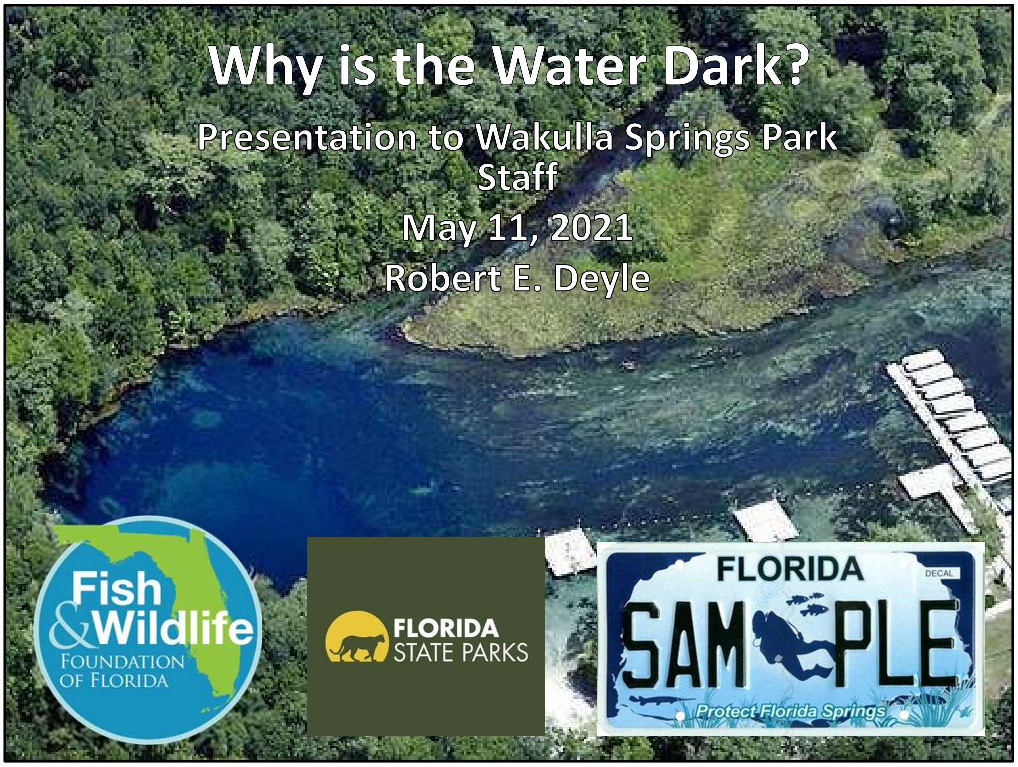


• I would like to share with you today what I believe we now know about why the water in the spring is “dark” so much more often than in the past, resulting in the almost complete cessation of glass-bottom boat tours and contributing to the decline of the submerged aquatic vegetation that forms the foundation of the spring food web

• I will be drawing on research conducted by the Northwest Florida Water Management District, the US Geological Survey and other hydrogeologists, and a recently completed 4.5-year Wakulla Springs Alliance project funded with Protect Florida Springs tag grants from the Fish and Wildlife Foundation of Florida **[click]**.

• Also essential to the project’s success was the support provided by the Wakulla Spring State Park administration, in particular, former park manager Pete Scalco and current manager, Amy Conyers, who arranged for weekly boat access to the spring boil for sampling. **[click]**

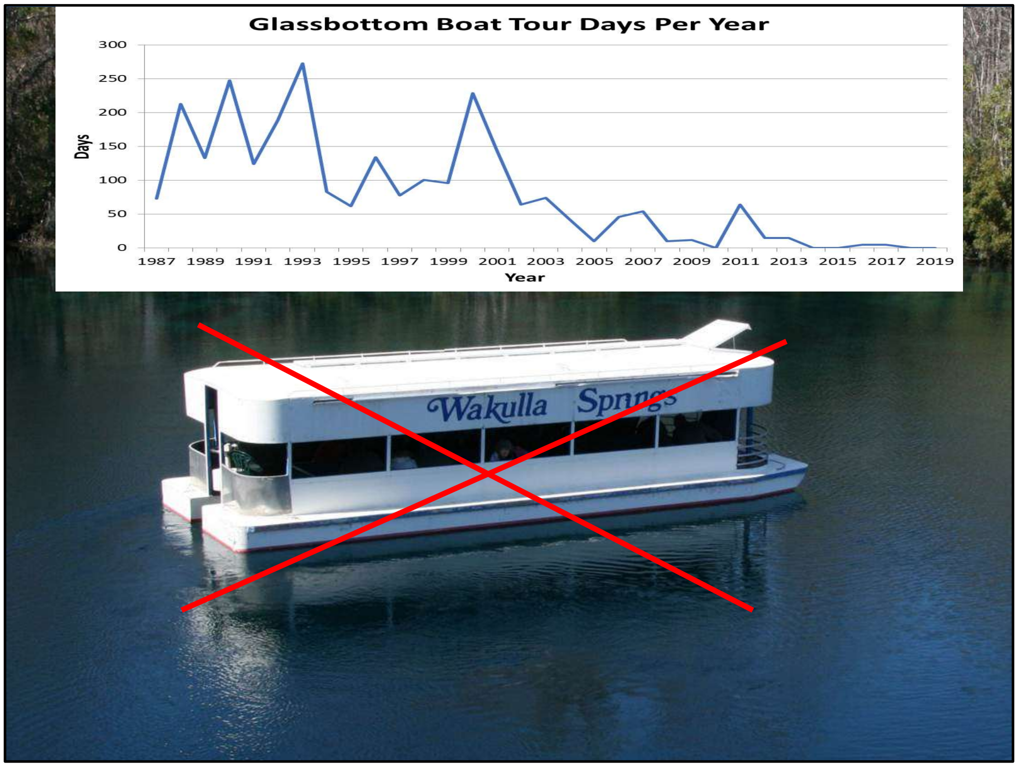
• Dr. Sean McGlynn collected and analyzed the weekly water quality and light data that are the backbone of the study, as well as conducting dye studies and water quality analyses of karst lakes and sinking streams that are sources of the light-absorbing substances responsible for the dark water conditions in the spring

• A host of volunteers assisted with field work at the spring and the karst lakes, including Cal Jamison, Sophie Wacongne-Speer, Emily Speer, Andreas Hagberg, and Bob Thompson

• When I moved to Tallahassee in 1991 you could see all the way to the bottom of the spring from a boat or the top of the dive tower through water "as clear as gin" and "sapphire blue," as one British travel writer once described it
• **[CLICK]** Historically, the water turned tea-colored after major rain events.
• Typically, visibility would return after a few weeks, unless we had prolonged periods of rain.
• But now as you know, the spring stays dark most of the time
• The periods of time when the water is brown have increased in duration and frequency
• **[click to next slide]** In addition, during times when the water has historically cleared, i.e., when you could see all the way to the bottom, the water appears green, with varying degrees of intensity

- The change is dramatically shown by comparing this low-altitude air photo from 1990 with the current Google Earth image that I downloaded a few weeks ago. **[click]**


Spring Boil Sample Location
Westside Spring
Google Earth
N
200 ft

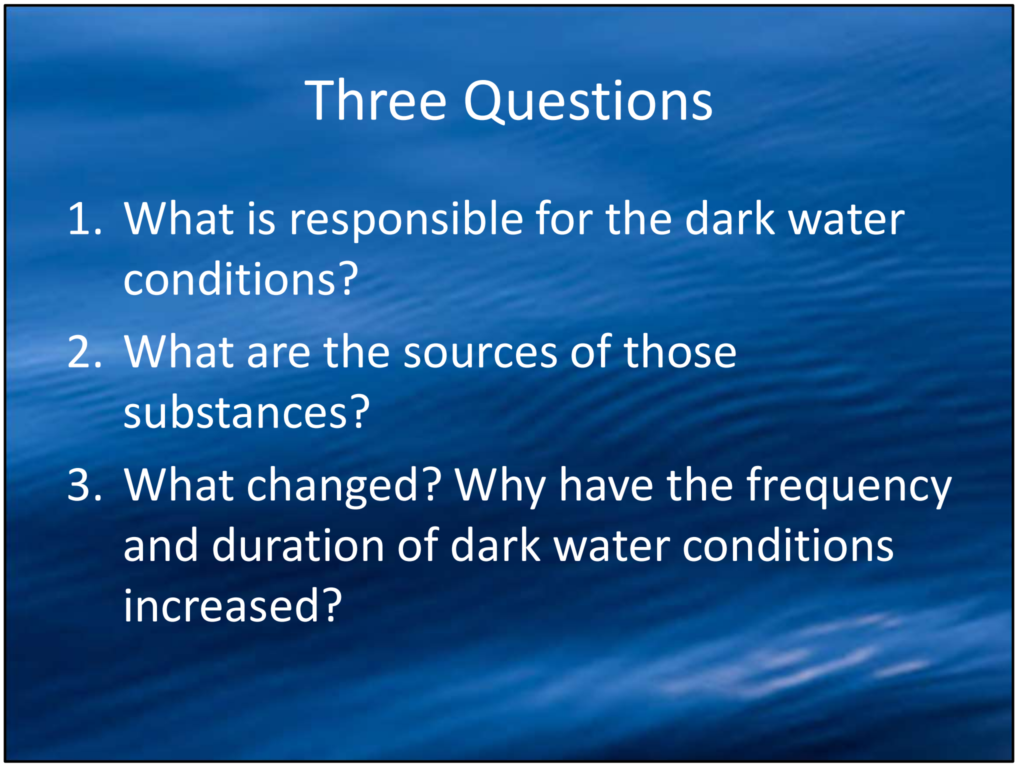


• Glass-bottom boat tours have been the most obvious casualty of the more frequent dark water conditions

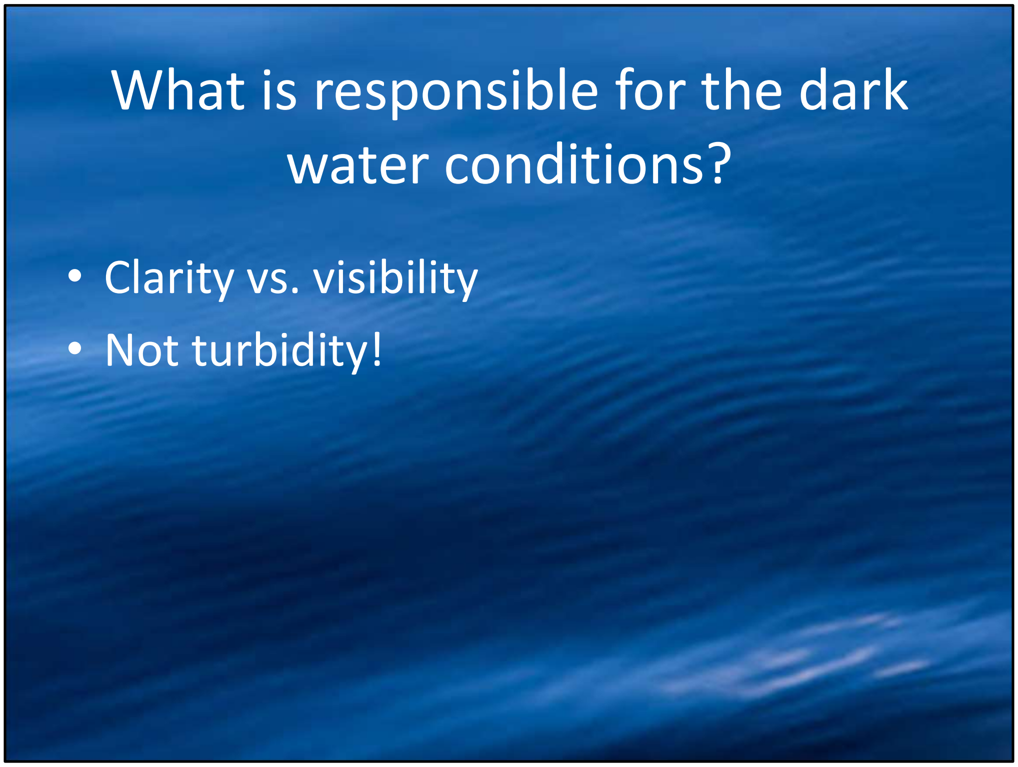
  • The park has typically suspended glass-bottom boat tours when the visibility is less than 75 feet because there's not much to see if the visibility depth is any less

• **[CLICK]** As shown on this chart, in the late 1980s and early 1990s we typically ran GBB tours 150 or more days a year

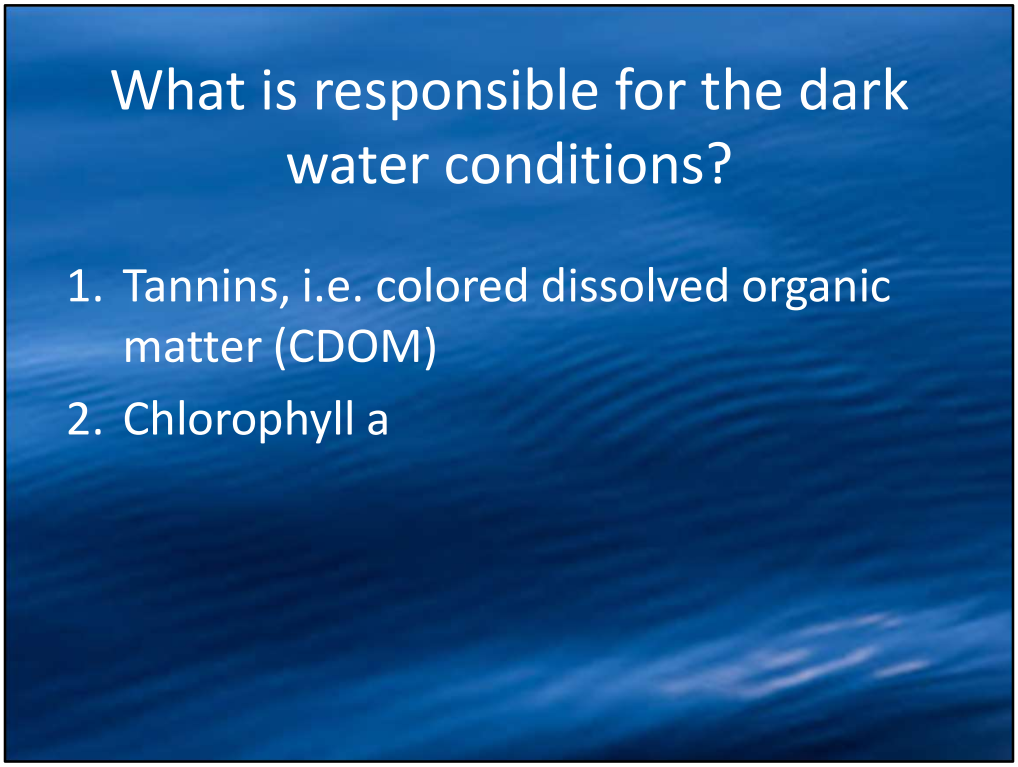
  • But that number fell off dramatically in 1994 (83)
  • It recovered briefly in 2000 and 2001; then fell off sharply again and has trended downward since
  • **[CLICK]** None since 2017



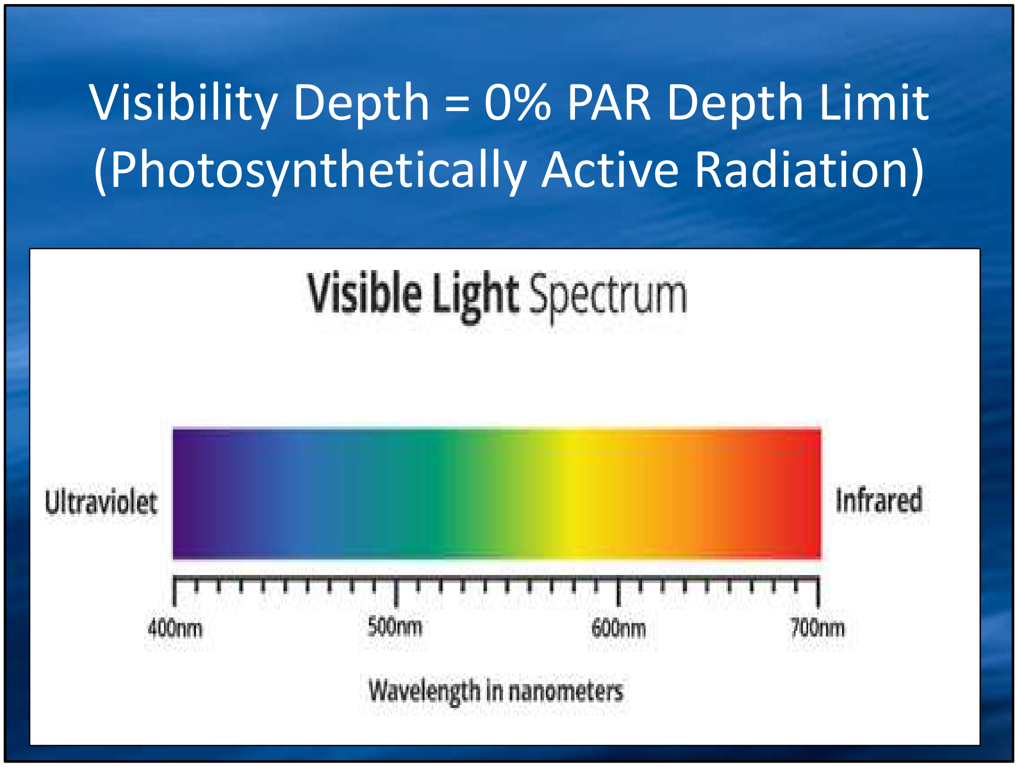
- What I'd like to do is address three questions
- **[3 clicks]**



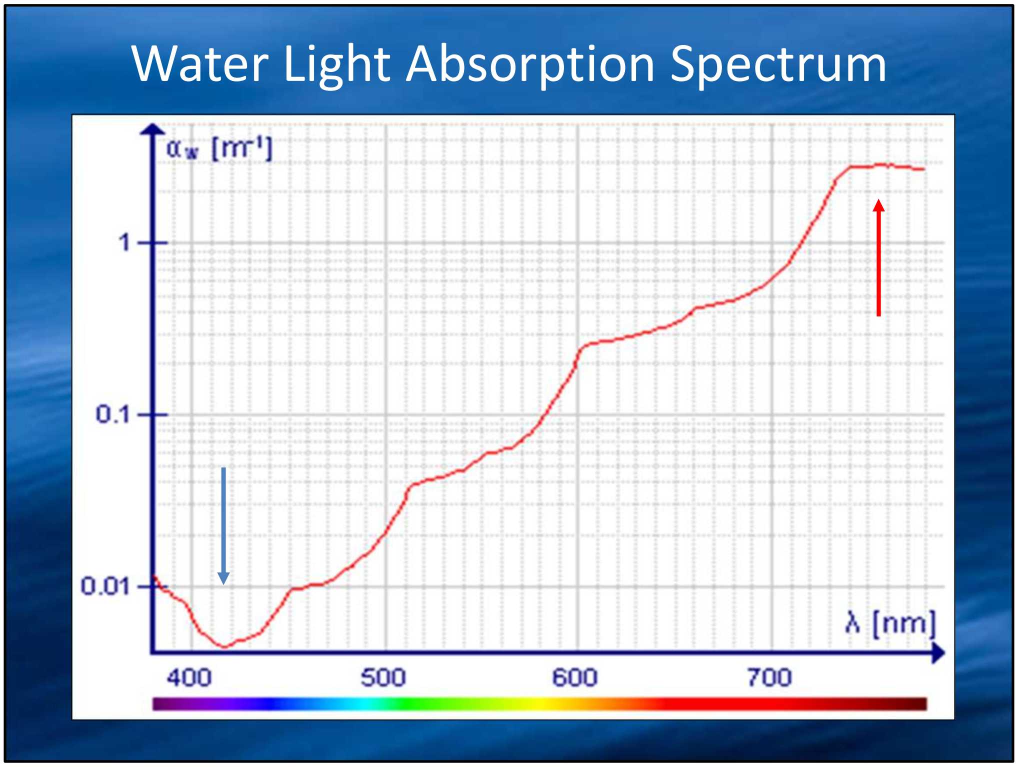
- **[click]** Folks often talk about the clarity of the spring, but I try to speak in terms of visibility.
- When we say that water is not clear we're often talking about "cloudy" water caused by suspended sediments or turbidity
- But that's generally not the case with Florida springs
    - Turbidity is typically very low compared with streams, ponds, and lakes
- **[click]** Turbidity data measured at the WMD gauge on the boat dock reveals that this is true for Wakulla Spring:
    - While cave divers and other observers report occasional turbid conditions . . .
    - statistical analysis indicates that turbidity is not a significant cause of the observed low visibility conditions that we call "dark water" **[click to next slide]**



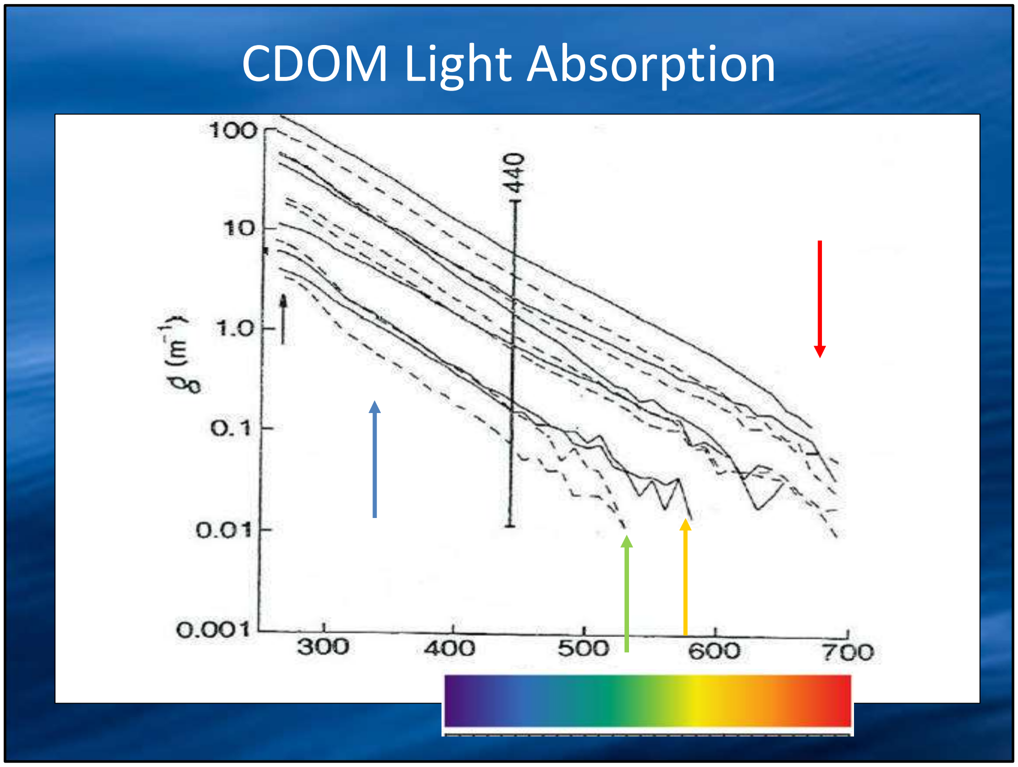
- The principal cause of low visibility in Wakulla Spring and most other springs in Florida is light absorption by dissolved substances
- Two such substances predominate:
    - **[click]** The first is what folks usually call tannins, which is one member of a class of naturally-occurring, complex organic molecules, referred to more generally as colored dissolved organic molecules or CDOM
    - **[click]** And chlorophyll, in particular, chlorophyll a, the pigment produced by algae and vascular plants that enables photosynthesis to occur



- For this research, Dr. McGlynn defined visibility depth as the depth at which all photosynthetically active radiation or PAR is extinguished by absorption or the 0% PAR depth limit
- The PAR spectrum is the range of wavelengths that plants can use for photosynthesis ranging from 400 to 700 nanometers
- It is equivalent to the spectrum that humans can see, what we call “visible light”

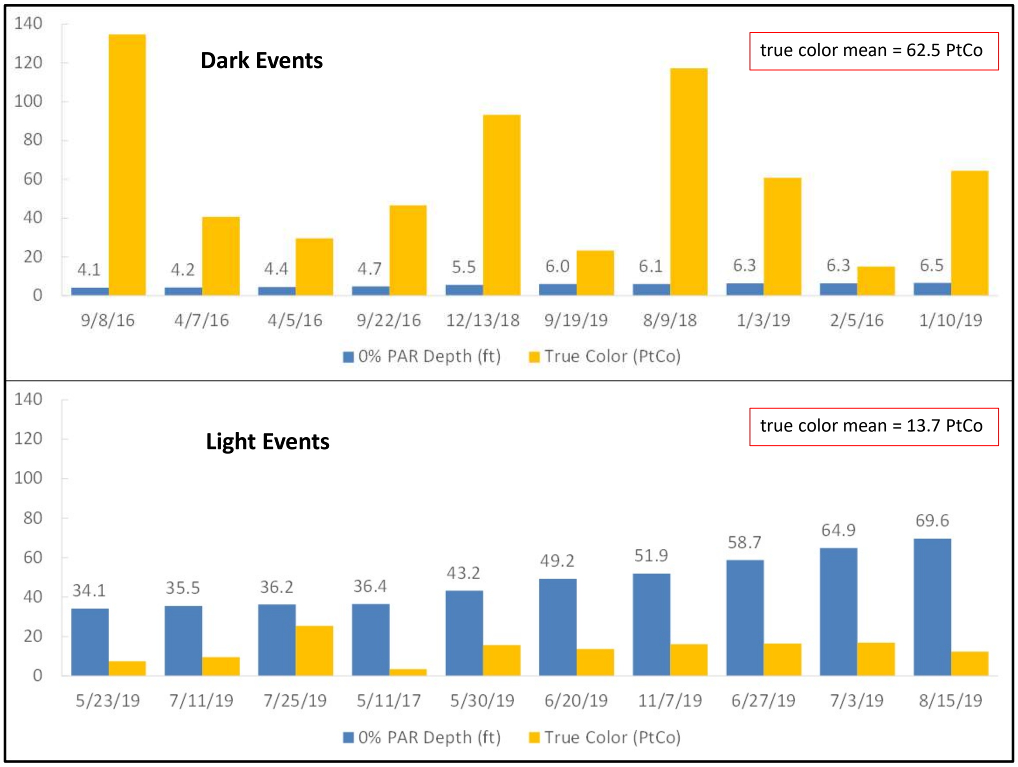


- Pure water absorbs light most strongly at the higher wavelengths in the red range **[click]**
- Thus it's the shorter blue wavelengths that are most fully transmitted, hence clean water looks blue **[click]**
- As Wakulla Springs once did [click to next slide]

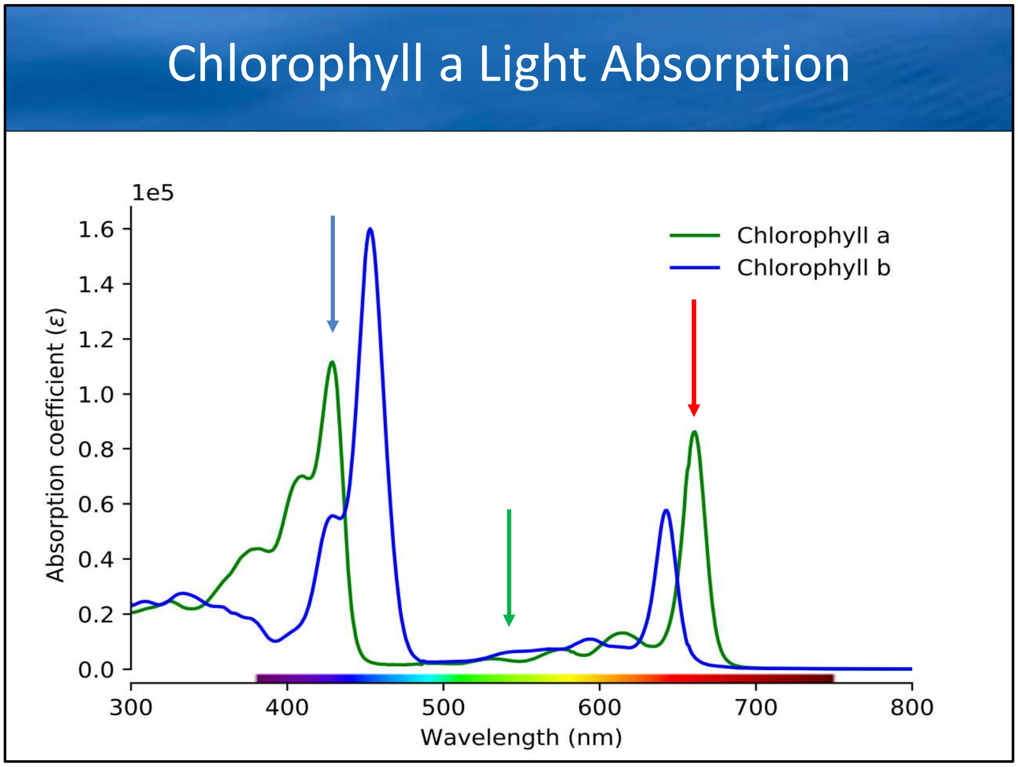


- This is a chart of light absorption by CDOM at different concentrations from a study of 26 lakes in New Zealand
- CDOM absorbs predominantly the shorter blue as well as ultra-violet wavelengths less than 400 nm which are outside the visible range **[click]**
- This shifts the dominant light transmission back to the right **[click]**
    - High concentrations of CDOM absorb enough of the blue light to make the water appear reddish brown
- At lower concentrations, less blue light is absorbed and the transmitted wavelengths shift to the left
    - Intermediate concentrations can yield a yellow to orange color **[click]**
    - Low concentrations can produce an apparent green color **[click]**
- This is nicely illustrated in the next slide

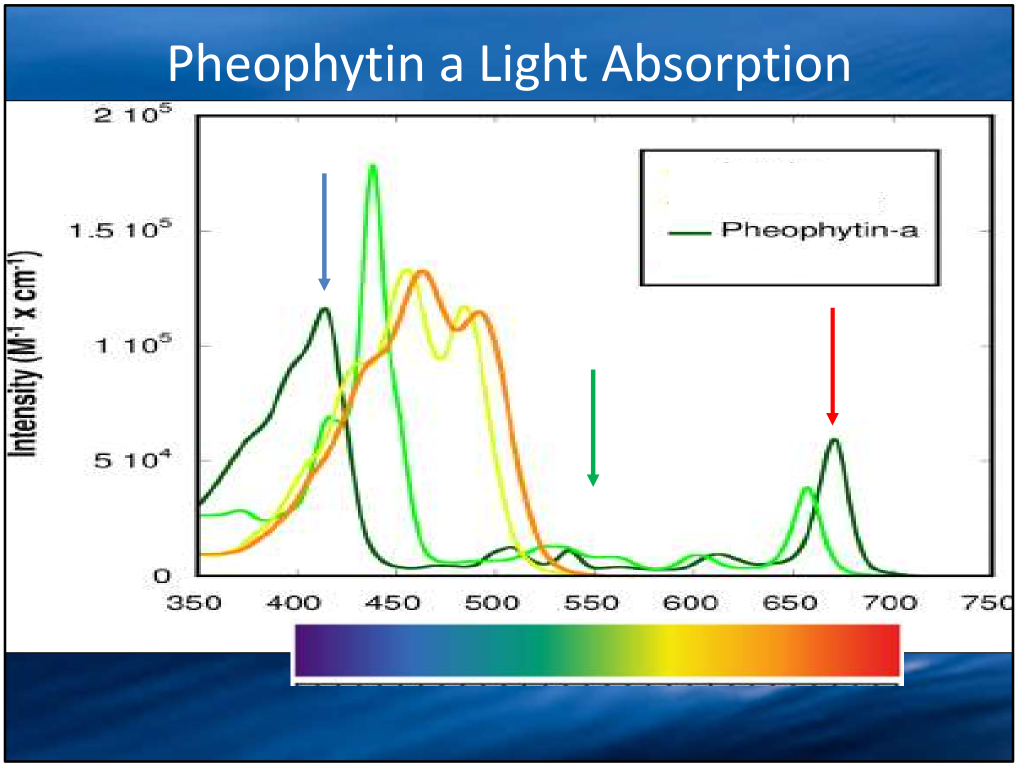
- This National Geographic photo depicts highly tannic water from the Santa Fe river flowing into the Ginnie Spring run in Gilchrist County
    - You can see the color shifts with decreasing concentrations of CDOM in the area above the diver



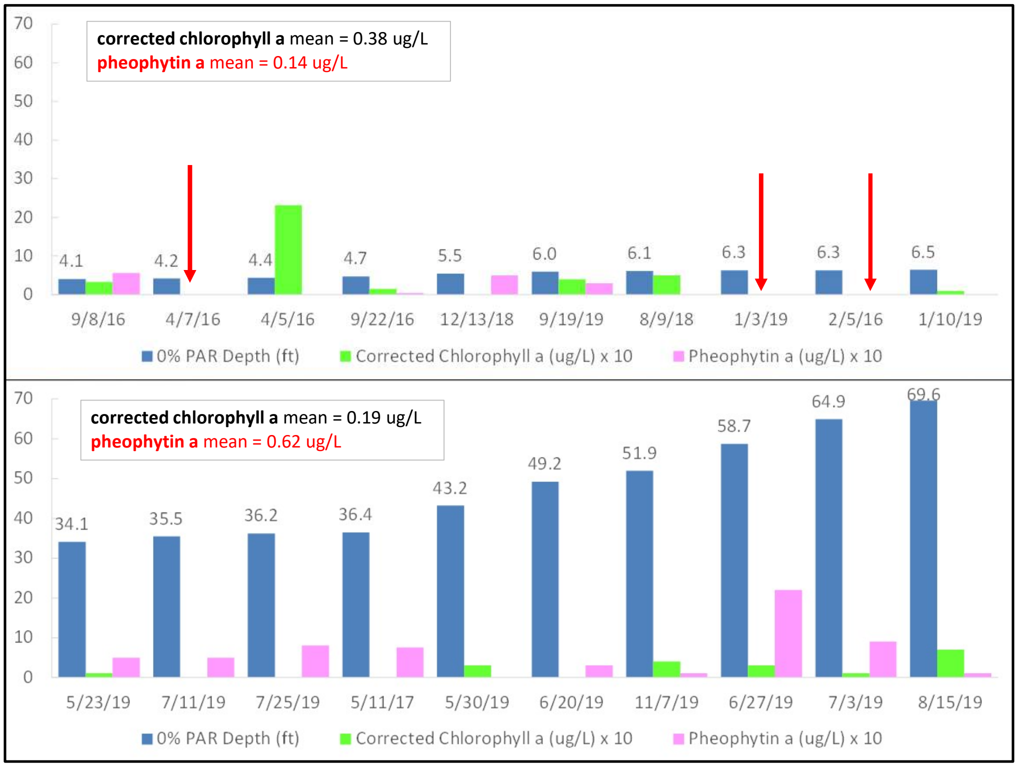
- Tannins measured as true color were detected at the spring boil all but five weeks out of 189 over the 4.5-year study period between Dec 2015 and Jan 2020
- If we compare their levels on the 10 dates when visibility was lowest, what we might call "dark water events,"
- **[click]** with those on the 10 dates when visibility was greatest, or "light events," we see a substantial difference:
    - **[click]** The mean true color level during the 10 dark events was 62.5 platinum-cobalt units (PtCo)
    - **[click]** During the 10 light events, the mean was only 13.7 PtCo
- Note that tannins are present on each of the "light event" dates when the perceived color of the water would have been green or greenish brown



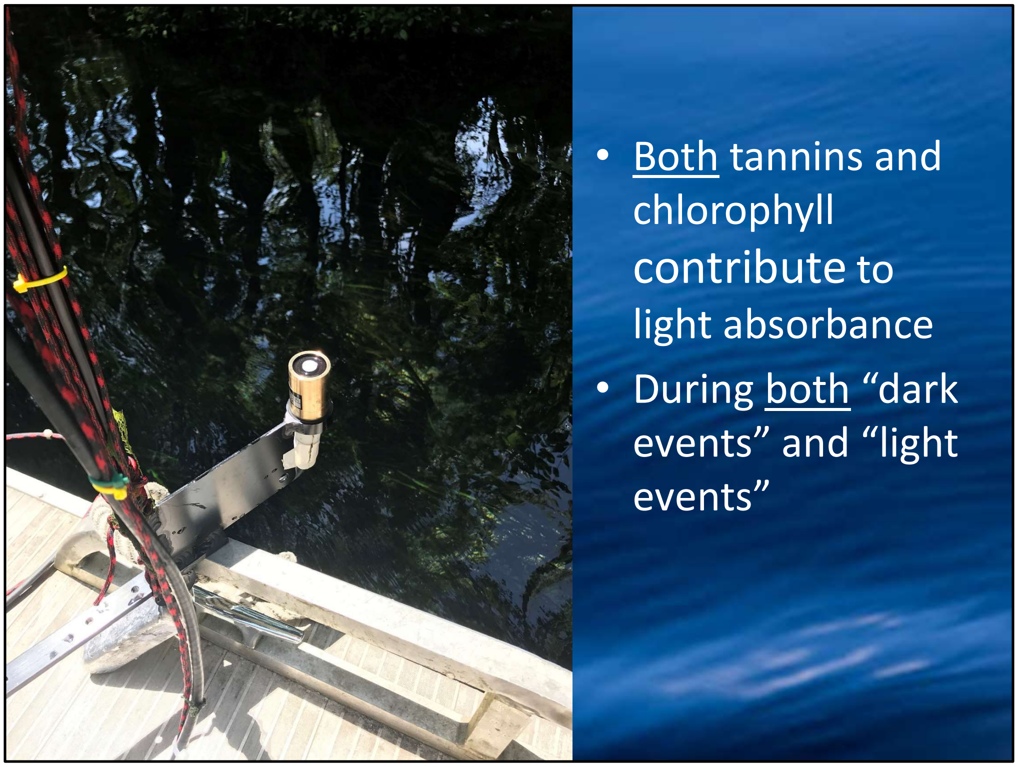
- Chlorophyll a absorbs light in two regions of the visible spectrum
  - with one peak in the blue range at 430 nm **[click]**
  - and a second in the red range at 665 nm **[click]**
- If we just introduce chlorophyll a to clean water the transmission peak shifts to the middle of the visible light spectrum and the apparent color is green **[click]**



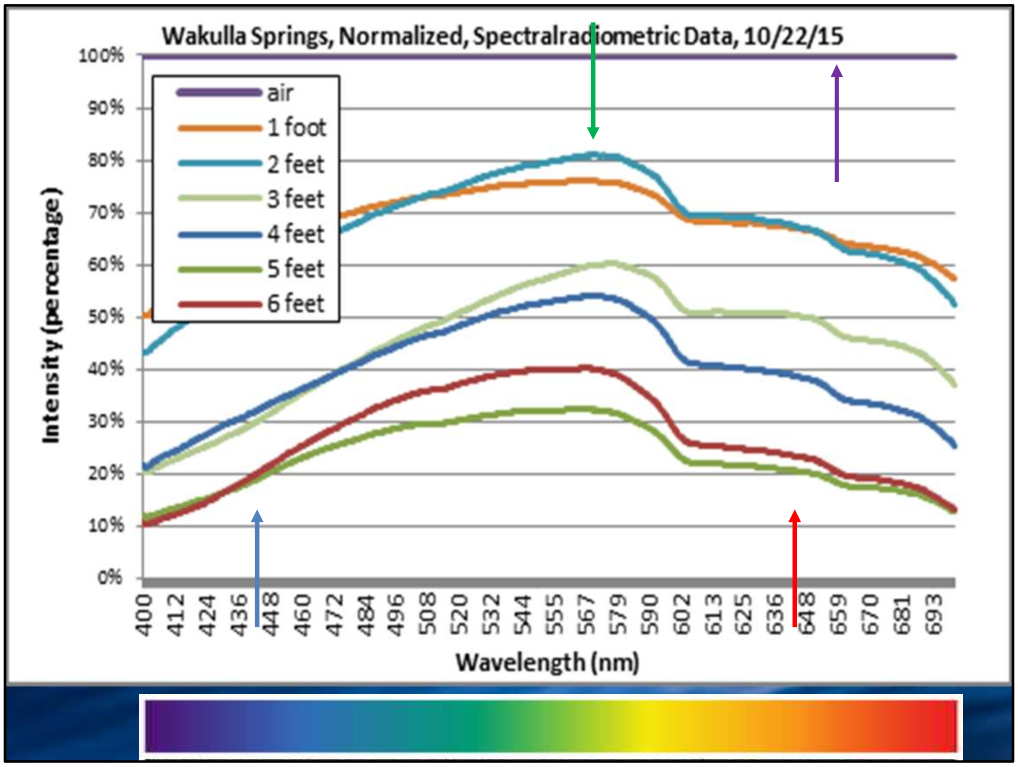
- Some of the chlorophyll we find in the spring is a degraded form called pheophytin
- Pheophytin a has a similar absorption pattern with slightly different peaks:
  - a blue range peak at 420 nm **[click]**
  - and a red-range peak at 654 nm **[click]**
- Again yielding an apparent color that is green **[click]**



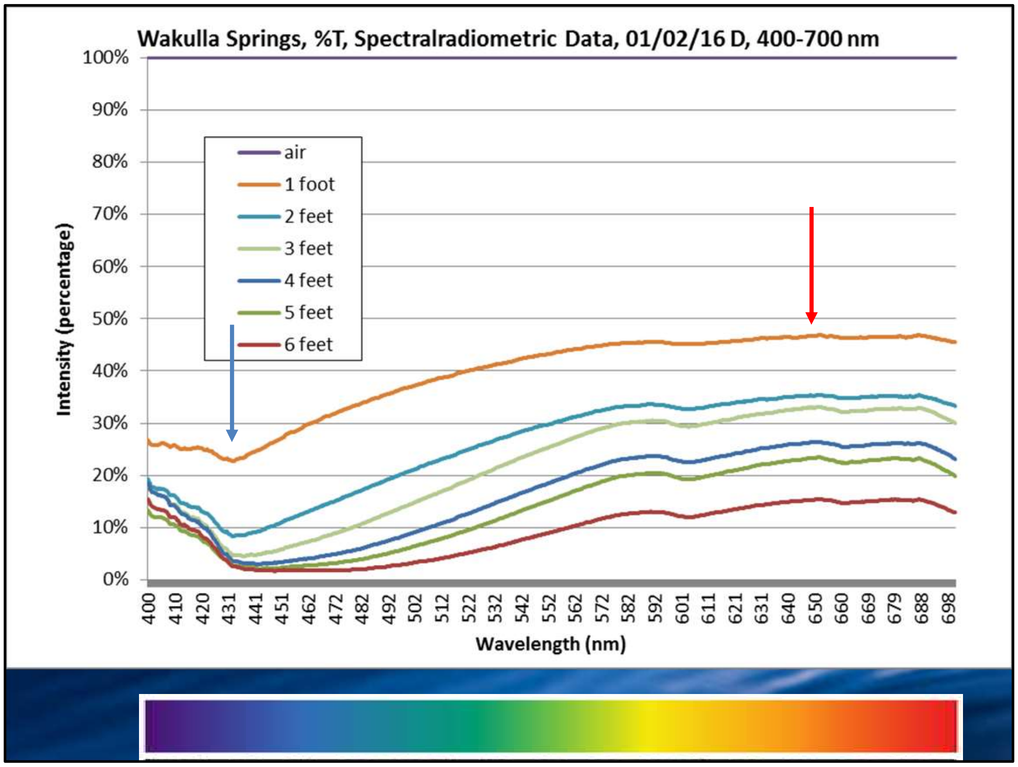
- This graph depicts again depicts the 10 dark event dates when visibility was lowest
- this time with concentrations of "corrected chlorophyll a" and pheophytin:
    - Corrected chlorophyll a is total chlorophyll a minus pheophytin
    - **[click]** On three dark event dates neither form of chlorophyll a was detected
- **[click]** Examining the 10 light event dates when visibility was highest
    - **[click]** Mean corrected chlorophyll a values are lower than for the 10 dates when visibility was lowest
    - **[click]** But mean pheophytin a values are actually higher
    - One or the other form of chlorophyll a was detected on each light event date



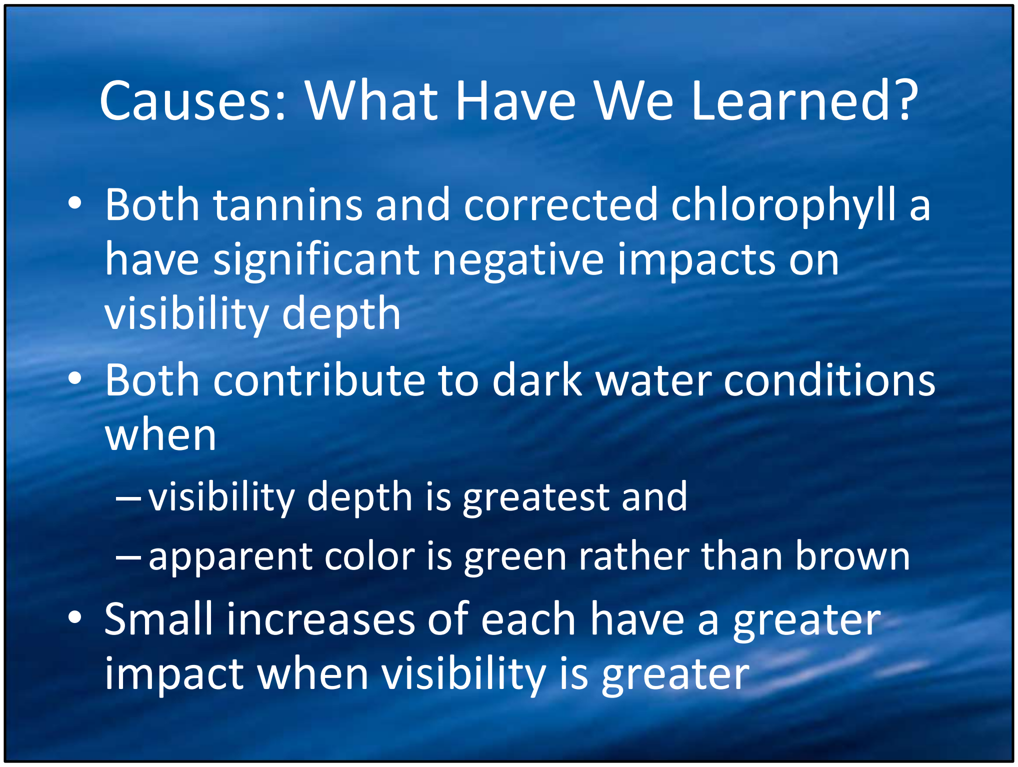
- The other evidence of the influence of tannins and chlorophyll on visibility depth comes from light absorption readings taken in the spring
- A device called a spectral radiometer is connected to a light-sensing probe lowered over the side of the boat
- The spectral radiometer measures the amount of light transmitted at each depth at each wavelength
- By calibrating it to a light reading just above the surface, it is possible to calculate the percent of light absorbed at each depth
- **[click]** Specrad analysis has confirmed that both tannins and chlorophyll contribute to light absorbance
    - **[click]** during both dark events when the spring appears brown
    - and during light events when it appears green



- This is a graph of percent visible light transmission created by Dr. McGlynn from the spectral radiometric readings taken during a light event when visibility depth was relatively high and the apparent color was green
    - It compares light transmission at each depth at each wavelength with transmission measured in the air just above the water surface – **[click]** the purple line at the top
- As is to be expected, percent transmission decreases with depth:
    - As light passes through more water, more light is absorbed by the water itself and any light-absorbing substances that are present
- During this light event
    - both the shortest wavelengths **[click]**
    - and the longer wavelengths **[click]** were being absorbed
    - indicating the presence of both tannins and chlorophyll
- **[click]** Greatest transmittance was in the middle in the green and yellow range

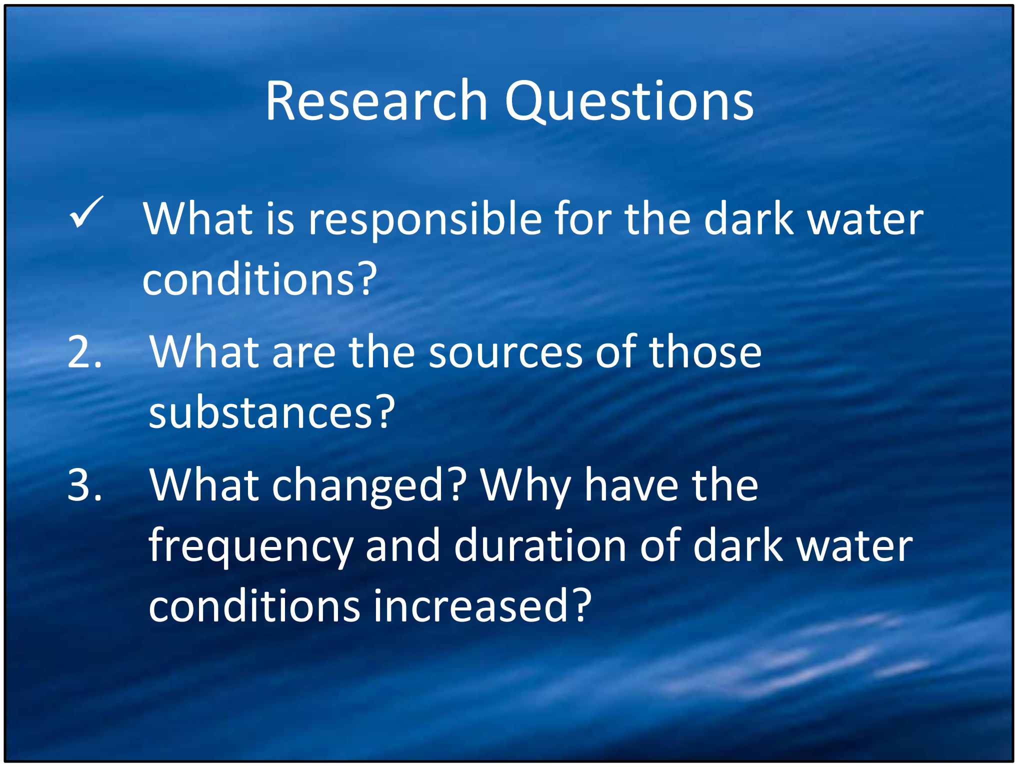


- This specrad graph illustrates the profile of a typical “dark event” when visibility depth was less and the apparent color was reddish brown associated with high tannin levels
- The shortest wavelengths were strongly absorbed **[click]**
- While the longer wavelengths in the red range were being more fully transmitted **[click]**

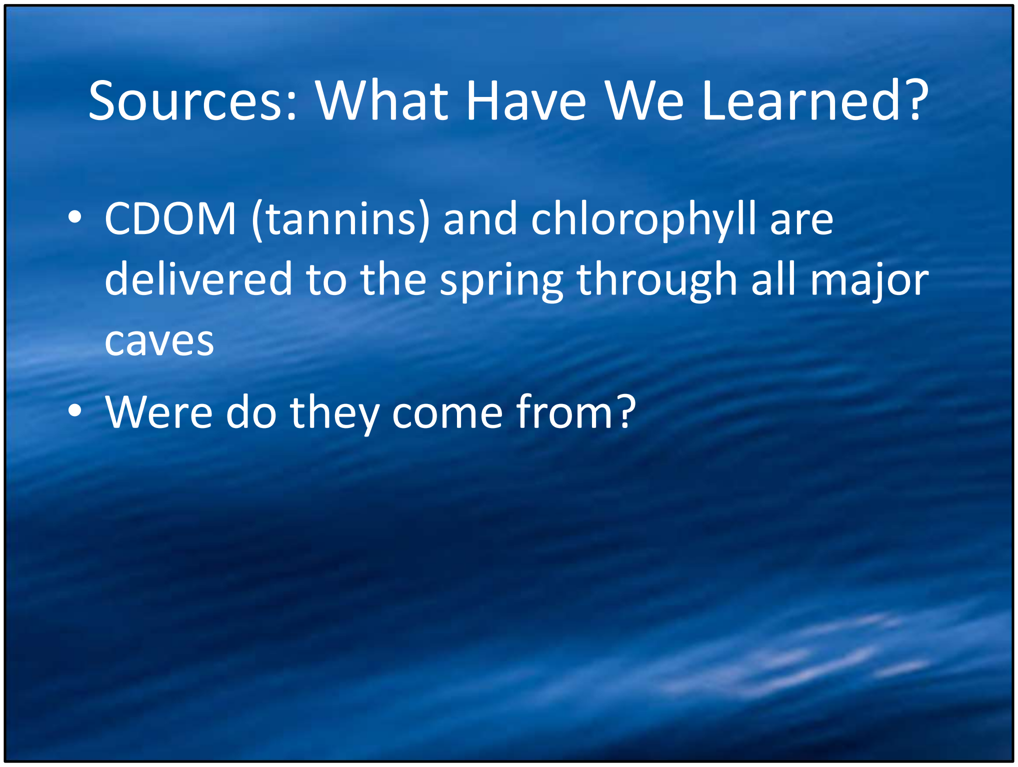


Statistical analysis reveals that

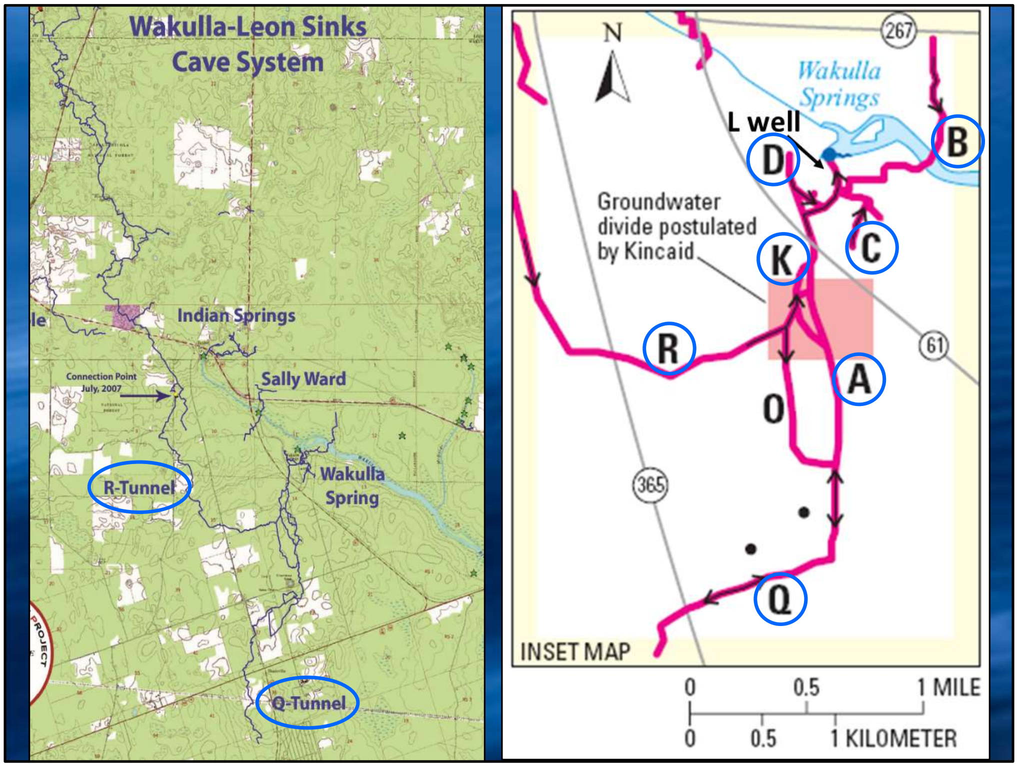
- **[click]**
    - However, pheophytin levels do not have statistically significant effects on visibility depth
- **[click]** Tannins and corrected chlorophyll a also contribute to dark water conditions when
    - **[click]** visibility depth is greatest and
    - **[click]** the apparent color is green rather than brown
- **[click]** Small increases of each have a greater impact when visibility is greater: a little bit goes a long way



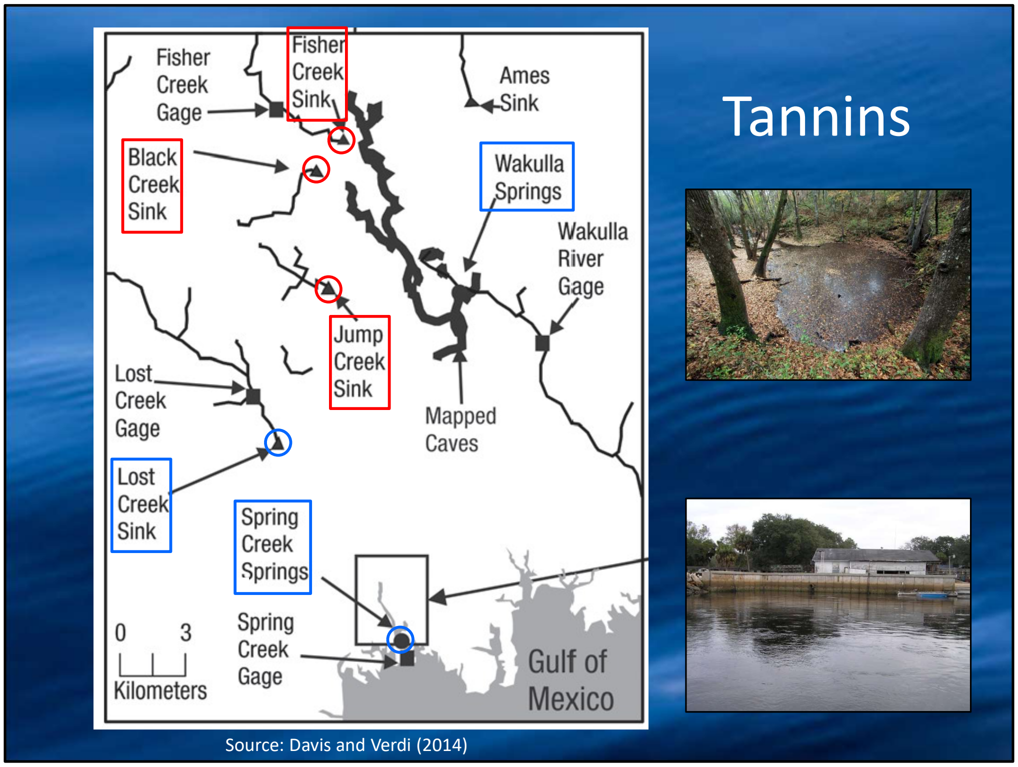
- Moving on to the next question, we ask "What are the sources of those substances?"



- Water quality sampling from the cave test wells conducted by Dr. McGlynn between August 2016 and August 2017 demonstrated that
    - tannins and chlorophyll are delivered to the spring in ground water flowing through all the major caves that converge upstream of the spring vent
- So, where do they come from?



- The largest loads of both tannins and chlorophyll a are carried via the K **[click]** and A **[click]** caves which convey about 80 percent of the total inflow to the spring
- The K cave receives flow from the R tunnel which connects to the Leon Sinks cave system to the north **[click]**
- The A cave receives flow from the Q tunnel which generally flows north to the spring **[click]**



• The principal sources of tannic water inputs to the R tunnel are three sinking streams in the Leon Sinks area of Apalachicola National Forest that flow into sinkholes, or swallets **[click]**, north of the spring **[3 clicks]**:

- Fisher Creek
- Black Creek
- Jump Creek

• Dye studies have shown that discharges to their swallets reach Wakulla Springs in 9-10 days

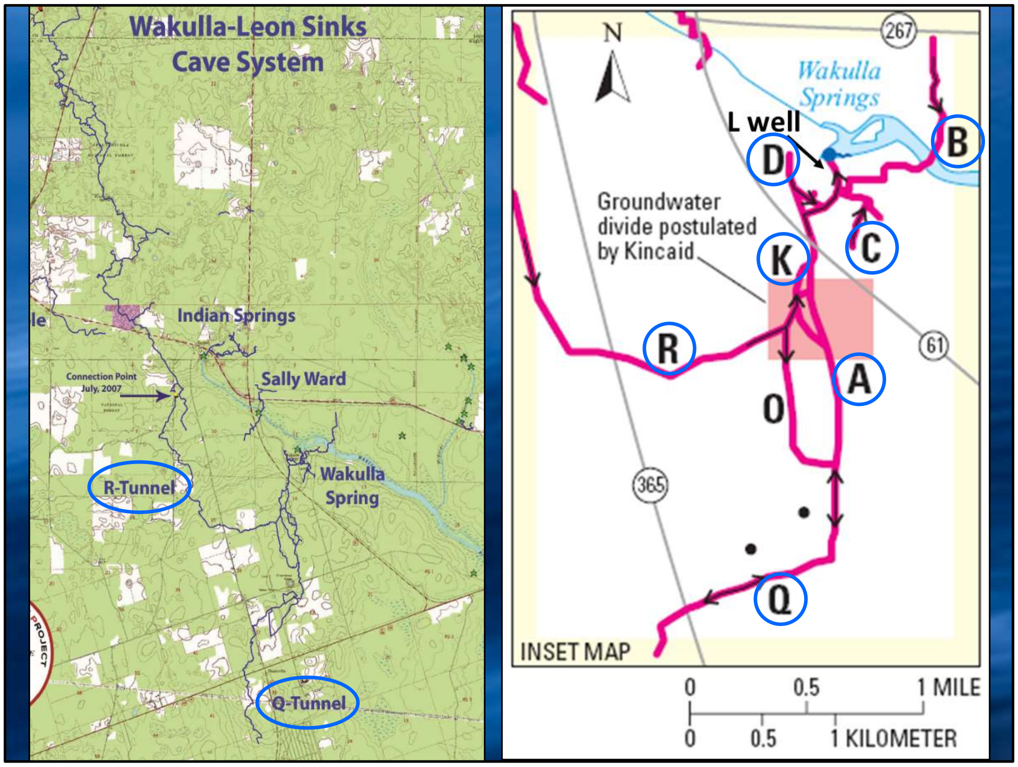
• When rainfall is scarce these may stop flowing altogether; that is when the spring formerly appeared aqua blue

• The principal source of tannic inputs to the Q tunnel is flow from a fourth sinking stream, Lost Creek,

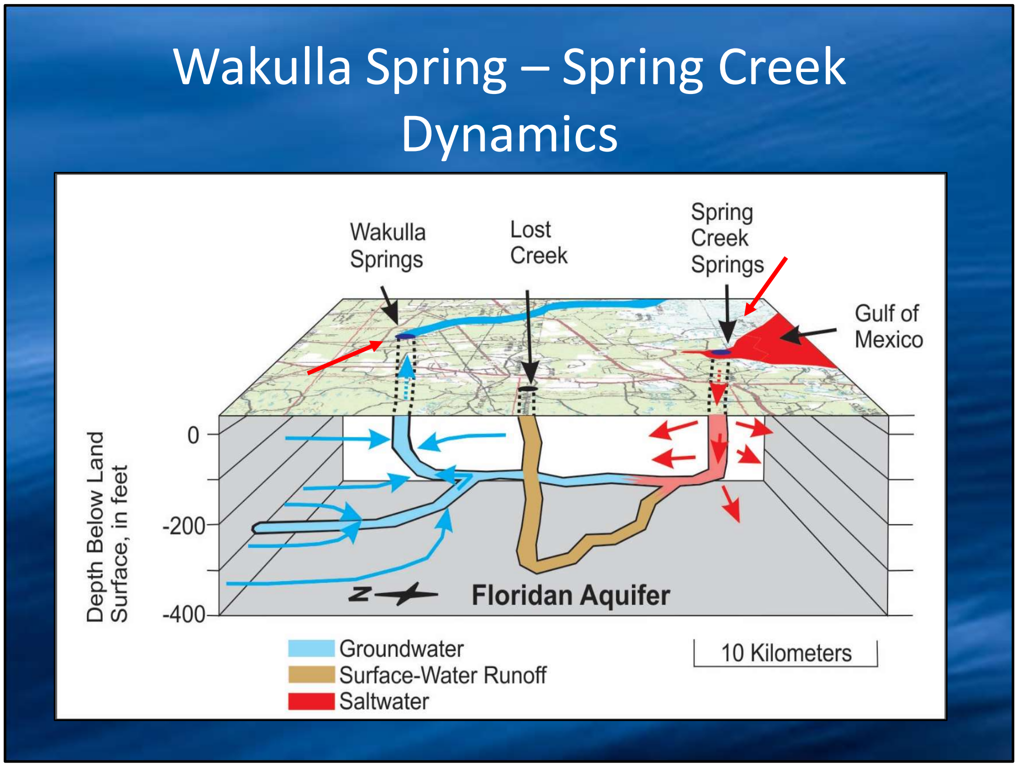
- which also flows out of the National Forest, but its swallet lies southwest of the spring **[click]**
- Lost Creek's discharge formerly flowed predominantly to caves connected to the Spring Creek spring group at the coast **[click]**

• However, after periods of protracted low rainfall, flow at Spring Creek sometimes stops or even reverses with saltwater flowing up into the aquifer

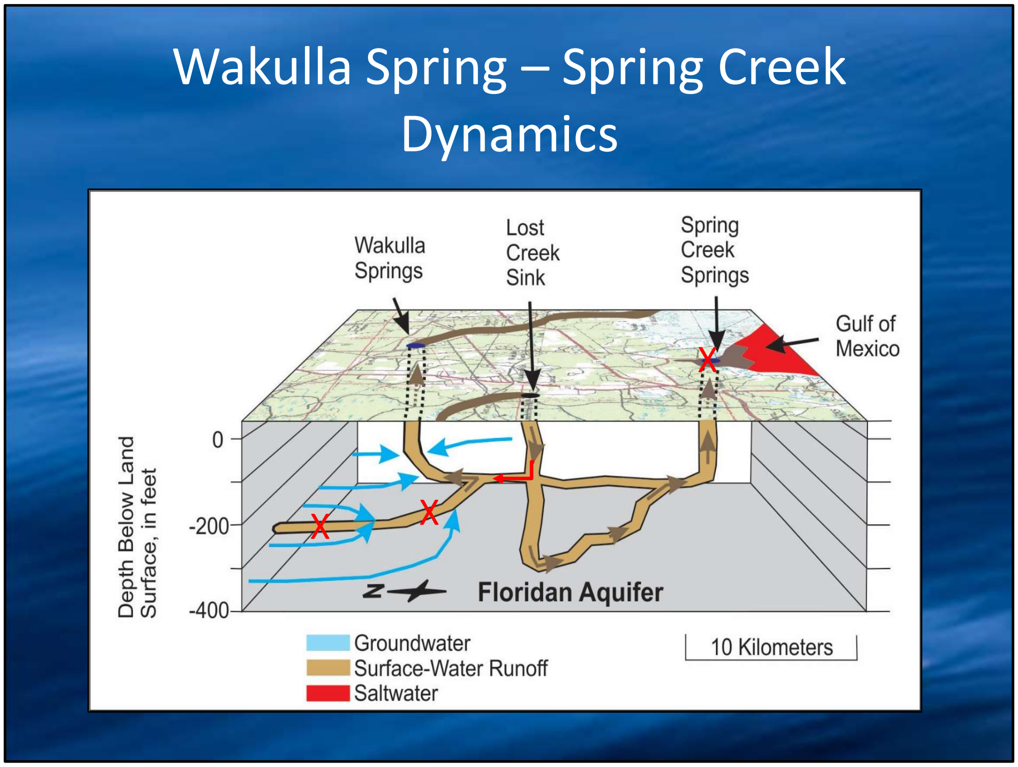
- When this happens dye studies have demonstrated that the Lost Creek discharge to the aquifer can flow north into the Q tunnel and contribute tannic inflows to the spring



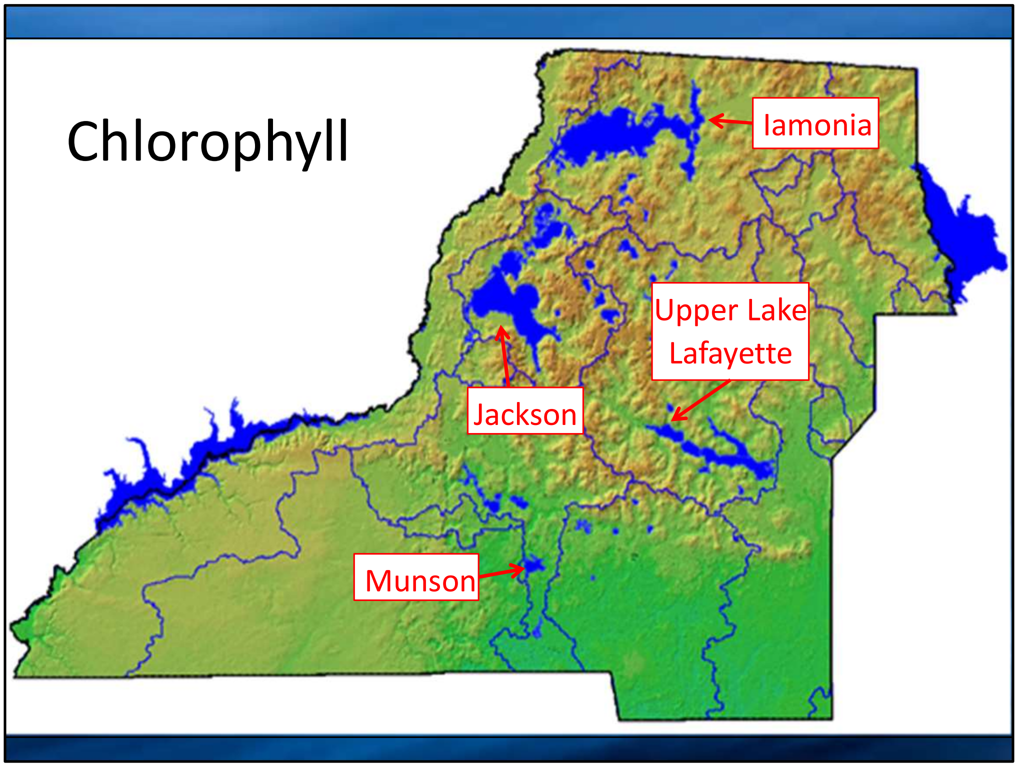
- Additional tannin inputs to the R and Q tunnels, as well as the B, C, and D caves near the spring,
  - originate from the many smaller sinks and swallets that pock-mark the area,
  - flowing through smaller conduits or as matrix flow through the karst limestone



- Let's take a closer look at this diagram by hydrogeologists Davis and Verdi to examine what happens when the Spring Creek spring group stops flowing due to saltwater intrusion associated with low rainfall conditions
  - **[click]** Saltwater flows into the Spring Creek caverns forming a high-density "plug" that resists outflow into the Gulf
  - **[click]** Water levels begin to rise at Wakulla Spring as matrix and conduit flows south of the spring reverse

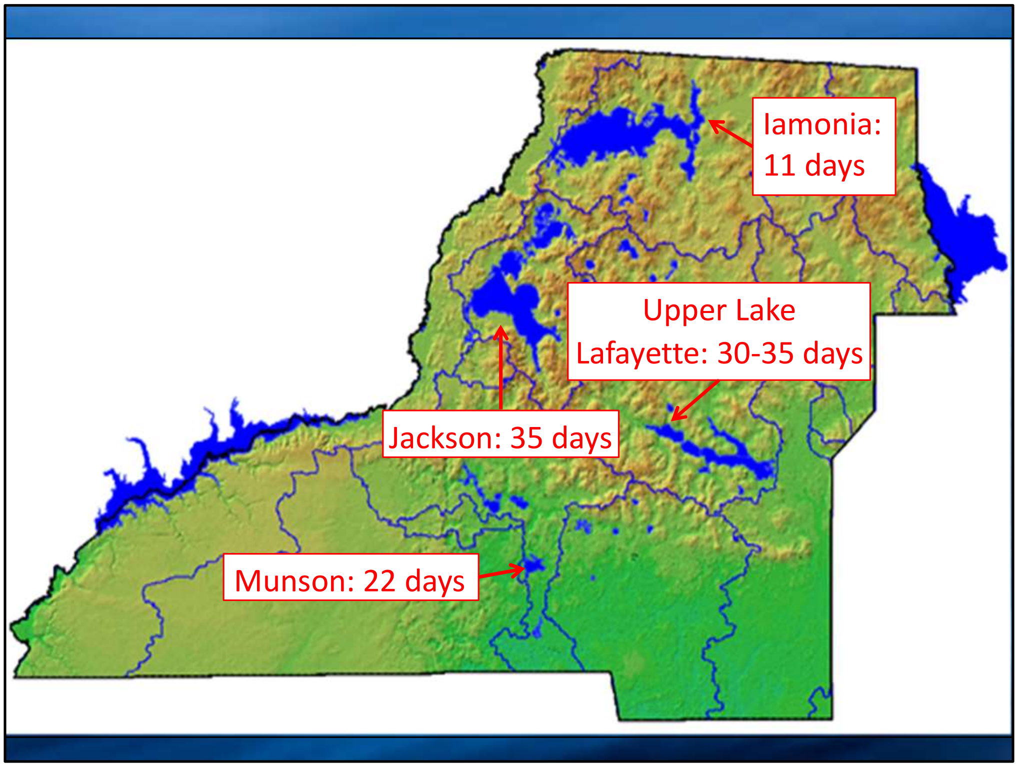


• After sufficient rainfall, the sinking streams, including Lost Creek, begin to flow and Spring Creek again discharges into the Gulf as shown in this figure
• However, there is a transition period when the saltwater plug at Spring Creek still holds back the southward flow **[click]**
  • and tannic water from Lost Creek flows north to Wakulla adding to the dark water load **[click]**
• Because of its larger watershed, Lost Creek can continue to flow after tannic flows from the Leon Sinks sinking streams cease **[click]**
  • Tannic discharges continue to enter Wakulla Spring,
  • likely contributing to the apparent green dark water conditions at the spring from low concentrations of tannins



- The sinking streams are not significant sources of chlorophyll
- It most likely originates from one or more karst lakes in the springshed north of Wakulla which discharge to the aquifer via sinkholes and bottom seepage into the karst limestone matrix
    - **[click]** Iamonia
    - **[click]** Jackson
    - **[click]** Upper lake Lafayette
    - **[click]** Munson

• Chlorophyll likely travels to the Wakulla cave system from these sources via both conduit and matrix flow

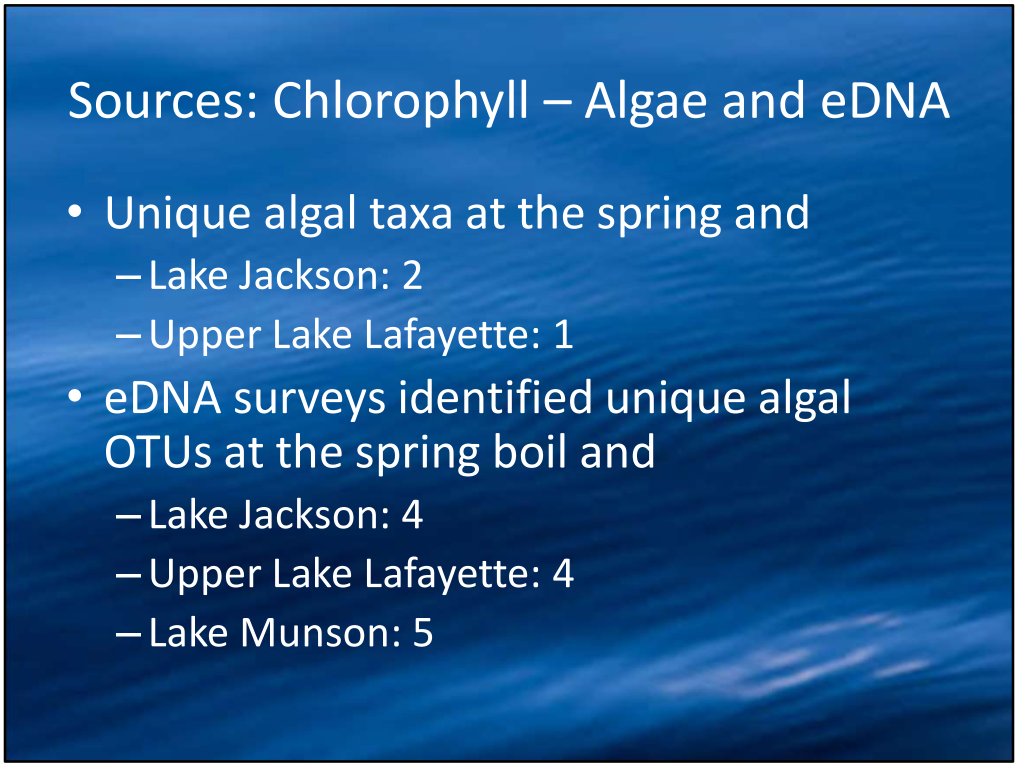


- Dye studies have documented connections to Wakulla Spring from each of these lakes:
  - **[click]** Lake Munson via Ames Sink in 22 days
  - **[click]** Lake Jackson in 35 days
  - **[click]** Upper lake Lafayette in 30-35 days
  - **[click]** Lake Iamonia in 11 days

Sources: Chlorophyll – Algae and eDNA

- Collect samples from major karst lakes and spring
- Analyze for
  - Algal taxonomy
  - Environmental DNA (eDNA)

- Comparison of samples from the karst lakes and the spring analyzed for algae taxa and environmental DNA supports the hypothesis that these are sources of the chlorophyll in the ground water flowing into Wakulla Spring

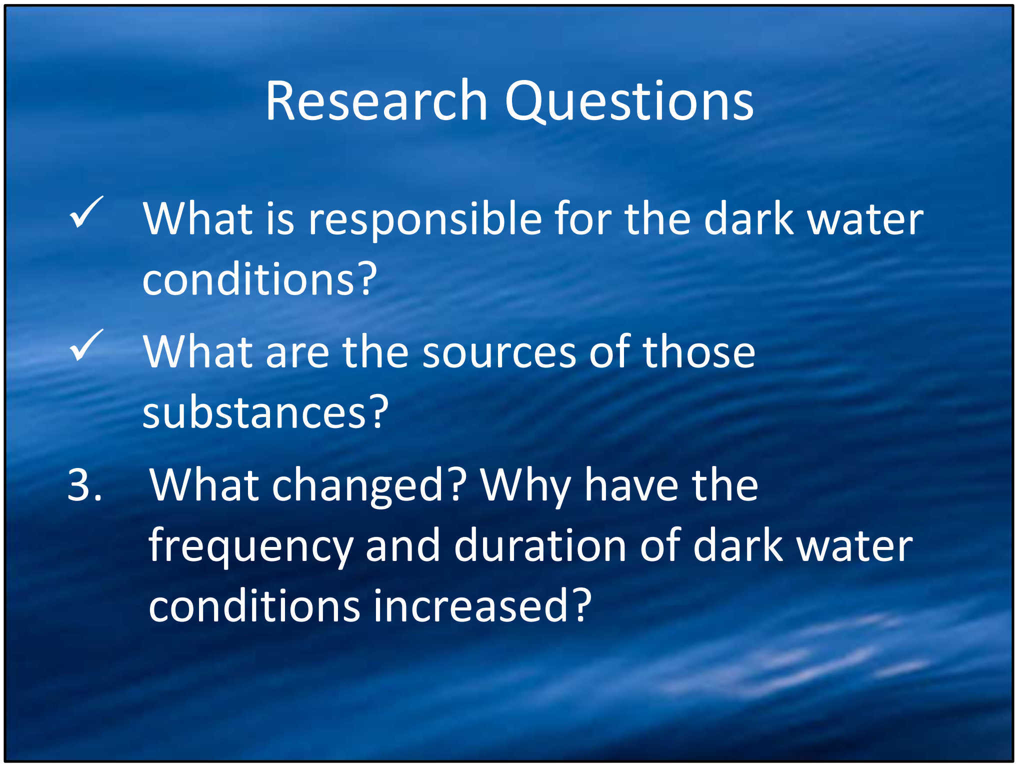


- **[click]** Algal analyses identified three taxa at the spring that were only present in Lake Jackson or Upper Lake Lafayette **[click]**
    - No algal taxa identified at spring were unique to Lake Munson
- **[click]** Environmental DNA analyses identified 13 operational taxonomic units or OTUs at the genus and/or species level at the spring that were only present in Lake Jackson, Upper Lake Lafayette, or Munson

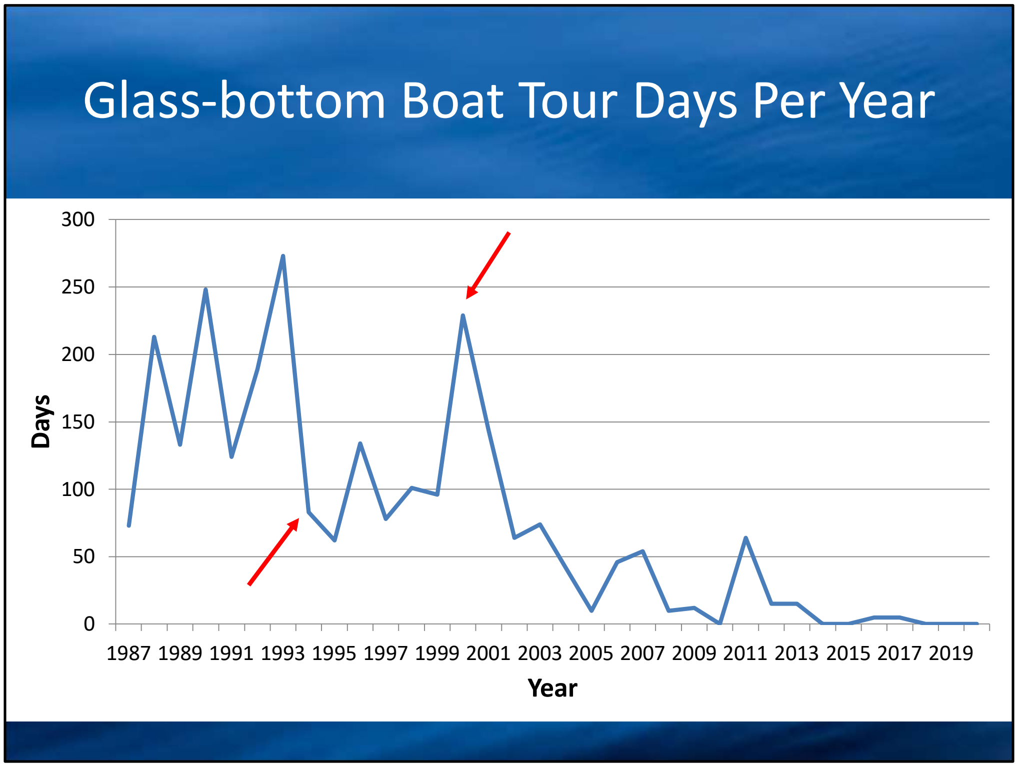
Species-Level Eukaryote Algae OTUs: Lakes and Spring

	Upper Lake Lafayette	Lake Jackson	Lake Munson/ Ames Sink	Lake Iamonia	Spring Boil
Upper Lake Lafayette	1	0.583	0.714	0.593	0.533
Lake Jackson	0.583	1	0.619	0.640	0.517
Lake Munson	0.714	0.619	1	0.625	0.500
Lake Iamonia	0.593	0.640	0.625	1	0.441
Spring Boil	0.533	0.517	0.500	0.441	1

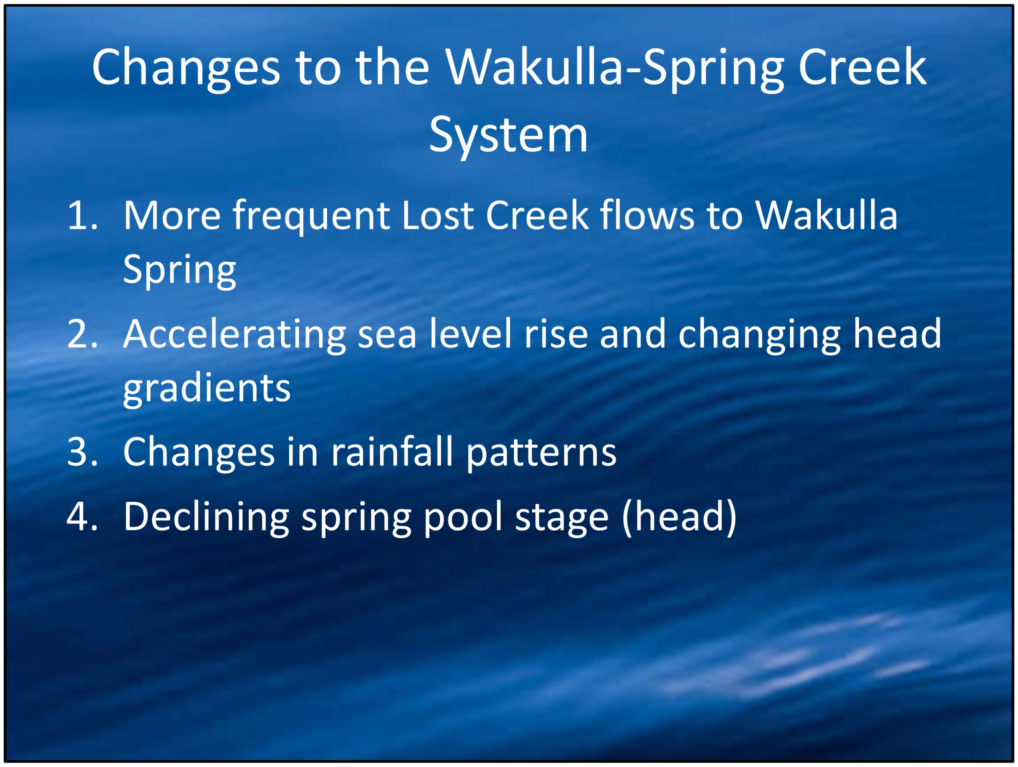
- Comparison of the algal eDNA composition of the lakes with the spring also revealed a fairly high degree of similarity on a scale of 0 to 1
- Upper Lake Lafayette (ULL) was the most similar, while Lake Iamonia was the least



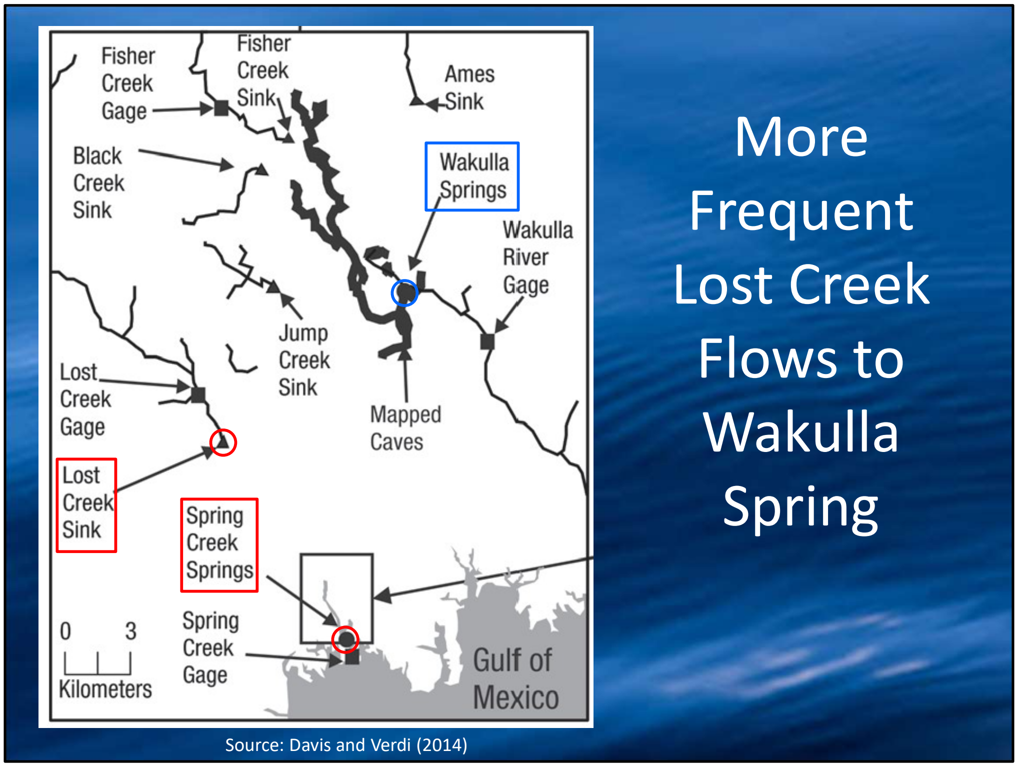
- Finally, let’s tackle the question of why. What has changed that might explain the increased frequency and duration of dark water conditions at the spring?
- But let’s start by reminding ourselves about the changes that have been observed in dark water conditions.
- Our best proxy is the record of glass-bottom boat tour days **[click to next slide]**



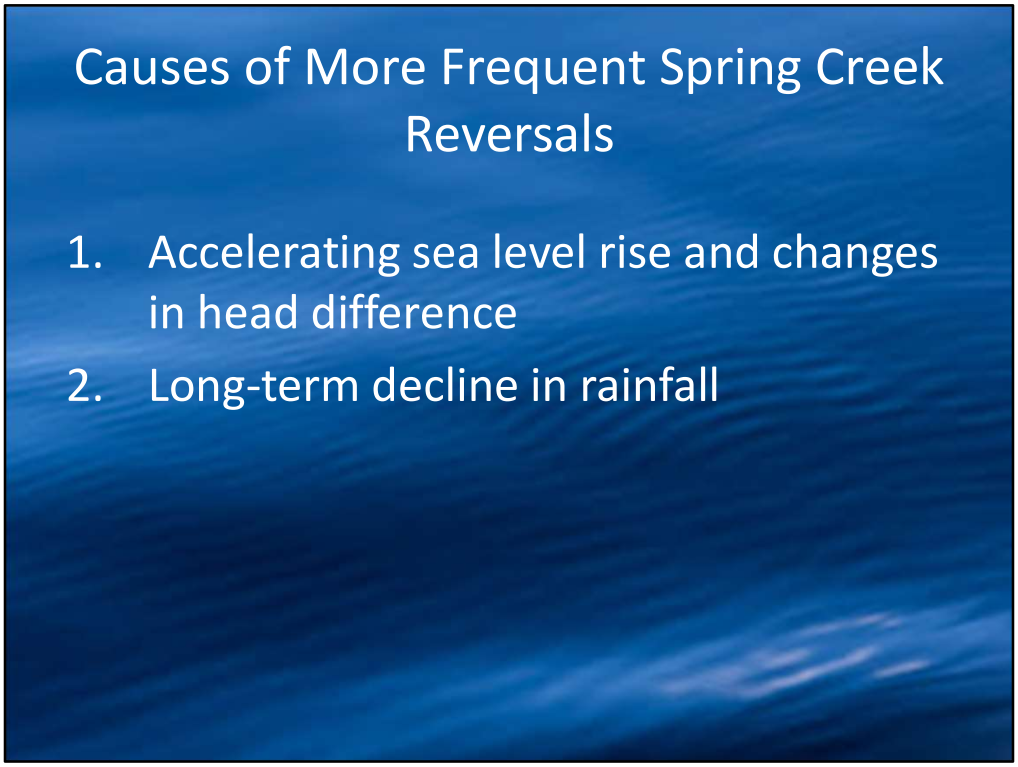
- The initial drop occurred in 1994 **[click]**, apparently starting a trend that has declined to 5 to 0 days per year since 2014,
    - **[click]** with the exception of a peak in 2000 that corresponded with a lower-than-normal rainfall year.
- Sandy Cook, who served as park manager from 1994 to 2008, has indicated that the decline in glass-bottom boat tour frequency was not due to changes in staffing, equipment, or the visibility criterion for conducting tours.



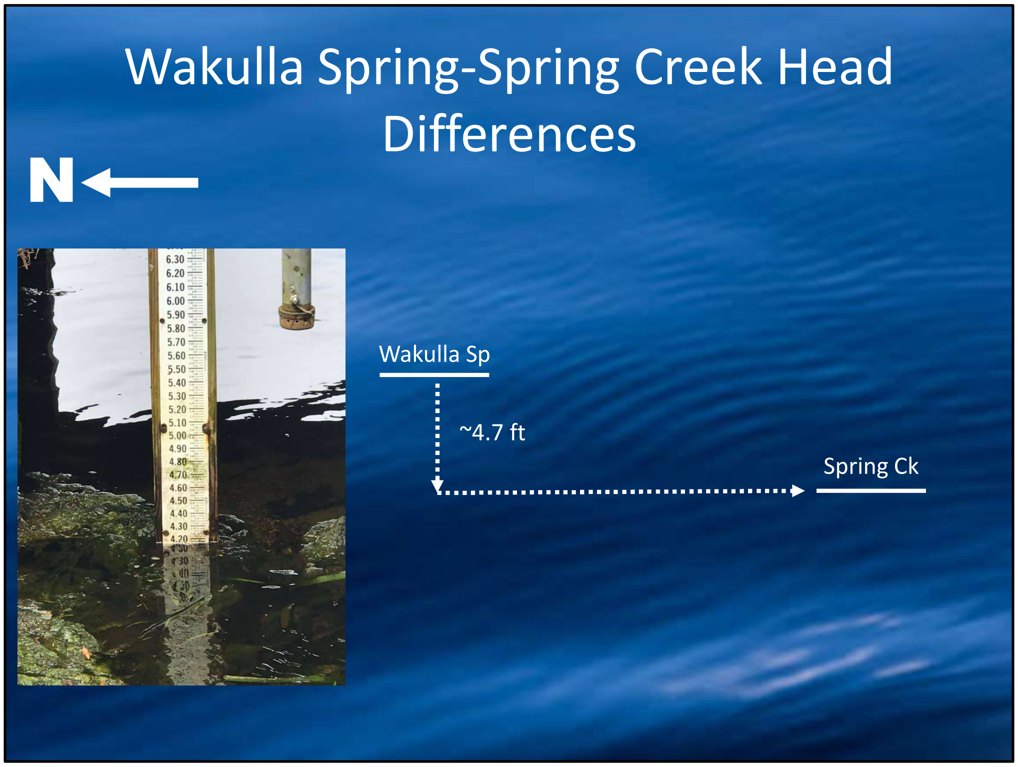
- Four changes have occurred that may be contributing to the observed increases in the frequency and duration of dark water conditions
- Click through them



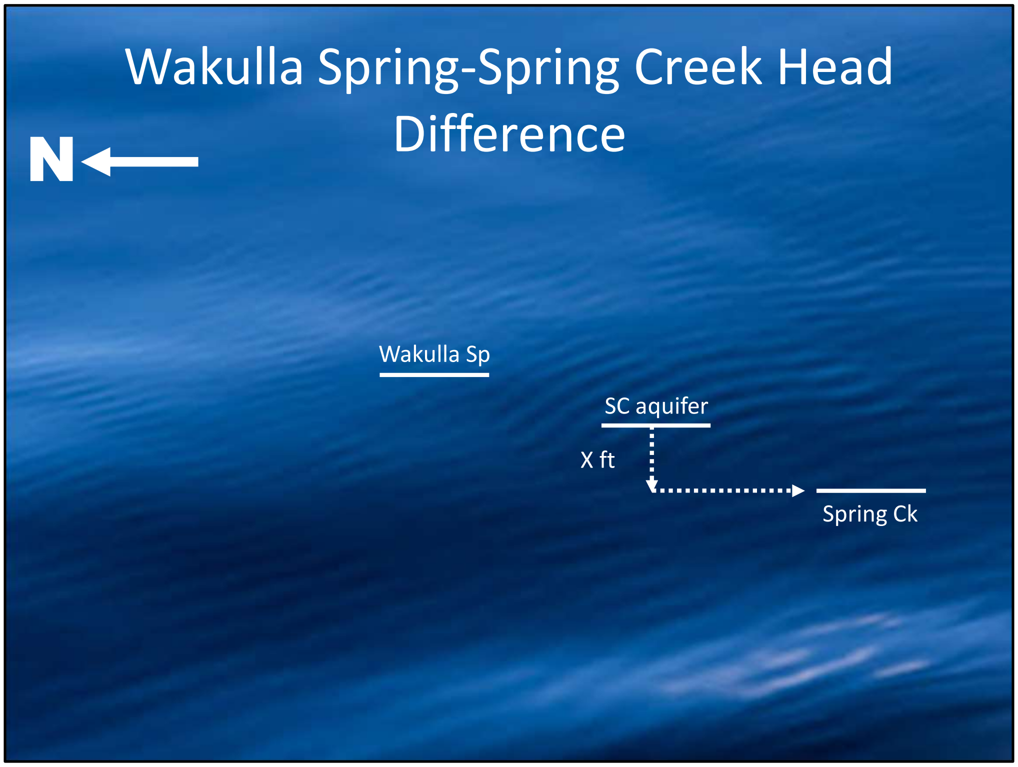
- While long-term, consistent discharge data are not available for the Spring Creek spring group, members of the Spear family who have resided adjacent to the main boil for at least two generations indicate that reversals are occurring more frequently
- These would contribute to more frequent and/or prolonged dark water episodes as we've discussed



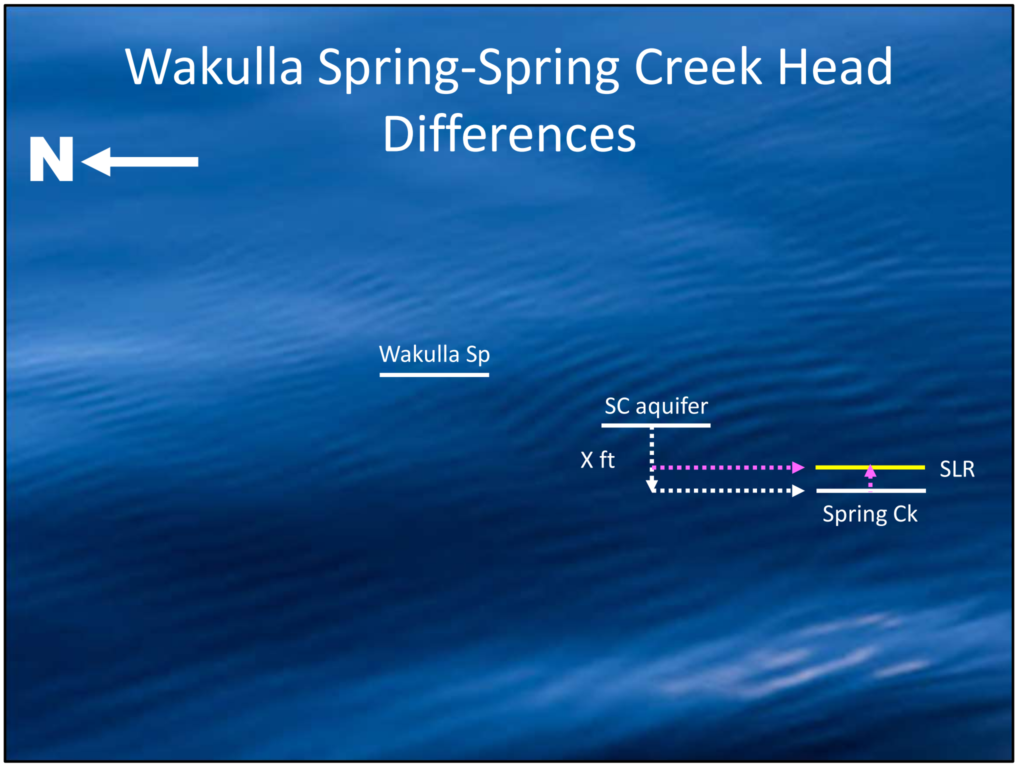
- So why might reversals in the Spring Creek Springs Group discharge be happening more often?
- Two principal driving forces:
  - **[click]** Accelerating sea level rise and associated changes in head difference
  - **[click]** Long-term decline in rainfall



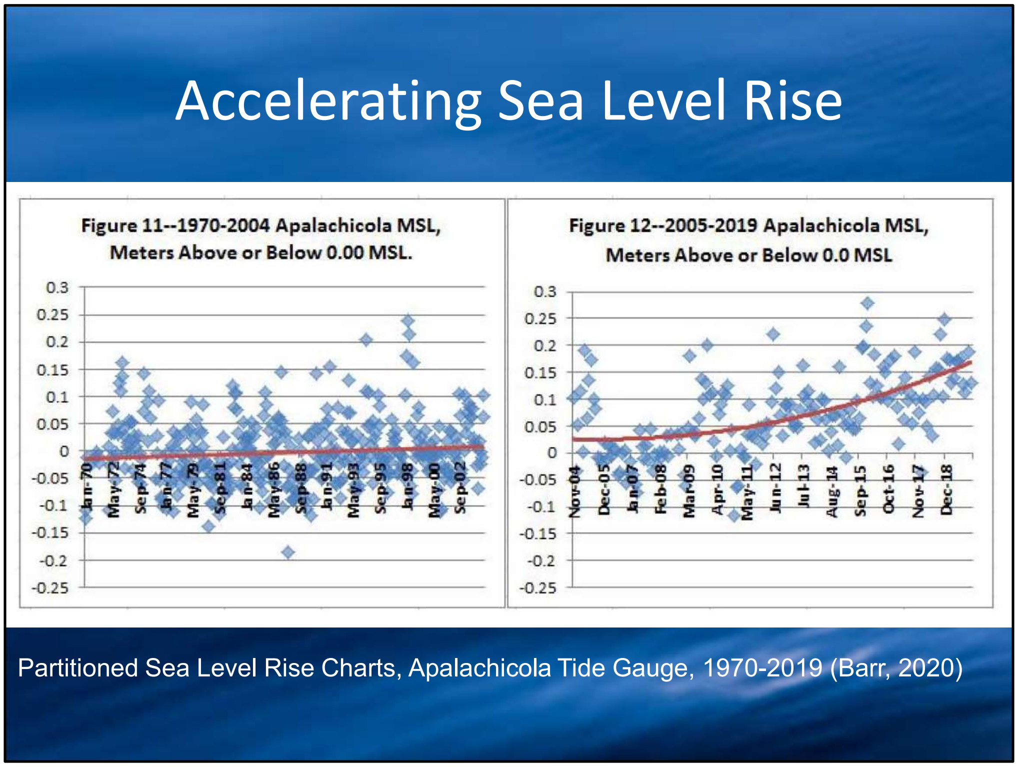
- The head difference in fresh groundwater systems is essentially the difference in elevation between two hydrologic features
- As shown here, the average head difference between the Wakulla Spring pool elevation or stage and the Gulf of Mexico at the Spring Creek Spring Group lately has been about 4.7 feet **[click]**
- **[click]** You can check this on any given day with the recently installed USGS staff gauge at the boat dock which is calibrated to mean sea level, i.e. North American Vertical Datum 88 (NAVD88) [photo by Cal Jamison, 5/6/21]



- The surface of the Spring Creek aquifer, south of Wakulla Spring, slopes towards the coast
- If we pick some reference point in that aquifer, the head difference with Spring Creek will be X feet depending on recent rainfall and withdrawals

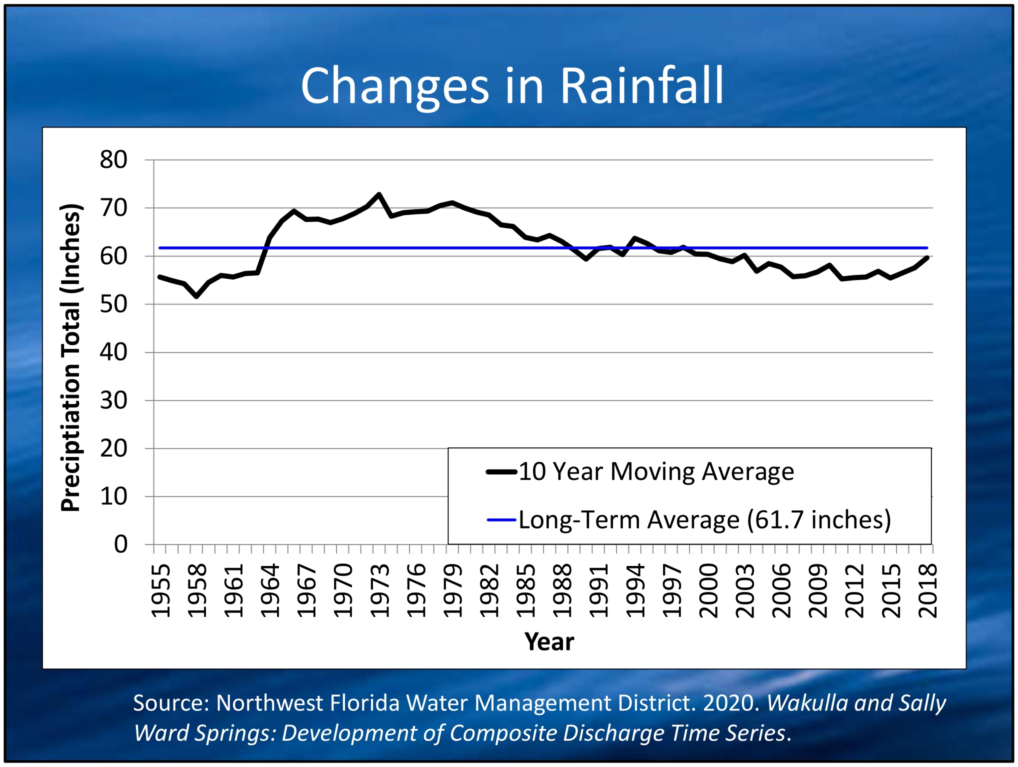


- As sea level rises, the head difference between the aquifer and Spring Creek diminishes resulting in more frequent reversals because it takes a smaller rainfall deficit to induce one

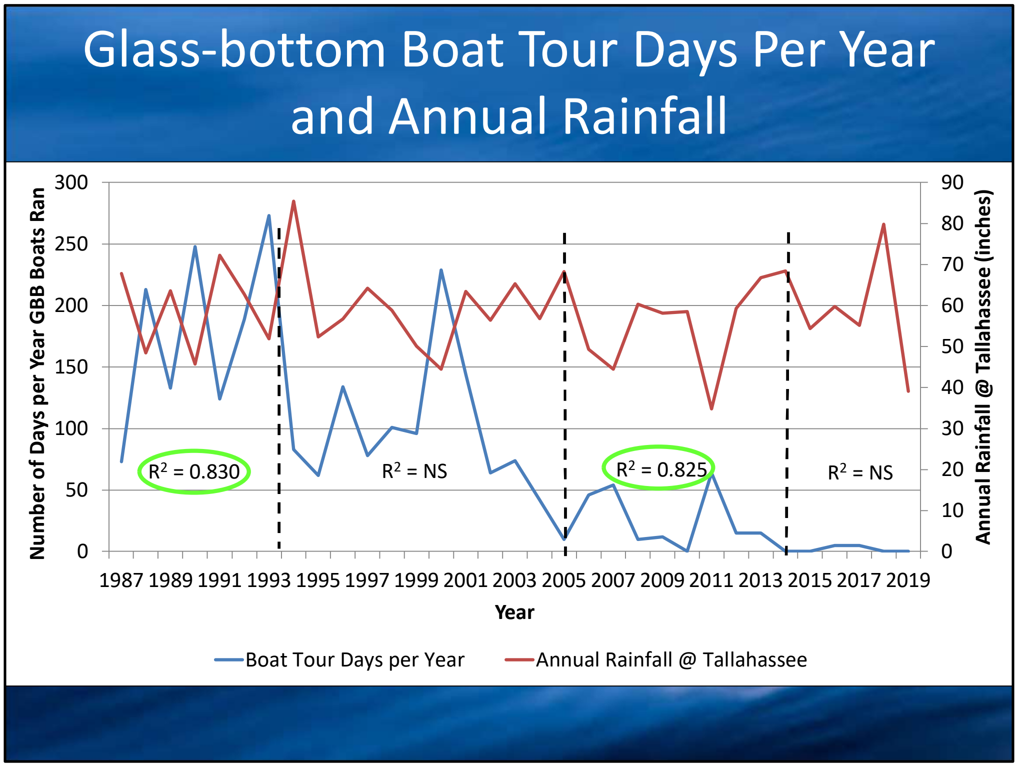


Partitioned Sea Level Rise Charts, Apalachicola Tide Gauge, 1970-2019 (Barr, 2020)

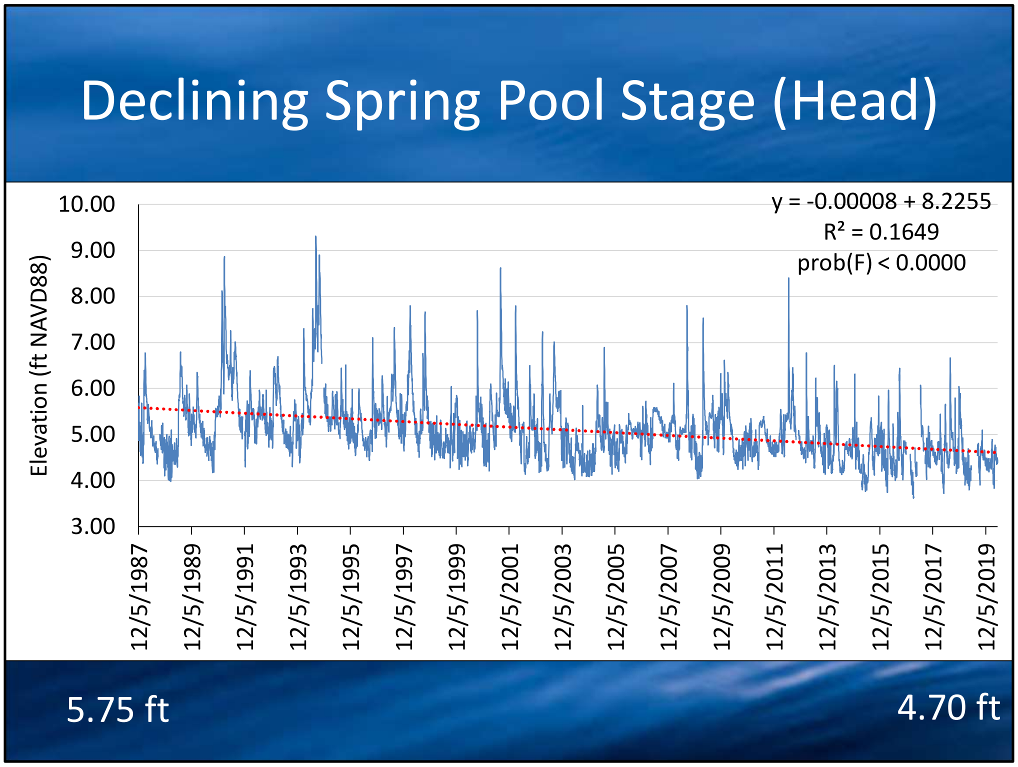
- As these charts show, sea level is not only rising over time, the rate is accelerating
- Therefore, we should anticipate that the frequency with which Spring Creek reversals occur will increase at an accelerating rate was well
    - Smaller and smaller rainfall deficits will suffice to set up a sufficient head difference between the Spring Creek aquifer and the spring group for reversals to occur



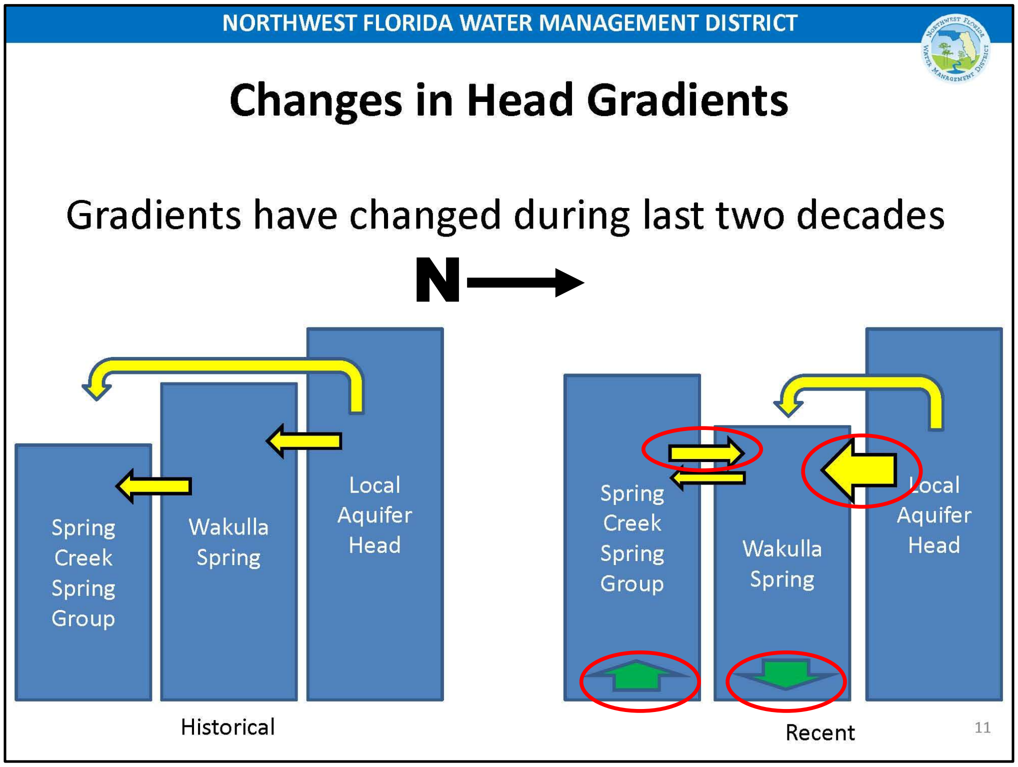
- A trend of decreasing rainfall also could contribute to more frequent Spring Creek reversals
- Indeed, this graph from the Water Management District's MFL Technical Report indicates that there has been a trend of decreasing annual rainfall since the late 1980s based on the 10-year moving average
- On the other hand, declining rainfall also would be expected to result in less frequent and/or shorter duration inflows of tannins to Wakulla Spring from the sinking streams to the north
- So rainfall change is probably not the major driving force behind more frequent and prolonged dark water at Wakulla



- If we graph annual glass bottom boat tour days with annual precipitation at the Tallahassee airport we find a strong, statistically significant, inverse relationship during two periods
- Consistent with the historical pattern of dark water conditions being associated with prolonged rainfall and associated discharges from the sinking streams to the north
    - **[click]** 1987 – 1994
    - **[click]** 2005-2014
- But that relationship hasn't held since 2014



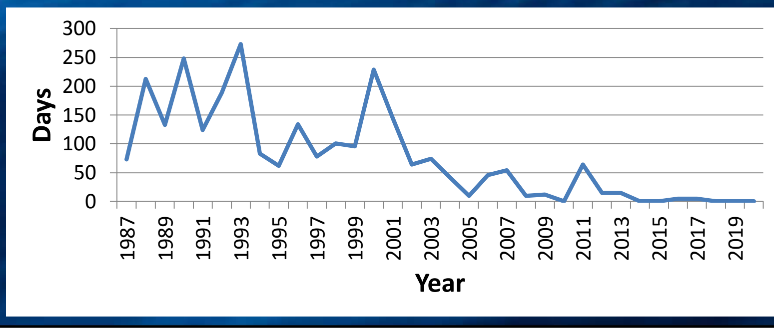
- The other trending phenomenon has been a progressive decrease in the spring pool stage or head as measured by the WMD for the period December 1987 through May 2020 at their gauge at The Ways
- Comparing the end points of the trend line shown here, pool stage has decreased from a predicted value of about
  - **[click]** 5.75 ft North American Vertical Datum 88 (NAVD88) in 1987 to
  - **[click]** 4.70 ft NAVD88 in 2019
  - **Reference:** The elevation of the USGS gauge at Spring Creek is 0 ft NAVD88
- Declining Wakulla Spring pool stage is likely a driving force behind more frequent and prolonged inflows of tannins from both the north and south
  - and perhaps more frequent and prolonged inflows of chlorophyll from the north



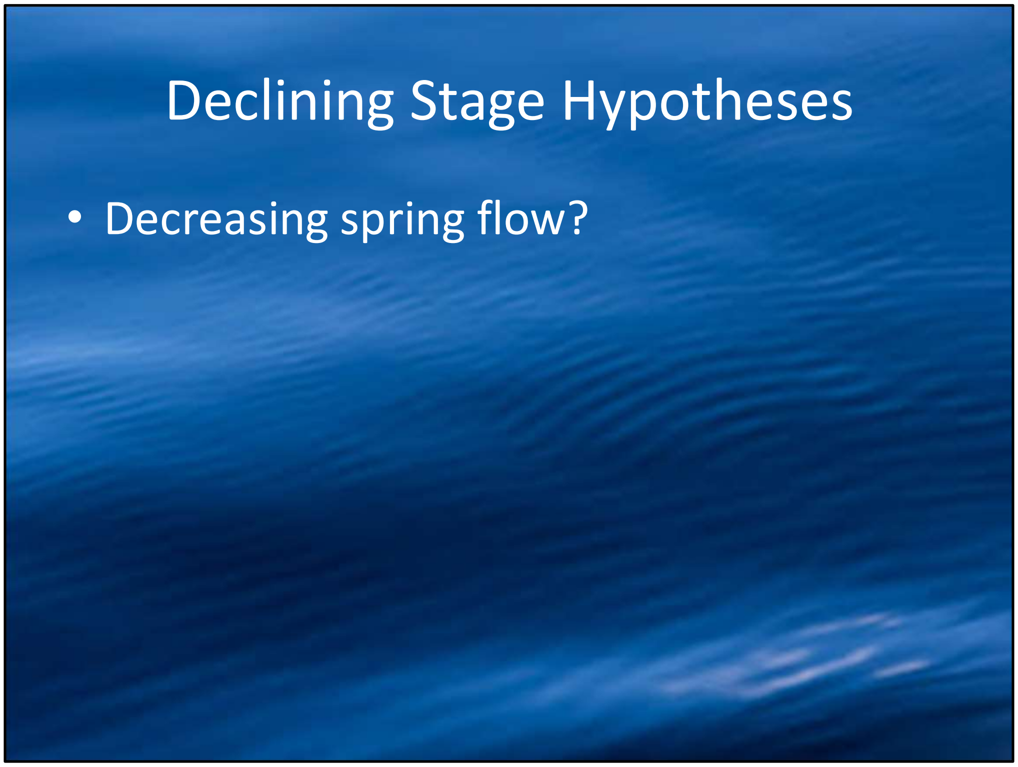
- This figure prepared by Water Management District staff summarizes the changes in head differences between Wakulla Spring and Spring Creek and the Floridan aquifer north of the spring
    - **[click]** Accelerating sea level rise continues to increase the head at Spring Creek at an ever-increasing rate
    - **[click]** While declining pool stage elevation continues to decrease the head at Wakulla Spring
- As a result,
    - **[click]** Wakulla Spring is receiving more frequent groundwater inflows from the south
        - including tannic water from Lost Creek as well as tannic water within the limestone matrix that formerly flowed south
    - **[click]** And more frequent inflows from the aquifer to the north
        - including more prolonged discharge of tannic water within the matrix after the sinking streams cease to flow
        - As well as more prolonged inflows of chlorophyll through the matrix
- This leaves us with two last questions **[click to next slide]**

Next Questions

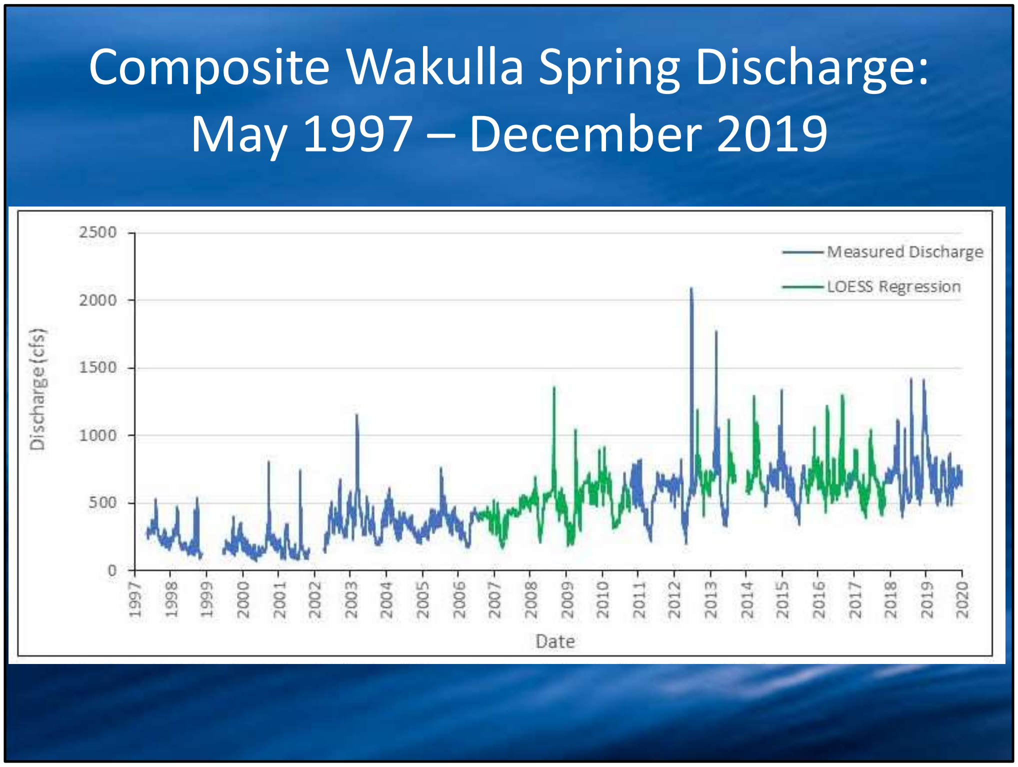
1. Why is the Wakulla Spring pool stage (head) dropping?
2. What happened circa 1994 to trigger the decline in visibility and decreased glass bottom boat tours??



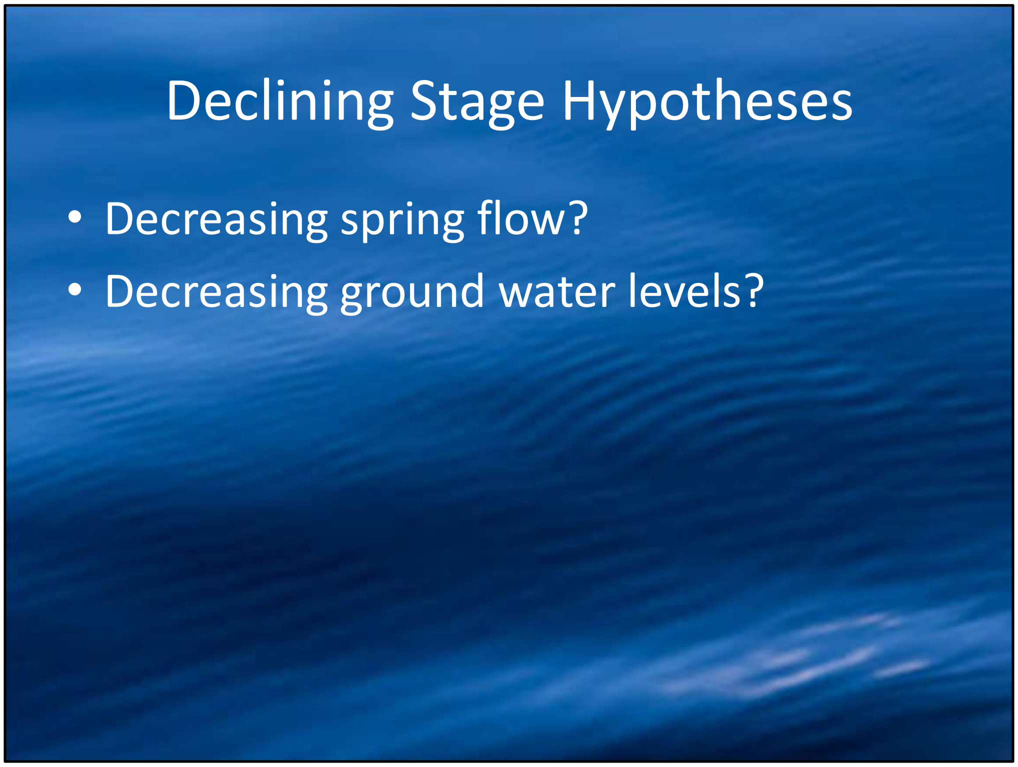
- **[click]** What explains the observed decline in spring pool stage/head?
- **[click]** What happened circa 1994 to trigger the decline in visibility and decreased glass bottom boat tours?



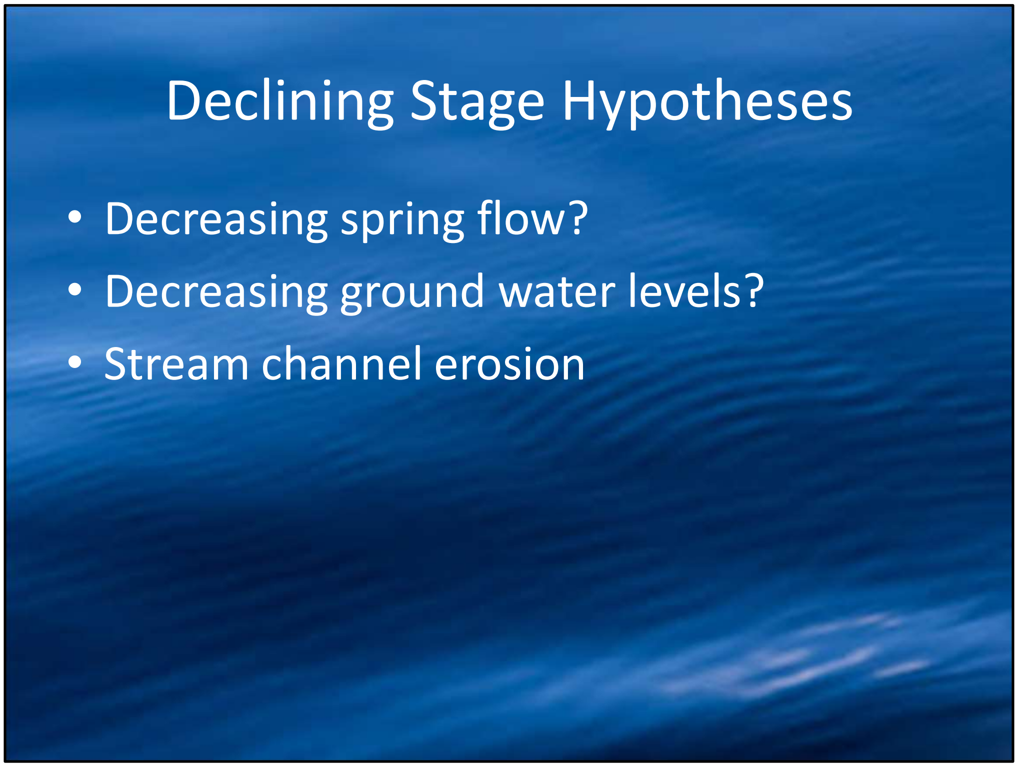
- **[click]** One straightforward explanation would be that spring flow or discharge is decreasing, but in fact, that is not the case **[next slide]**



- Overall, discharge has <u>increased</u> over the period 1997 through 2019, with a levelling off since about 2012 (Wakulla – Sally Ward MFL Technical Assessment, p. 75)
- Meanwhile stage has been decreasing
- In fact, stream discharge has been increasing since at least 1930
- Davis and Verdi (2014) attribute this to rising sea level

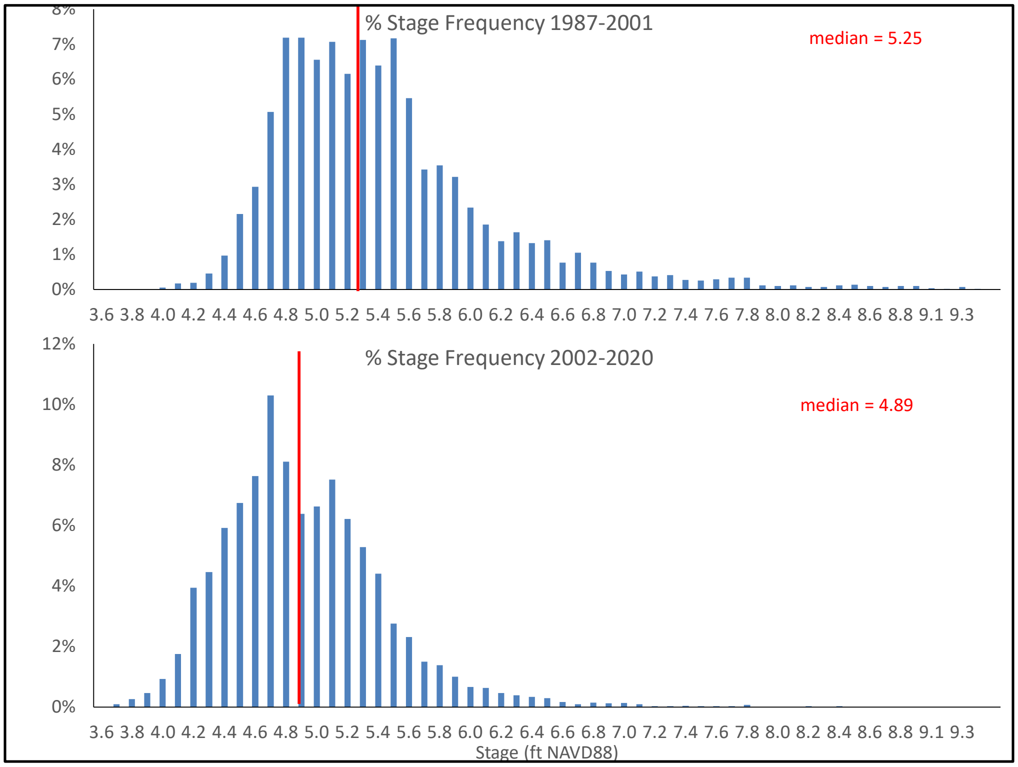


- **[click]** Another hypothesis that may help to explain the trend of declining spring pool stage
    - is a long-term trend in declining ground water elevation in the springshed north of Wakulla Spring
- Limited available data indicate that there has been no such decline
- Furthermore, hydrogeologists at the Water Management District and others have advised me that this is not a plausible scenario since discharge has bene increasing



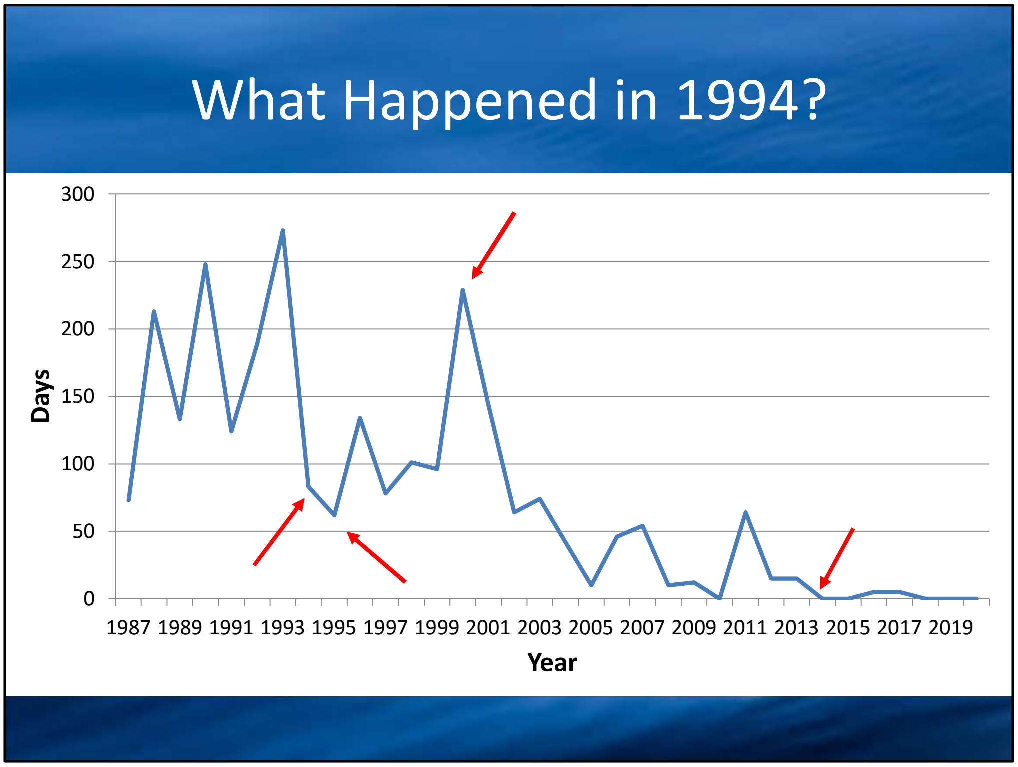
- The leading hypothesis at the moment is stream channel erosion initiated by the first major hydrilla purge in 2002

- As you may know, large scale herbicide treatment was initiated in April 2002 to try to control the hydrilla invasion,
  - which began in swimming area in 1997 and had spread down river past the tour boat turn around by 2000
- That first treatment killed off 70 to 80 percent of the hydrilla standing crop,
  - resulting in a surge of dead plants that washed down the river,
  - removing the organic sediment layer, along with rooted submerged aquatic vegetation,
  - and scouring the bottom sediments
- Comparison of stage data before and after 2002 suggest that event triggered ongoing river bottom erosion



- Here we see the stage frequency distribution for the period 1987-2001
  - The histogram bars represent the percent frequency for each stage level
  - Between 1987 and 2001, values are clustered around a median of 5.25 feet
- **[click]** The pattern for 2002-2020 shifts to the left, centered on a median of 4.89 feet
- Which leads to one more question about declining stage **[click to next slide}**

- **[click]** The most straightforward hypothesis is that the increasing discharge from the spring is accomplished by increasing stream flow velocities which would result in continuing erosion
- Hydrologists at the WMD are entertaining this possibility
- If so, accelerating sea level rise may lie at the root of these changes



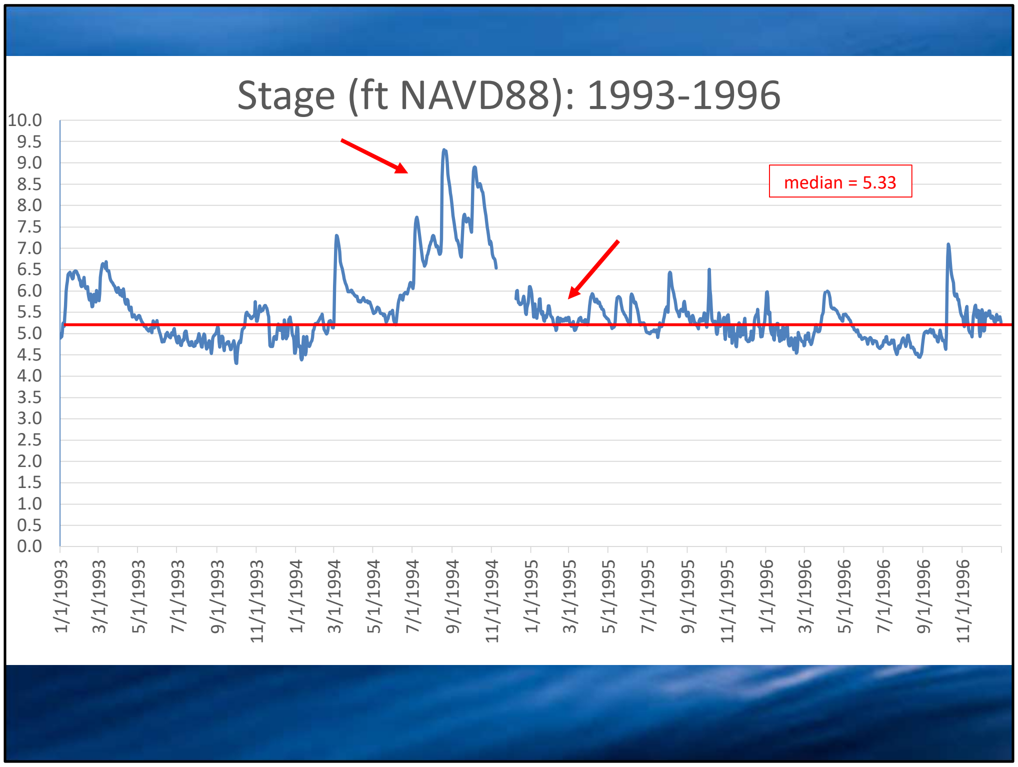
- You'll recall, however, that the initial sharp decline in glass bottom boat tours occurred in 1994 **[click]**
- GBB tours went down again the following year, 1995 **[click**,]
    - and then began a rebound that peaked in the drought year of 2000 **[click]**
    - Followed by a prolonged decline that has bottomed out at 5 days or less since 2013 **[click]**
- So the first question is, did the trend of decreasing river stage begin in 1994?

1994 Departures from 1995-1999 Average Monthly Rainfall

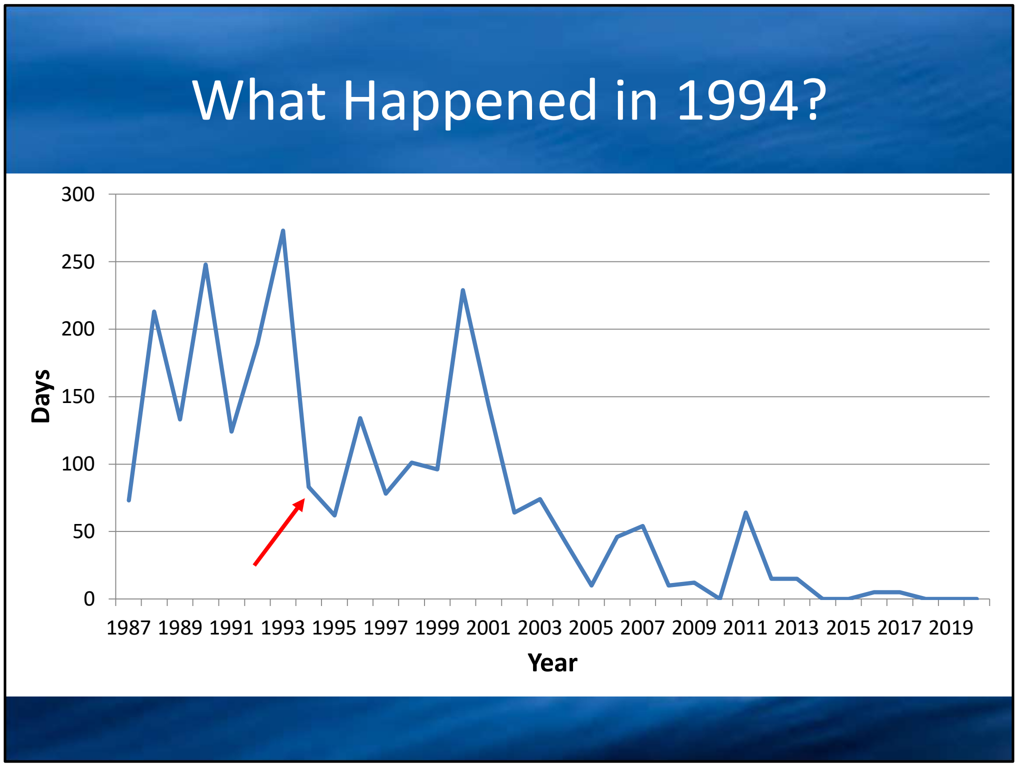
Month	Rainfall (in)	Departure from 1995-1999 Monthly Average (5.31 in)
June	13.1	2.5x
July	22.7	4.0x
August	12.8	2.5x
September	7.6	1.4x
October	10.0	1.9x

Source: Dana Bryan (2020)

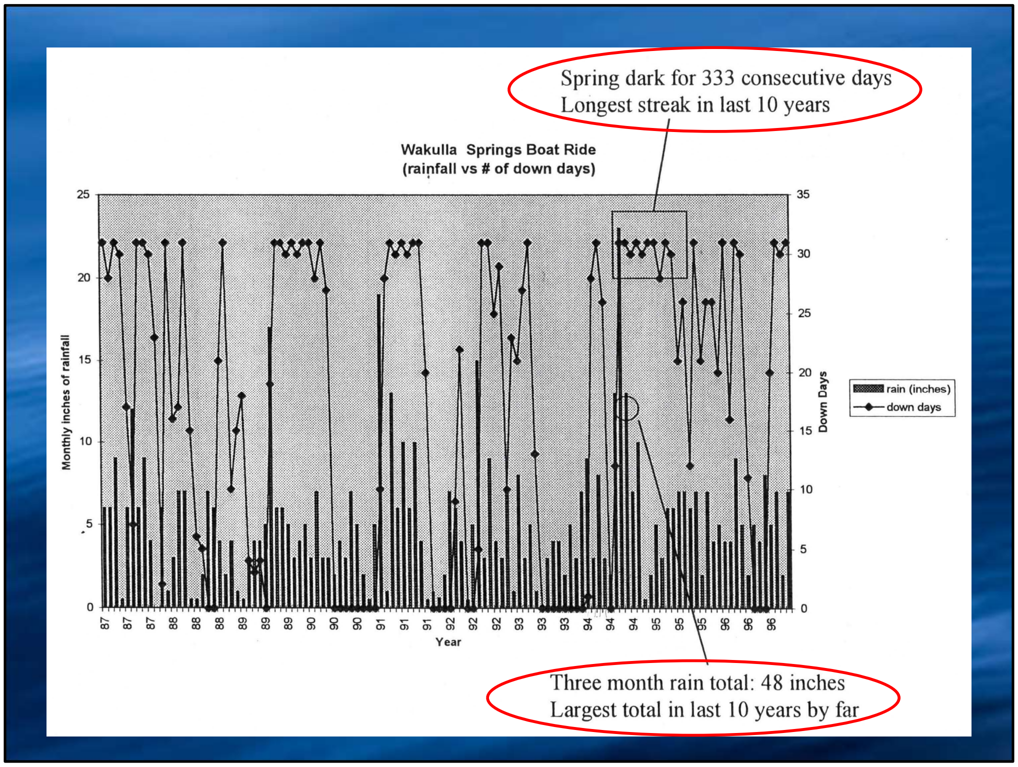
- The summer and fall of 1994 were marked by unusually high rainfall including that from two tropical storms:
    - **[click]** Alberto, which dropped 9 inches of rain at Tallahassee airport between July 1st and July 3rd
    - **[click]** and Beryl, which produced 7.75 inches of rain August 15 through 16
- This was accompanied by a substantial increase in river stage **[click to next slide]**



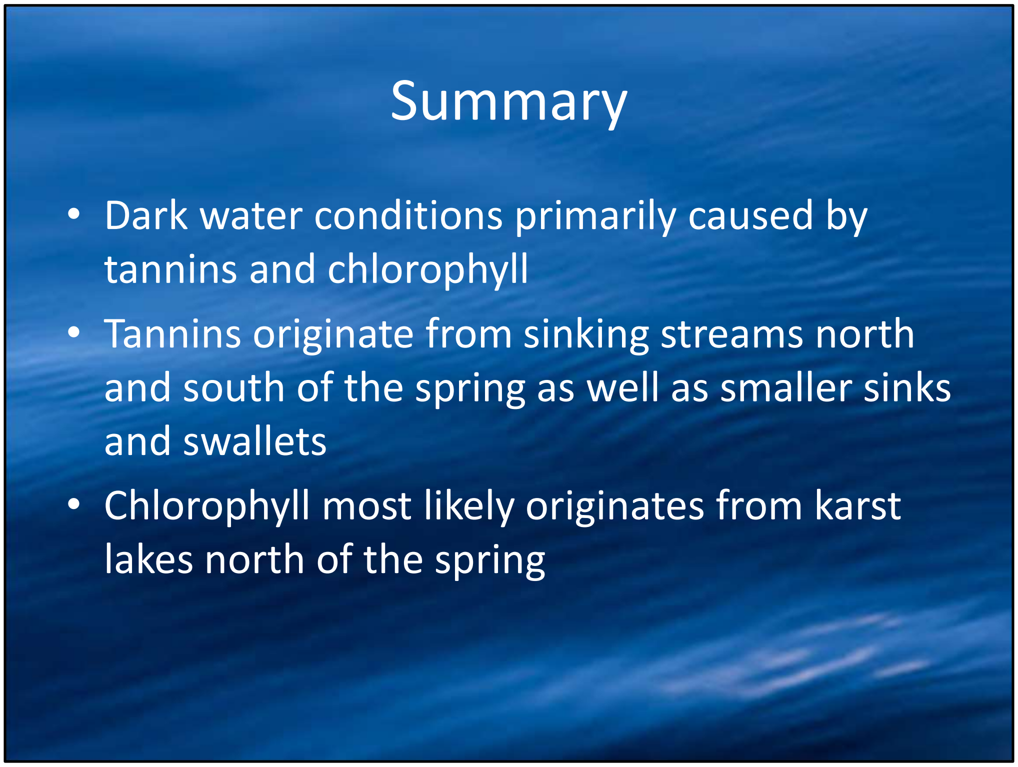
- High 1994 upper river stage levels **[click]**, as measured at The Ways are shown here, associated with the heavy rains
- However, by February 1995 **[click]**, stage had returned to the 1993-1996 median of 5.33 feet, with no clear evidence of the onset of a trend in declining stage



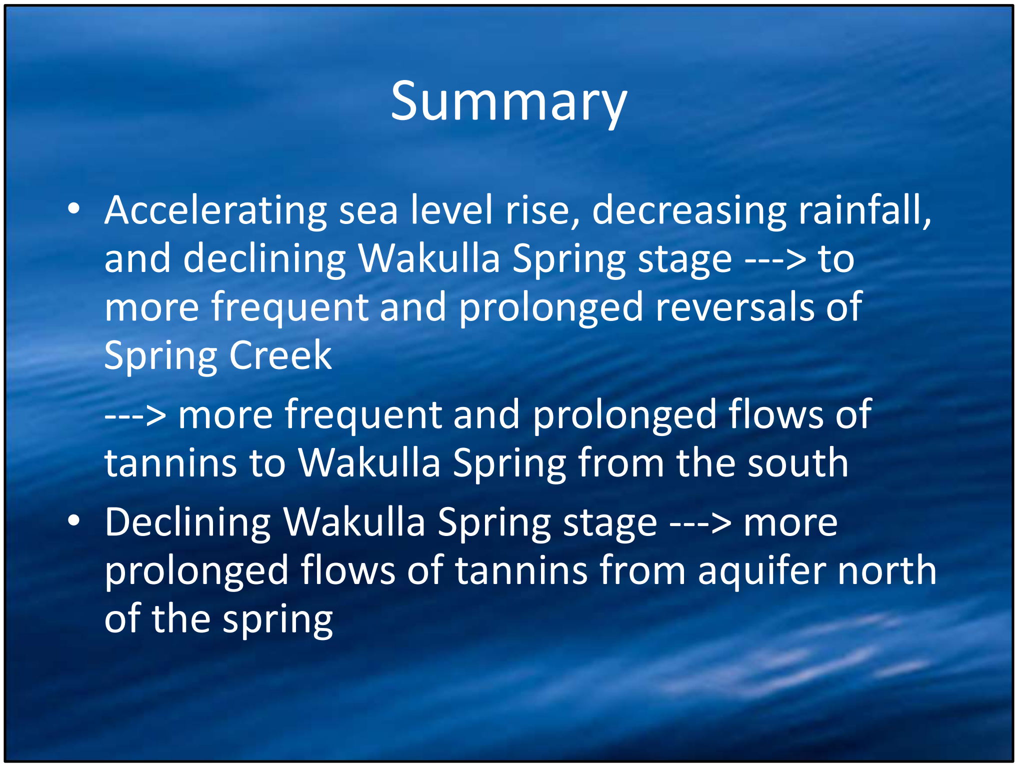
- It was, in fact, high and prolonged tannin levels that were responsible for the 1994-1995 precipitous drop in GBB tours
- A report prepared by FDEP staff member Joe Hand in 1997 documented that GBB tours were suspended for 333 consecutive days because of tannic water conditions **[click]**



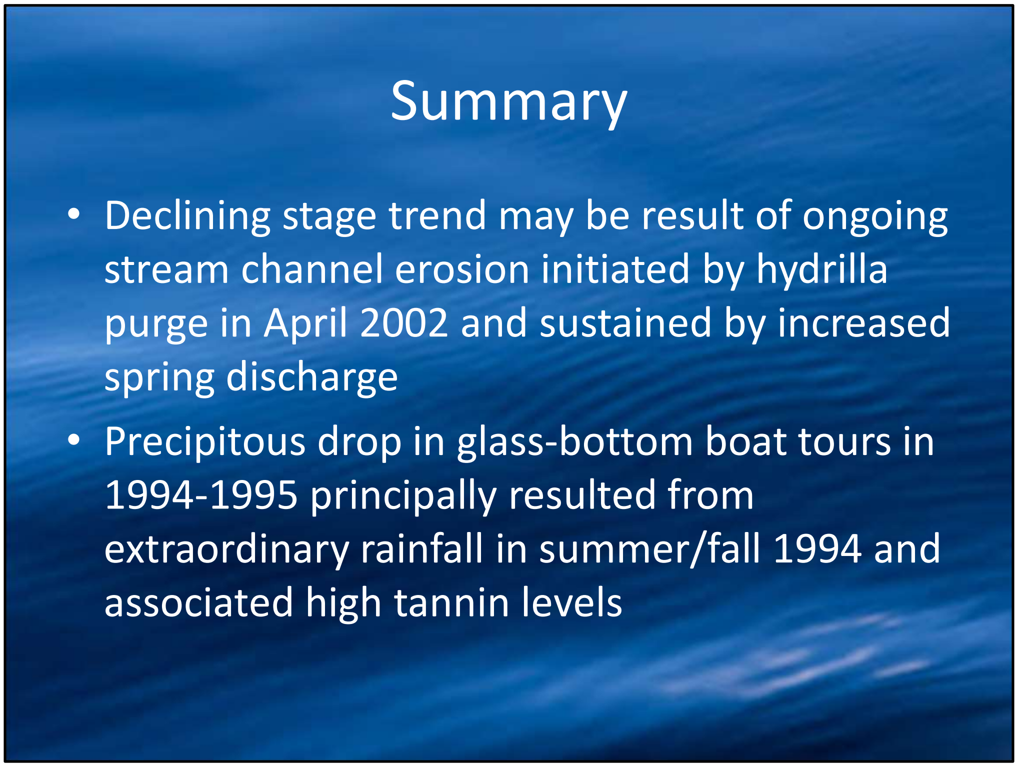
- The line graph with the data points depicts the number of GBB down days per month **[click]**
    - With that down period the longest in the preceding 10 years that the park had been in operation
- The bar chart is monthly rainfall **[click]**
    - With that three month total the greatest over the preceding 10 years



- So what do we think we know?
- **[click]** Dark water conditions at Wakulla Spring are primarily caused by tannins and chlorophyll
- **[click]** Tannins originate from sinking streams north and south of the spring as well as smaller sinks and swallets
- **[click]** Chlorophyll most likely originates from karst lakes north of the spring

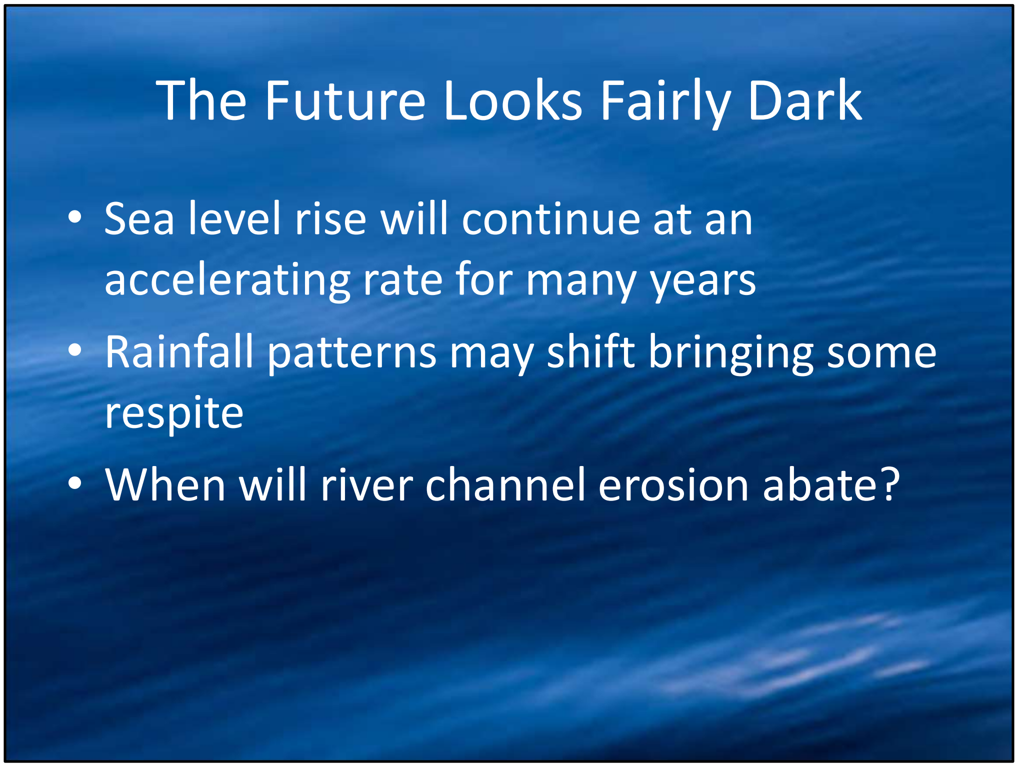


- **[click]** Accelerating sea level rise, decreasing rainfall, and declining Wakulla Spring stage likely have led to more frequent and prolonged reversals of the Spring Creek springs group
    - **[click]** Resulting in more frequent and prolonged flows of tannins to Wakulla Spring from the south including discharges form Lost Creek
- **[click]** Declining Wakulla Spring stage likely has led to more prolonged flows of tannins, and perhaps chlorophyll, from the aquifer north of the spring after rainfall subsides

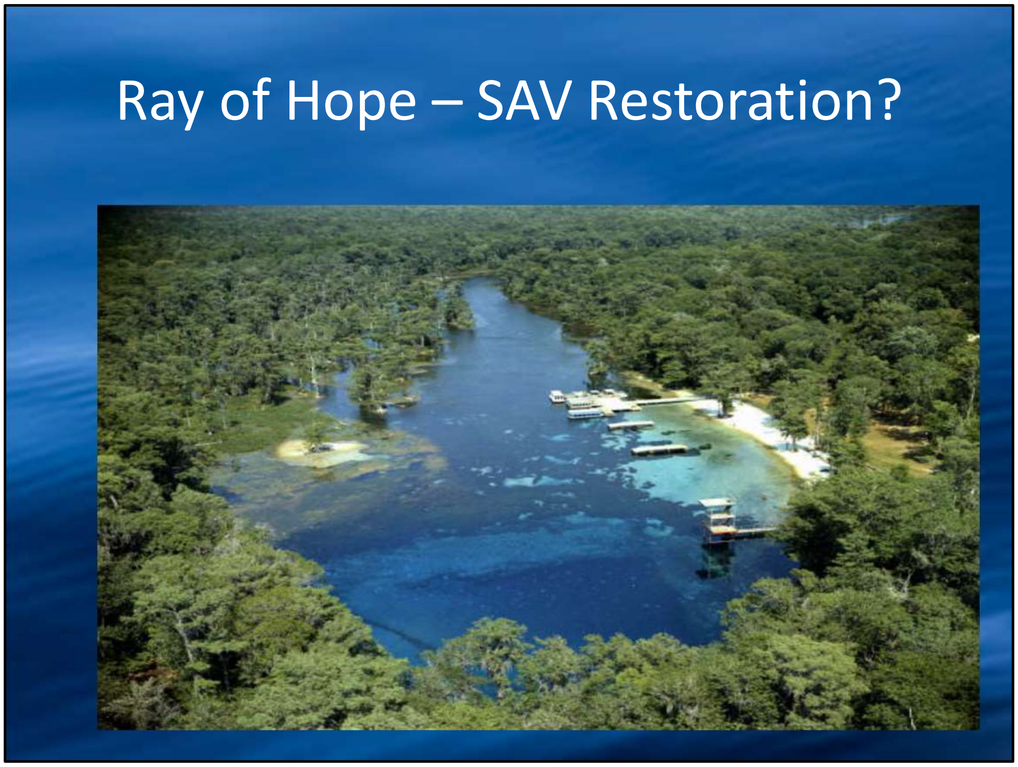


- **[click]** The declining stage trend may be the result of ongoing stream channel erosion initiated by the first major hydrilla purge in April 2002

- **[click]** The initial precipitous drop in glass-bottom boat tours in 1994-1995 was principally the result of extraordinary rainfall in summer/fall 1994 and associated high tannin levels



- **[click]** Sea level rise will continue at an accelerating rate for many years
- **[click]** Rainfall patterns may shift bringing some respite
- **[click]** When will river channel erosion abate?



- Would revegetation help?
- If we could restore the submerged aquatic vegetation community to what it was like back in the late 1960s, we might be able to
    - stabilize the remaining sediments
    - reduce stream velocity
    - and stabilize or at least slow the upper river and spring pool stage decline