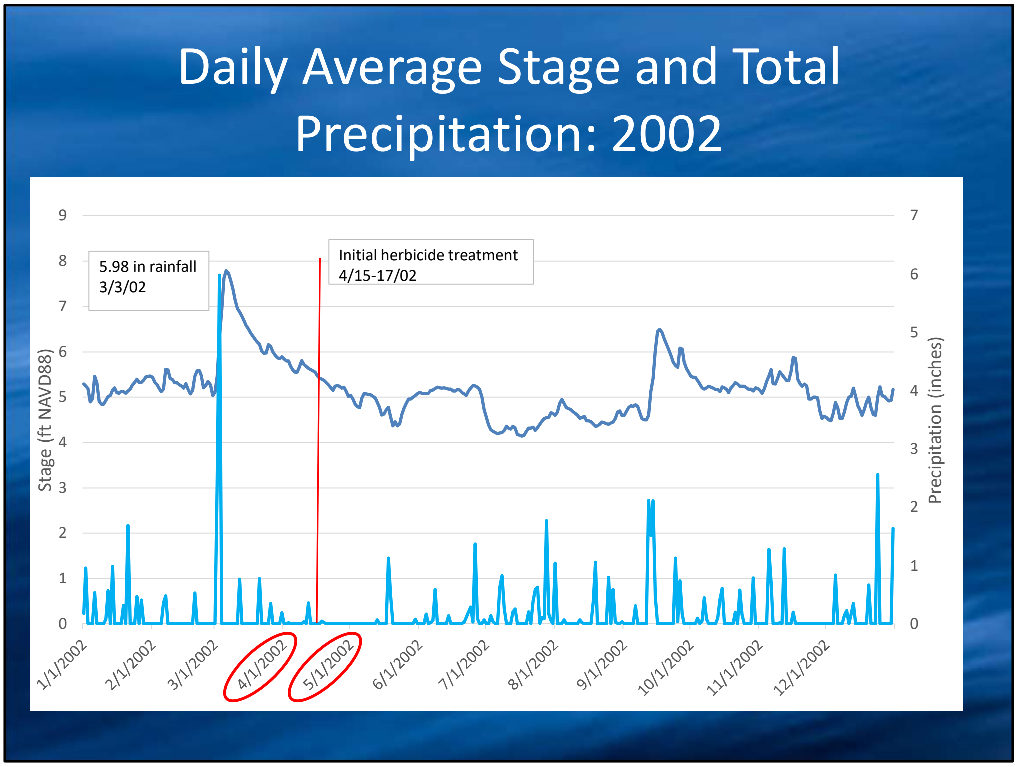

- **[click]** A third hypothesis is that changes in river hydraulics, specifically an increase in the stream channel cross section, could be responsible for the declining stage trend:
    - A larger channel cross section would allow the water to drain more quickly thereby lowering the spring and river stage
- For this to be the case, given the conflicting trends of decreasing stage and increasing spring flow, the river channel cross section would have to be continuing to expand

Looking east toward the boat dock, hydrilla mats smother the upper Wakulla River in 2001 (JVD)

- The WMD, in its draft MFL Technical Assessment, suggests that the decline in stage was initiated by the large-scale herbicide treatment of hydrilla that occurred in April 2002,
- They cite Jesse Van Dyke’s 2019 report on the efforts to control hydrilla at the Park between 1997 and 2007
  - which described a damming effect and resulting raised pool stage from the hydrilla proliferation between 1997 and 2000,
  - followed by a surge and decreased stage resulting from the massive die-off after the April 15-17, 2002 herbicide treatment.




- The stage data between 1995 and 2002 show no clear evidence of a damming effect as the hydrilla spread between 1997 and 2000 from the boat dock to the tour boat turnaround about one mile downstream
- The peaks are generally associated with high rainfall events **[click]**
- But even accounting for this, the pattern is a bit difficult to discern

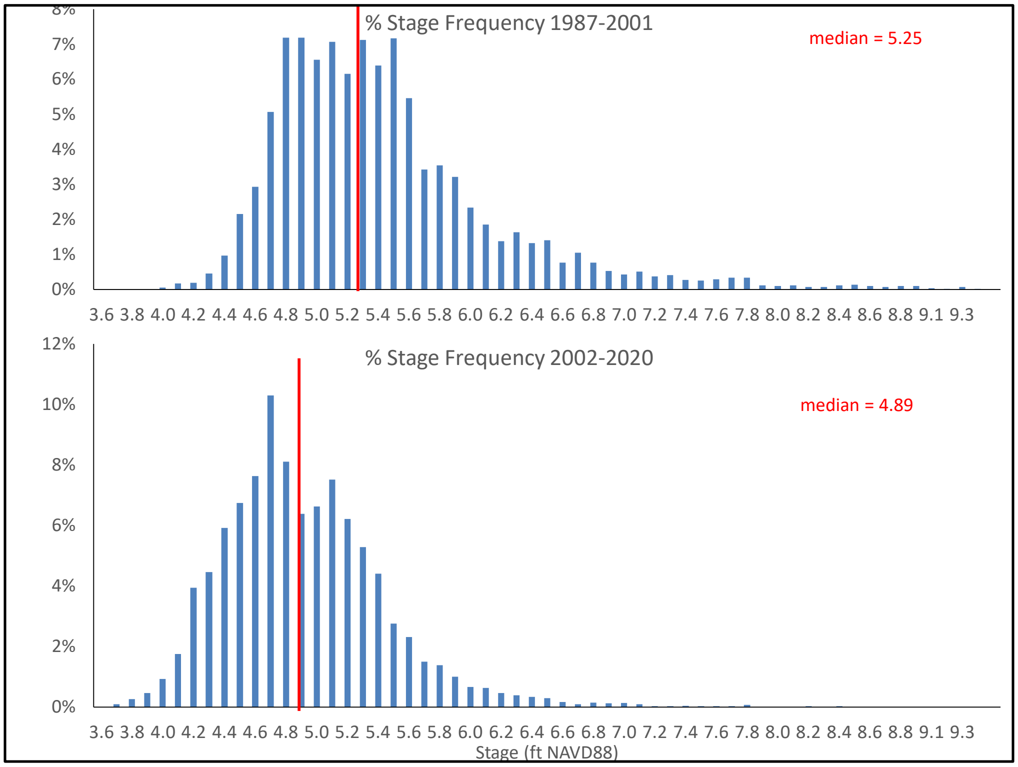



- There also is no evidence of an abrupt drop in stage following the herbicide treatment in April 2002.
- Jesse Van Dyke reported (2091, p. 4) that the average water levels measured at the park declined 1.4 feet from the beginning of April through the end of May **[click]**
- This figure reveals, however, that the stage decrease over that time was the continuation of a decrease after a major peak of 7.58 feet on 3/8/02 resulting from a 5.98-inch rainfall event on 3/3/02 **[click]**

## Median Stage Levels Pre- and Post-Herbicide Treatment

| Time Period | Median Stage (ft NAVD88) |
|---|---|
| 1987-1996 | 5.29 |
| 1997-2001 | 5.22 |
| 2002-2020 | 4.89 |

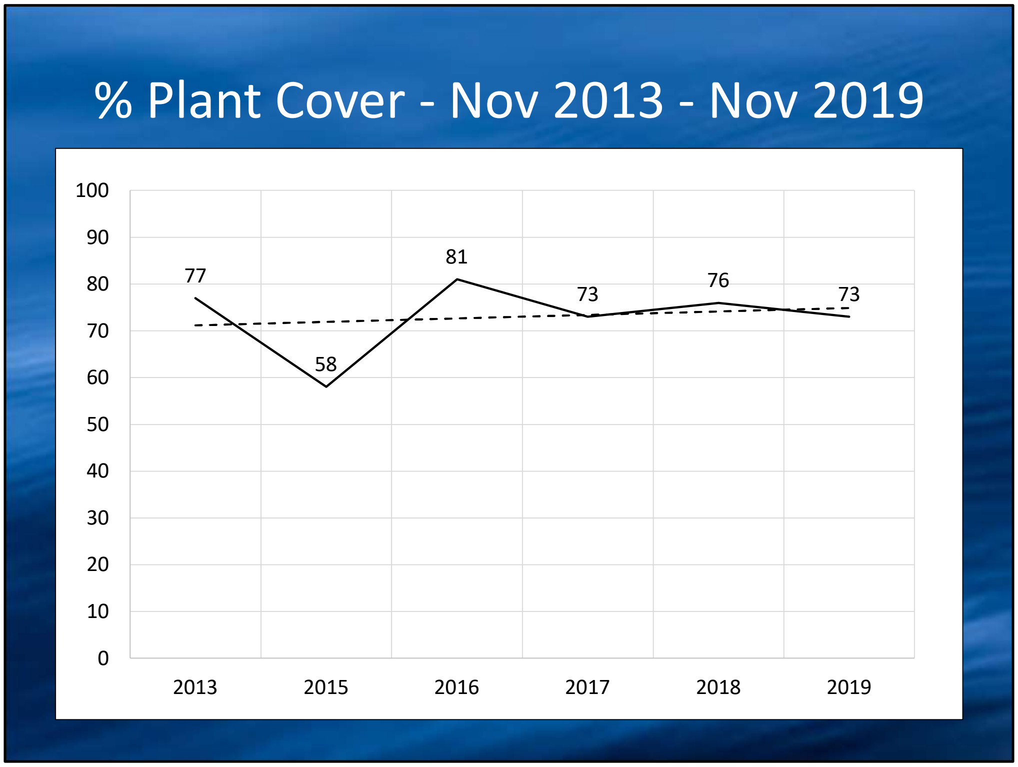
- If we look at median stage levels we can get a sense for changes with less influence from the outlying high rainfall events
    - The median is the 50th percentile value; i.e. 50% of the values are lower than the median and 50% are higher than the median
- **[click]** Here we see that during the period prior to the hydrilla invasion, 1987-1996, the median stage was 5.29 feet
- **[click]** That dropped, rather than increased, during the hydrilla invasion from 1997 to 2001 prior to the first major herbicide treatment in April 2002
- **[click]** But then we see a substantially lower median stage for the period after the major hydrilla purge in 2002
- So, while there was no abrupt drop in stage, the hydrilla purge appears to have been associated with the beginning of a long-term decreasing trend.



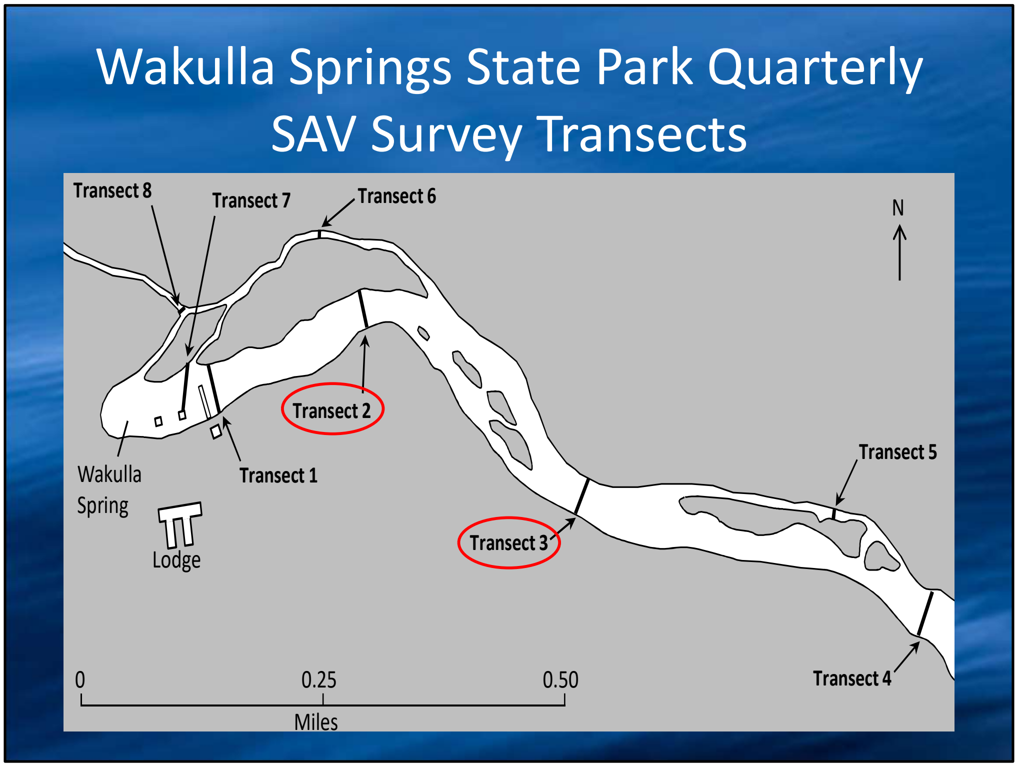

- The evidence for a substantial shift after 2002 is bolstered by examining the frequency distributions of daily stage levels prior to and after the 2002 major herbicide-induced hydrilla purge
- Here we see the stage frequency distribution for the period 1987-2001
- **[click]** And here we see the pattern for 2002-2020
    - Note again, the substantial decrease in median
    - But note also that the entire distribution shifts to the left
- So what would explain the continuing decline in spring pool and upper river stage since 2002?
- One possibility is that the massive removal of hydrilla along with several inches of organic sediments resulted in prolonged exposure of bare sediments to erosion.

# Low-Altitude Aerial Photo of Wakulla Spring and Upper River circa 1967

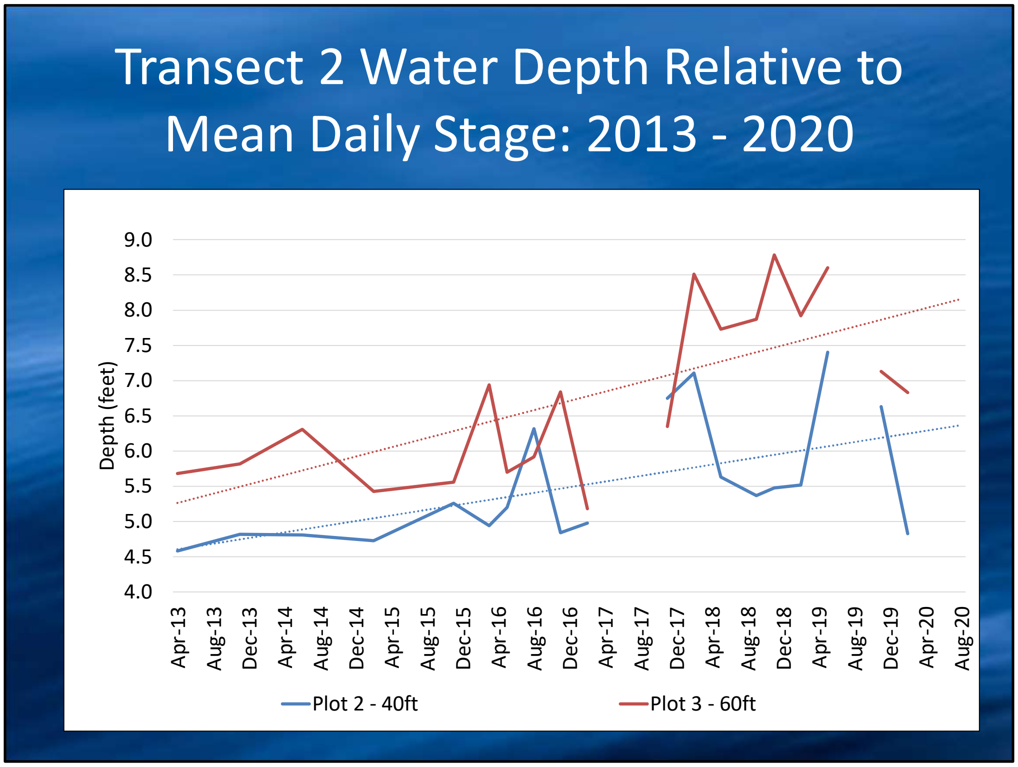
- We know from low altitude photos of the river just below the spring in the late 1960s, as well as first-hand accounts, that the river channel was densely vegetated with submerged aquatic vegetation (SAV) prior to the hydrilla invasion
- and that since its removal, large areas of bare sediment have persisted.



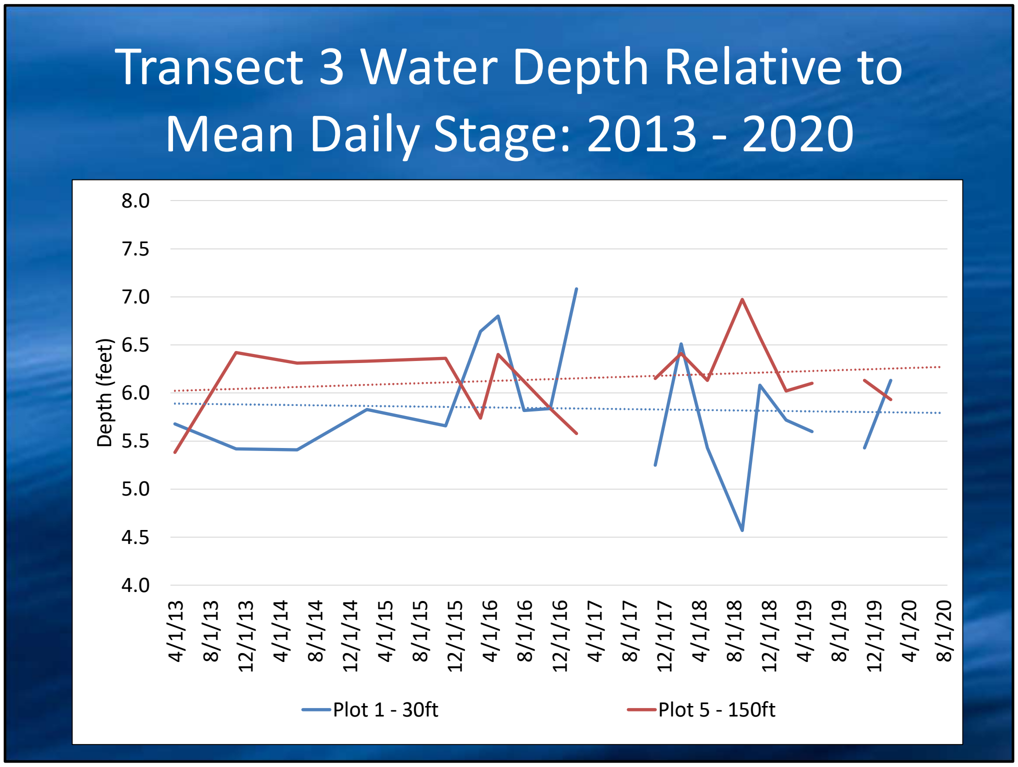

- Quarterly SAV surveys since 2013 show the average percent of plant cover over all transects in November ranging from 58 to 81 with no sign of improvement.



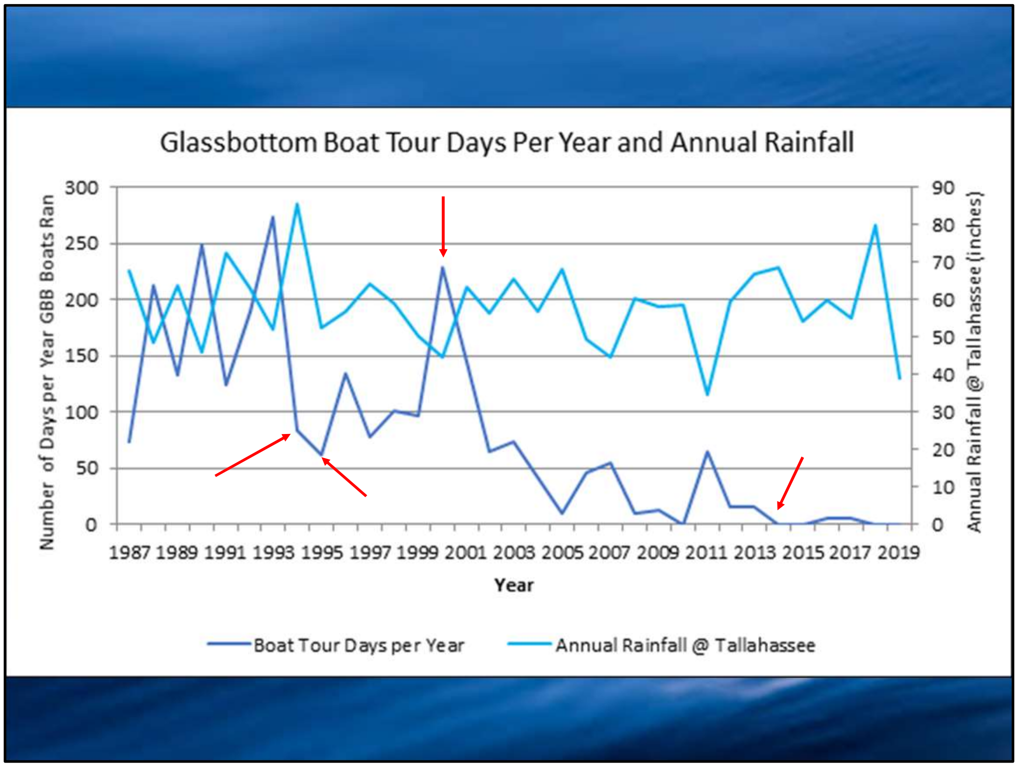

- Examination of water depth measurements [relative to long-term mean stage of 5.10 ft NAVD88] taken during the quarterly SAV surveys between 2013 and 2020 at the deepest positions along transects #2 and 3 show evidence of continuing erosion



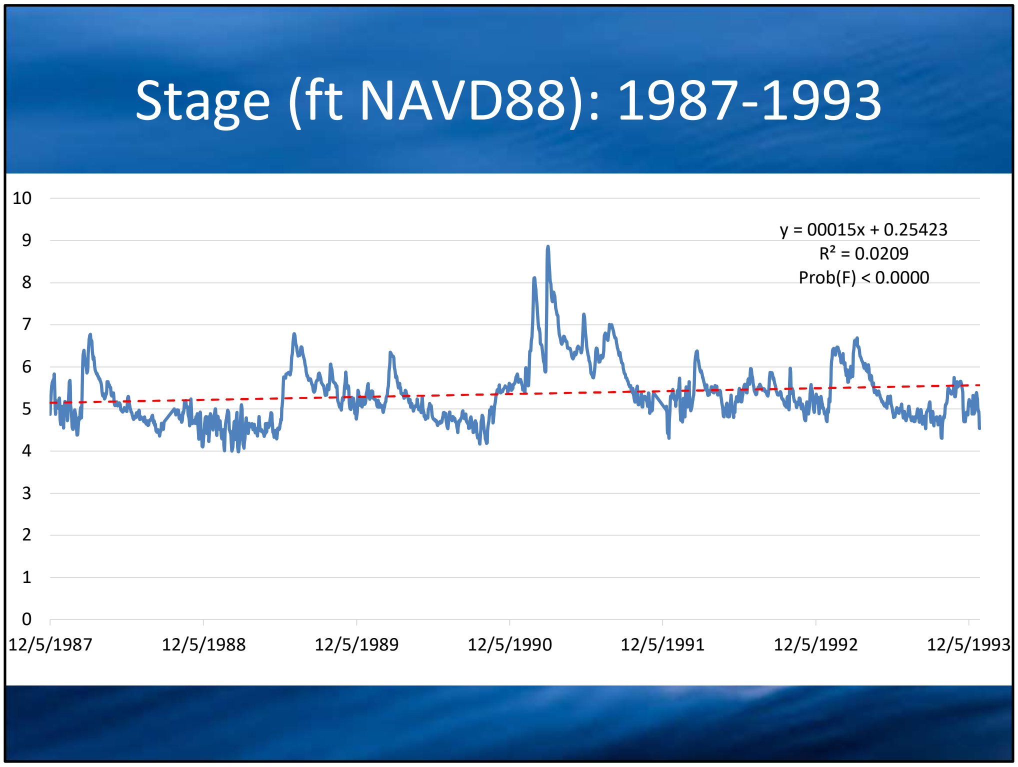

- At transect #2, just before the first turn, where current is the fastest (based on my boat driving experience) and bare limestone is now visible that was not exposed when I began driving tour boats in 2013 . . .
- We see increased erosion at distances of both 40 and 60 feet from the south bank, although it appears to have filled in some in late 2019 and early 2020



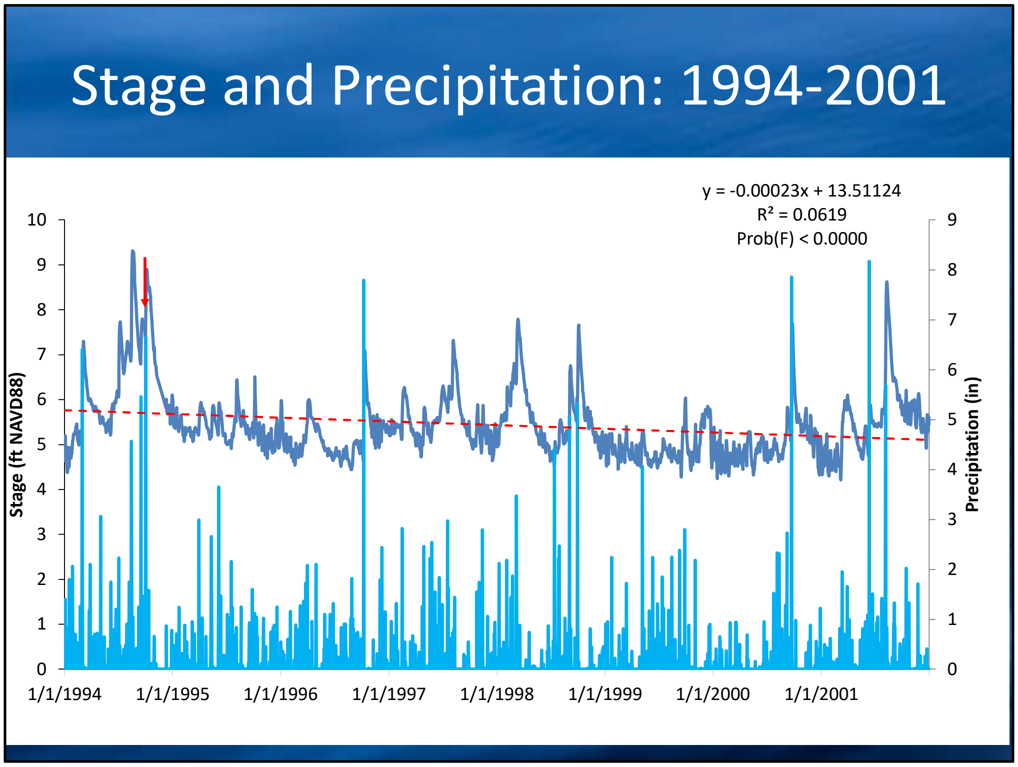

- The trend at transect #3, which is about 10 feet downriver of the boat tram gauge, reveals some evidence of erosion at plot 5 (150 feet from the south bank)
- but a slight decrease in water depth at plot #1 (30 ft from south bank) **[click]**




- You'll recall, however, that the initial sharp decline in glass bottom boat tours occurred in 1994 **[click]**
- I have, therefore, examined stage trends before and after that year . . .
  - which is the year the park experienced several major precipitation events including tropical storm Beryl
  - and a substantial and prolonged increase in river stage that has been hypothesized to have been the cause of the demise of the apple snail, and along with it, the limpkin.
- I think it's likely that the major drivers behind the low number of GBB tours that year was some combination of dark water associated with all the rain and the prolonged period of elevated river stage.
  - I have been told that boat tours were suspended for some time then because the high water submerged the boat dock.
- GBB tours went down again the following year, 1995 **[click**,]
  - and then began a rebound that peaked in the drought year of 2000 **[click]**
  - Followed by a prolonged decline that has bottomed out at 5 days or less since 2013 **[click]**




- Looking at the stage trend prior to 1994 we see a positive trend between 1987 and 1993

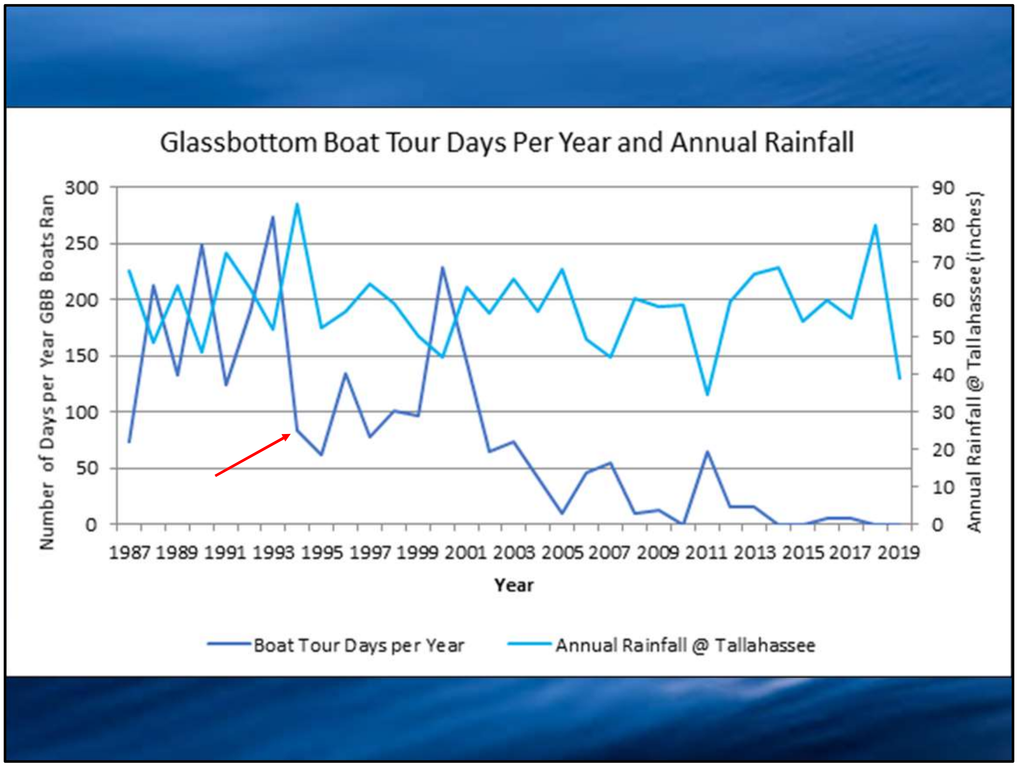



- With a negative trend beginning in 1994
- The onset of the 1994 increase in stage appears to have been associated with
  - **[click]** a large rainfall event on March 1 of 6.4 inches
- Followed by multiple heavy rains on
  - **[click]** August 15 (TS Beryl = 4.6 in),
  - **[click]** Sep 16 (5.5 in),
  - **[click]** and Oct 2 (6.7 in).
- This may indicate that one or more of the 1994 rainfall events may have initiated the stream channel erosion that may be one of the primary forcing functions of the long-term trend of declining stage
- But, the problem with linear regression trend lines is that they are influenced by outlying values like the prolonged stage peaks associated with the rainfall evens in 1994

# Stage Trends Before and After 1994

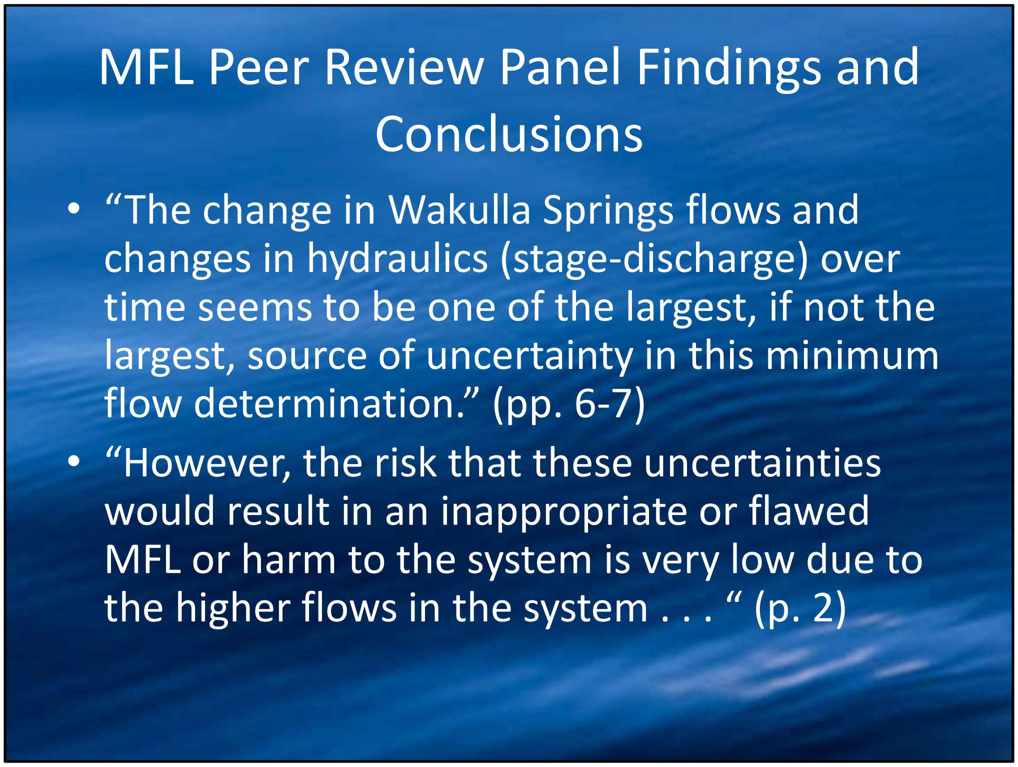
| | Median Stage | Trend Line Stats | | |
|---|---|---|---|---|
| **Interval** | | Prob(F) | Coefficient | R-squared |
| **1987-1993** | 5.23 | <0.0000 | 0.00015 | 0.0209 |
| **1995-2001** | 5.23 | 0.0231 | 0.02310 | 0.0214 |
| **2002-2020** | 4.89 | <0.0009 | -9.00E-05 | 0.1008 |

- So I partitioned the data before and after 1994
- This table shows both the regression trend line stats and the median stage levels for each time period
- **[click]** 1987-1993
    - Median is 5.23 feet
    - Trend is positive
- **[click]** 1995-2001
    - Median also is 5.23 feet
    - Trend is positive
- **[click]** 2002-2020 – As we saw before
    - Median decreases to 4.89 feet
    - Trend is negative




- It appears, therefore, that the stage decline was not initiated in 1994 and that more sleuthing is needed
- I had hoped to read through the waterfront reports for that period sometime in the near future to look for other clues


- Uncertainty about the what is driving the long-term decline in stage and its disconnect from the trend of increasing discharge flows also has implications for the Water Management District's proposed minimum flow for the Wakulla-Sally Ward Springs system
  - **[click]** The District released its draft Technical Assessment on November 20, 2020
  - **[click]** They conducted a public workshop on their draft proposed minimum flow rule on February 16
  - **[click]** The District released the final report of their Technical Assessment Peer Review Panel on Mar 1
  - **[click]** And presented the proposed rule to the District Governing Board on Mar 11
  - **[click]** They have not yet published the proposed rule in the Florida Administrative Record;
  - **[click]** Once they do so, that will open a final 21-day window for public comments on the proposed rule.




- The MFL Peer Review Panel found that **[click]**

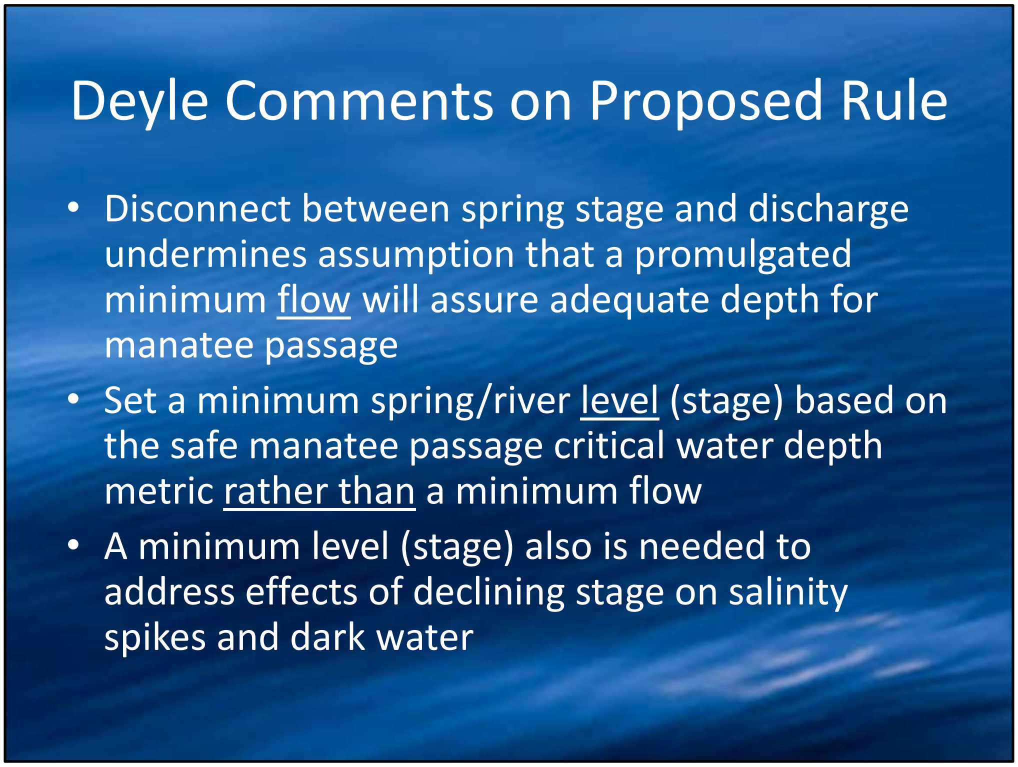
**[click]**

## MFL Peer Review Panel Findings and Conclusions

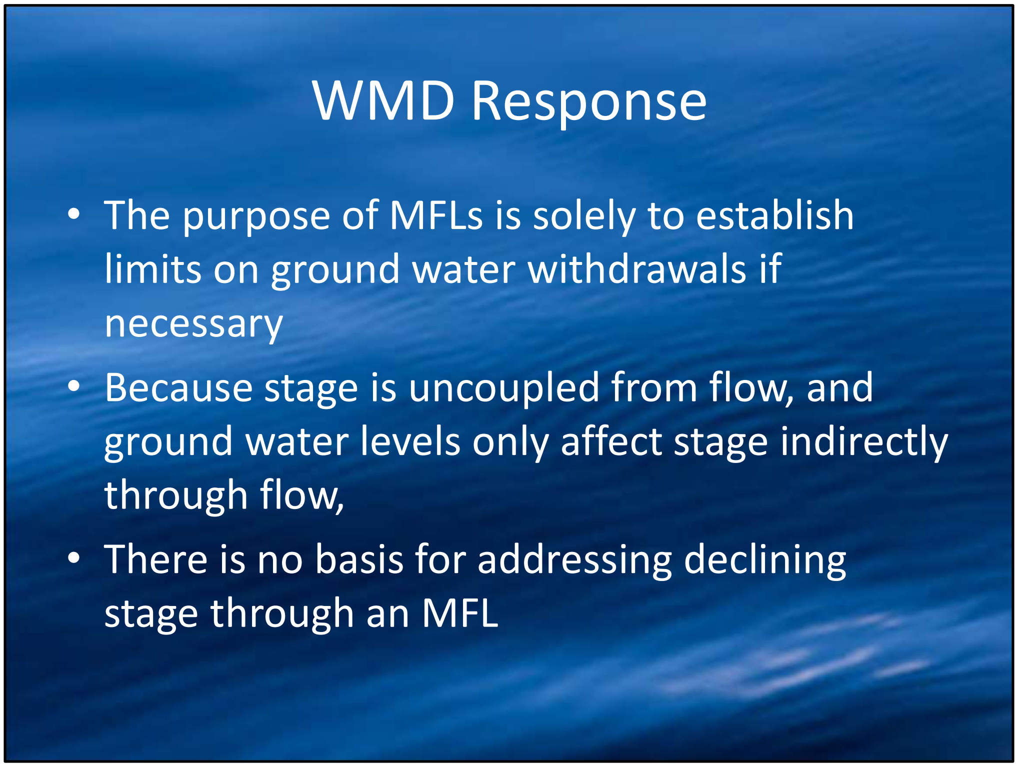
- In addition, groundwater withdrawals . . . that could reduce spring flow over the next 20 years are projected to be very small,

  which considerably decreases the risk that the proposed MFL would be reached in the foreseeable future or before the MFL is re-evaluated in the review cycle.” (p. 2)

- Furthermore, they found that **[click]** “groundwater withdrawals . . . that could reduce spring flow over the next 20 years are projected to be very small,
- **[click]** which considerably decreases the risk that the proposed MFL would be reached in the foreseeable future or before the MFL is re-evaluated in the review cycle.” (p. 2)




- I submitted personal comments on the proposed rule following the February 16 public workshop
- I argued that **[click] t**he disconnect between upper river/spring pool stage and spring discharge undermines the key assumption of the proposed rule
    - that a promulgated minimum flow of 539 cfs will assure maintenance of the critical 3.8 ft depth required to sustain the single limiting Water Resource Value metric of safe manatee passage




- The WMD’s response has been that
  - **[click]** The purpose of MFLs is solely to establish limits on ground water withdrawals if necessary
  - **[click]** Because stage is uncoupled from flow, and ground water levels only affect stage indirectly through flow,
  - **[click]** There is no basis for addressing declining stage through an MFL