Where's the Water Come From?

Toward A Water Budget for Wakulla Spring

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Abstract: *Drying up the Spring?*

Recent hydrologic studies in the Wakulla springshed (conducted or supported by the FGS/DEP, GeoHydros, the Woodville Karst Plain Project, the Florida State University, US Geological Survey, and the City of Tallahassee) give rise to concerns about groundwater availability in the Wakulla springshed. These include the groundwater tracer tests that have connected many of the sinking streams in the springshed to Wakulla spring, hydrologic metering of the tunnels within Wakulla cave that discriminate between groundwater and surface water components of the spring flow, and tracer tests and metering at the Spring Creek springs that show Wakulla and Spring Creek to be connected by large underwater conduits. Collectively, these studies reveal that the groundwater budget for Wakulla Spring is susceptible to harm from upland groundwater consumption and sea-level rise.

The Wakulla springshed, like all springsheds and stream basins in the world, has a water budget. Like a financial budget, the water budget defines the total inflow, the total outflow, and the change in water storage, which is like a savings account for water. Total inflow is primarily composed of all the rain that falls in the sprinshed plus any stream flow from streams that originate outside the springshed. Total outflow includes all of the water that flows out to the Gulf of Mexico in the Wakulla / St Marks River, all of the spring flow that enters the bay directly, all of the water that either evaporates or is used by plants, and all of the water that is pumped out of the ground and not returned to the aquifer in the springshed.

In order to utilize water resources for human needs, the supply of water must be ecologically sustained for the long term within the confines of the water budget. To maintain a sustainable water budget, total usage cannot exceed the total amount of water received. When it does, storage is reduced, water levels fall, and spring flows decline, which if continued unchecked can result in dried up spring basins, lakes, sinkholes, and rivers. If the total usage is less than the total inflow the amount of storage will increase, groundwater levels will rise, and spring flows will increase, which over a long enough period can result in flooding. Our status with respect to the water budget fluctuates seasonally, even monthly, depending on how much rain we receive and how much we're using so an effective gauge of our status must be based on long-term trends.

The water budget for the Wakulla springshed contains two major components that each have their own budget, groundwater and surface water. Groundwater is the relatively older clear water that reaches Wakulla Spring and is the primary component of the spring flow when the spring is clear and the glass-bottom boats are running. It consists of all the rain that falls on the ground in the upper reaches of the springshed that infiltrates into the aquifer, and flows through the rocks into the caves and out to the springs. This is the only source of water to the spring during dry periods when the streams stop flowing and also supplies nearly 100% of the water consumed in the springshed from groundwater wells.

Surface water is the dark tea-colored water that flows through the creeks and streams and is ultimately funneled rapidly into the aquifer through the swallets or sinkholes located at the end of the streams. We now know from the tracer tests and hydrologic metering that this water travels very quickly (days or weeks) to Wakulla spring is responsible for the dark water days that keep the glass-bottom boats at the dock. This new knowledge is critical to understanding our relationship to the Wakulla's water budget because we are not currently using surface water to any significant extent for water supply and our usage therefore primarily impacts only the groundwater component of the total water budget.

In order to ensure that we do not overdraft Wakulla's groundwater account, we must accurately measure and compare the total groundwater consumption in the springshed with only the groundwater component of the spring flow. To date these measurements have not been performed but we are able to make an educated guess as to where we stand. A reasonable estimate of the groundwater component of the discharge from both Wakulla and Spring Creek

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Abstract: *Drying up the Spring? – Cont.*

springs is roughly 400 million gallons per day where as the total permitted groundwater extraction in only the northern section of the Wakulla springshed exceeded 25% of that value in 2007. While this does not account for returns to the aquifer as for instance those that occur at the Tallahassee spray field, the value is large enough to warrant a closer analysis of the current and projected groundwater withdrawals as well as the plan for sustaining adequate groundwater (clear water) flow to Wakulla and the neighboring springs.

The consequences of over consumption in the Wakulla springshed would likely be dire. We know from the recent history of Florida's west coast and now even the Santa Fe river basin in north central Florida that over-pumping the Floridan aquifer can result in a complete loss of flow to smaller springs. The analog in the Wakulla springshed would be a loss of discharge from the smaller springs like Sally Ward, McBrides, Sheperd, and the springs along the middle section of the Wakulla River. Diminished groundwater levels will also decrease the already sporadic number of clear water days at the spring vent. Even more significantly though, because Wakulla and Spring Creek are physically connected, diminished groundwater levels in the northern part of the springshed will foster an increase in the duration and magnitude of the spring flow reversals in Spring Creek that have been occurring every summer since 2006. We know from recent studies that these reversals drive salt water into the aquifer conduit system and push it significantly inland. That influx of salt water results in higher than normal water levels in the south and increased salinities in the deeper part of the aquifer. If the duration and/or magnitude of these reversals increases, it is likely that the ecosystem in the southern part of Wakulla County and even the potability of the Floridan aquifer in that region will be jeopardized.

Sea level in the northern Gulf of Mexico is rising. On that, there is no dispute. There is little available long-term data on groundwater levels in the springshed. The longest records that do exist show a slow but consistent decline in aquifer water levels since the 1960's. Apparent flow at Spring Creek has changed significantly since 2006 but we are just now learning to what degree conditions have and are changing. We do know that for the first time in the memory of the oldest native residents in the Spring Creek region, boats need special paint to keep barnacles from growing on their bottoms. We also know that conditions at Wakulla spring have changed as well. When the Spring Creek springs reverse in summer, Wakulla's flow dramatically increases and the water clarity drops resulting in fewer clear-water days in the basin. In total, these data and observations are at very least ample cause for a closer and more serious look at the groundwater budget and groundwater consumption in the springshed.

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What we know about Wakulla

- Wakulla Spring is one of the largest 5 springs in Florida.
- It's historical average discharge is ~ 390 ft^3/sec or 250M gal/day (one 50m Olympic swimming pool every 3.7 secs).
- Largest observed range in discharge of any spring in the State
  - ~16M – 1.2B gal/day – published
  - ~150M – 1.4B gal/day – measured 2004-2007
- The range is so large because Wakulla draws its water from two fundamentally different sources.
  - *Groundwater* flow that originates as rainfall as far north as Albany GA and travels through the Floridan aquifer to the caves that connect to the spring.
  - *Surface water* that originates as rainfall within the stream basins west and north of Wakulla, flows into swallets, and then underground into the caves that connect to the spring.

What we know about Wakulla

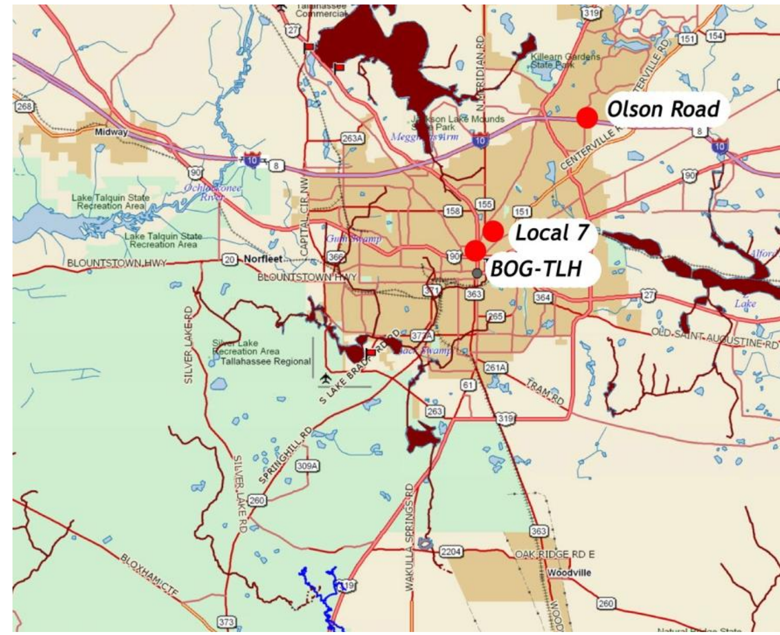
- Water discharging from Wakulla Spring has historically fluctuated between crystal clear and dark brown (tea colored).
- The water at Wakulla Spring is normally clear when the flow is low and tea colored when the flow is high.
- Groundwater tracer tests have definitively shown that the tea-colored water travels to the spring from swallets in days to weeks.
- Groundwater tracer tests have also shown that the clear groundwater travels to the spring from the northern part of the basin extending at least from the Apalachicola National Forest to the City of Tallahassee's SE Spray Field at a rate of >=800 feet per day once it reaches the southern part of Leon County (the edge of the confining unit).

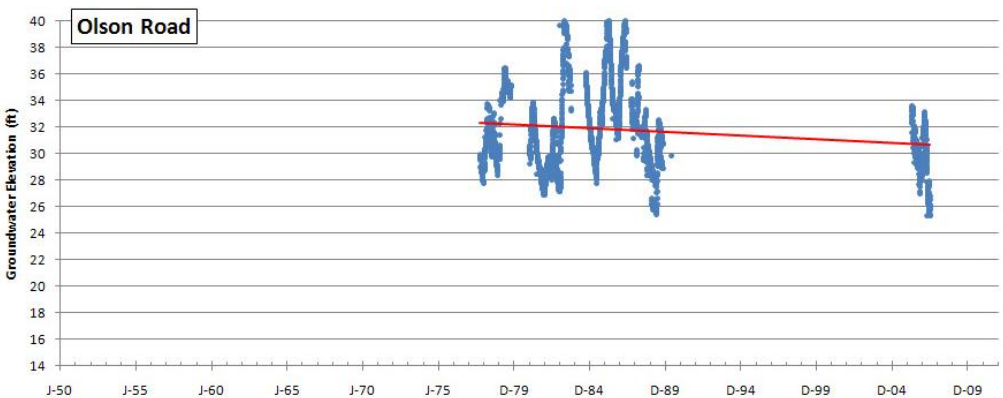
What we know about Wakulla

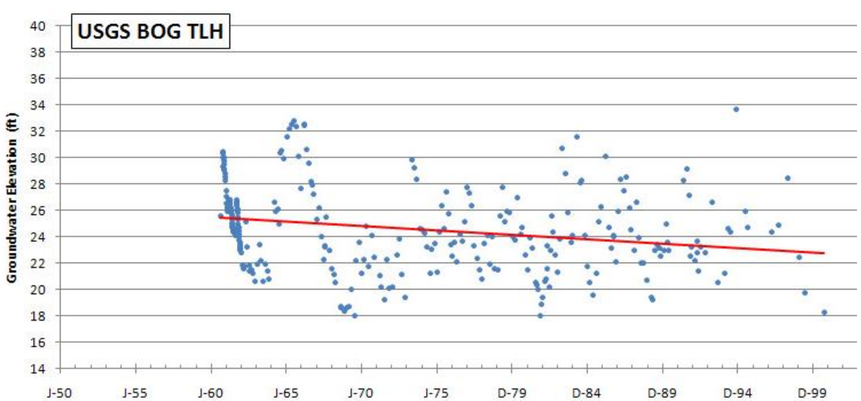
- Pumping from wells in the Wakulla Springshed pulls water from the clear water (groundwater) component of flow to the spring. The more we pump, the less will be available for the springs.
- Returns of pumped water to the aquifer within the springshed such as the Tallahassee Spray Field reduce the impact of pumping on spring flows but can reduce water quality.

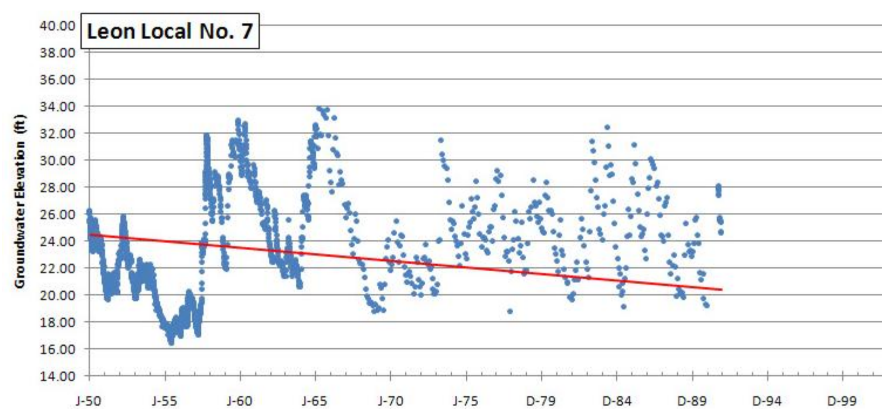
Disconcerting Hydrologic Trends

- Groundwater levels appear to be declining since the 1970's (*USGS & NWFWMD)*
- Extractions are rising
- Sea level in the Gulf is rising by 1.5 to >4 mm/yr









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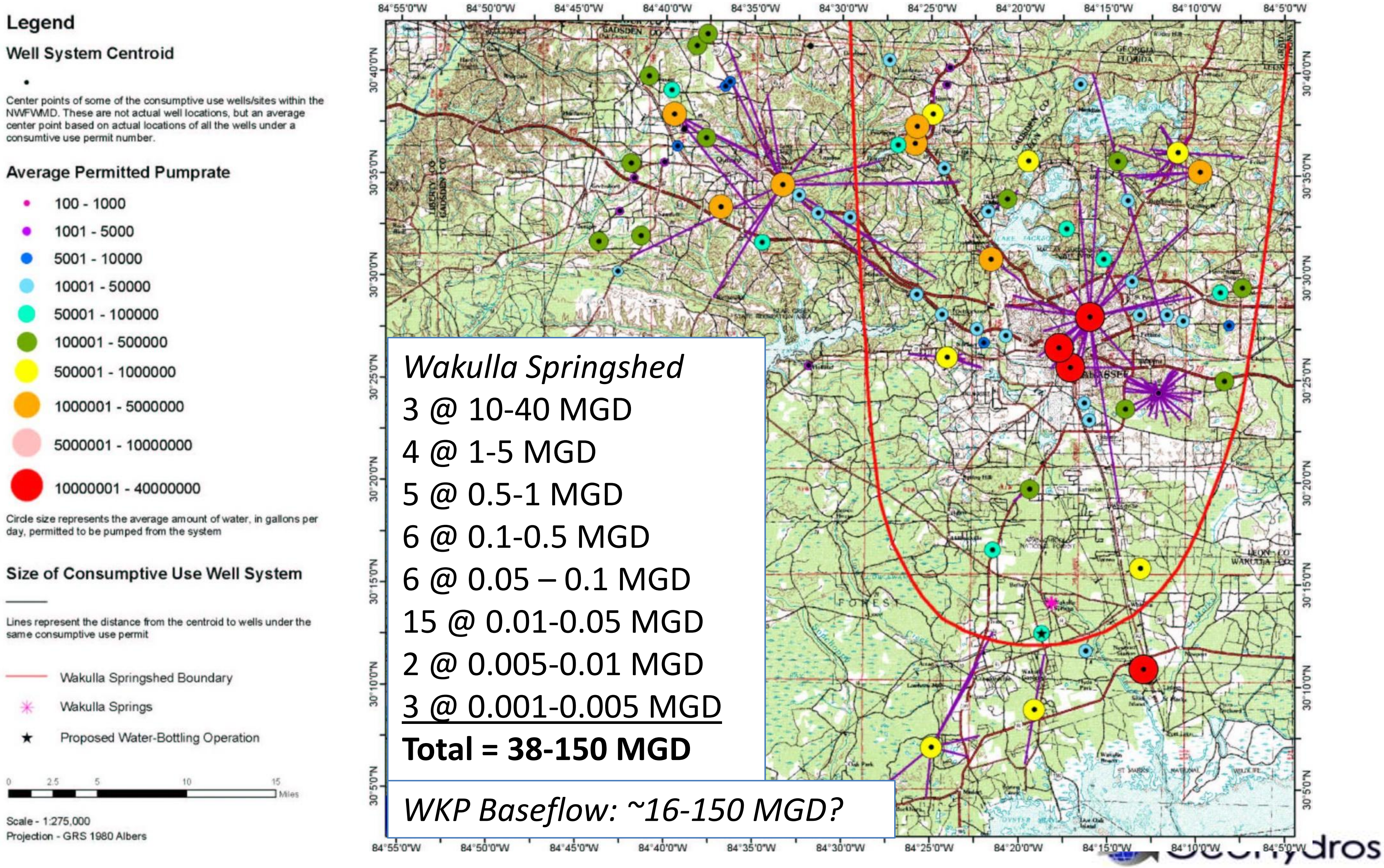
Permitted Groundwater Withdrawals

Average Allowable Withdrawals ~2009



Wakulla Springshed
3 @ 10-40 MGD
4 @ 1-5 MGD
5 @ 0.5-1 MGD
6 @ 0.1-0.5 MGD
6 @ 0.05 – 0.1 MGD
15 @ 0.01-0.05 MGD
2 @ 0.005-0.01 MGD
<u>3 @ 0.001-0.005 MGD</u>
Total = 38-150 MGD

WKP Baseflow: ~16-150 MGD?

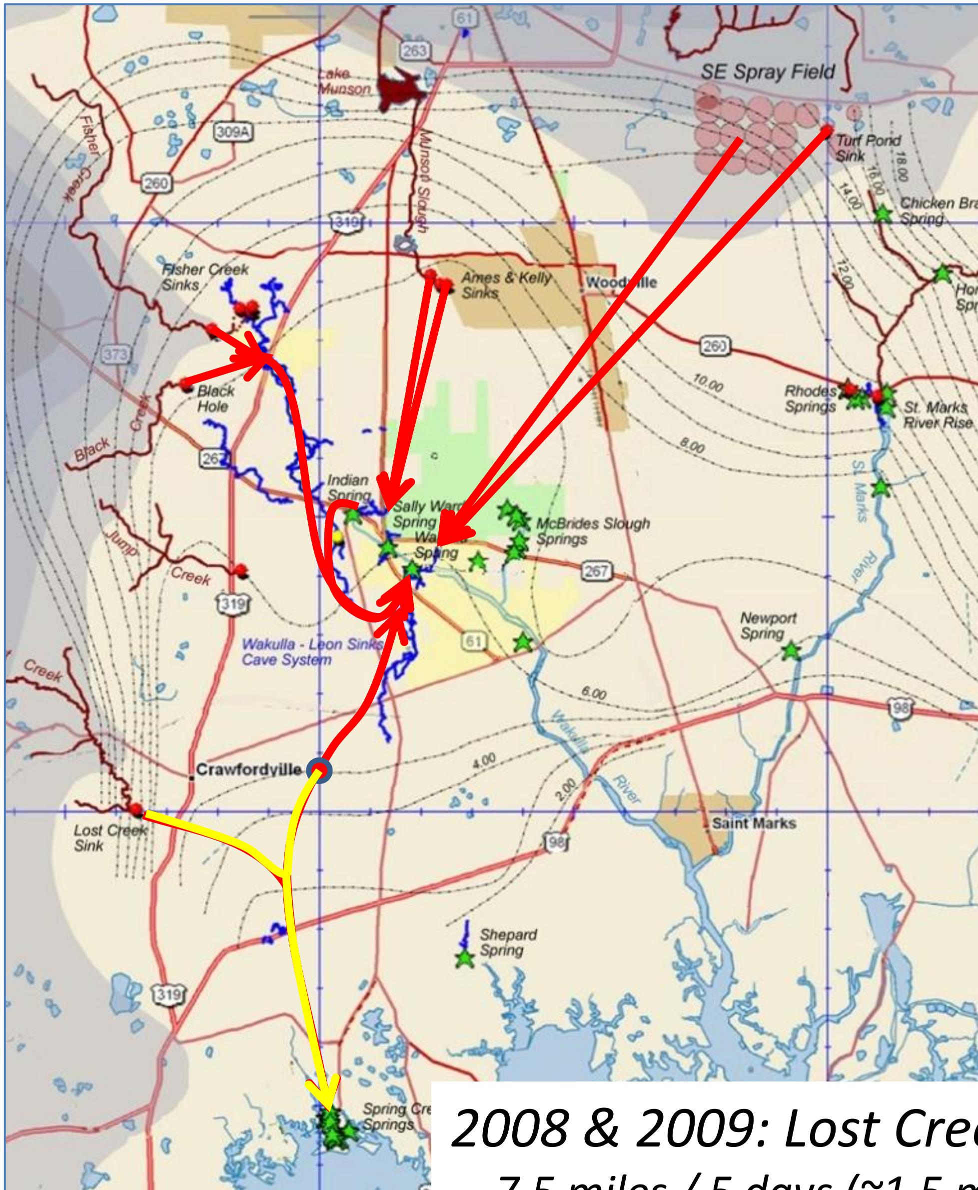
Wakulla & Spring Creek…

- Wakulla and Spring Creek springs are connected by one or more underwater caves and share water flowing through the aquifer (both clear groundwater and tea-colored surface water) from the north.
- Spring Creek began reversing for significant periods during the summer in 2006 and has been doing so every summer since then.
- When Spring Creek reverses, salt water travels through the caves as far as HWY 98 where we have measured salinity increases in the caves ~300 feet below the water in sinkholes.
- Spring Creek continues to reverse or not flow until the rains come back in the Fall or as a result of storms and increased surface water flow into the swallets (particularly Lost Creek).

Wakulla & Spring Creek…

- When Spring Creek isn't flowing, the groundwater that used to flow to it, flows to Wakulla instead causing the measured flow in the Wakulla River to increase.
- The water that shunts up to Wakulla is lower quality and clarity than the regular groundwater flow to Wakulla.
- The addition of that water to Wakulla's flow causes the water clarity at the spring to decrease to the point that the glass bottom boats cannot run.

Tracing the Water Flow …



2002: Fisher Creek – Emerald Sink
1.7 miles / 1.7 days (3,770 ft/day)

2003: Black Creek – Emerald Sink
1.6 miles / 1.6 days (2,670 ft/day)

2004: Emerald Sink – Wakulla Spring
10.3 miles / 7.1 days (7,650 ft/day)

2005: Kelly Sink – Indian Spring
5.2 miles / 13.5 days (2,040 ft/day)

2005: Ames Sink – Indian Spring
5.2 miles / 17.2 days (1,600 ft/day)

2005: Indian Spring – Wakulla Spring
5.5 miles / 5.9 days (4,890 ft/day)

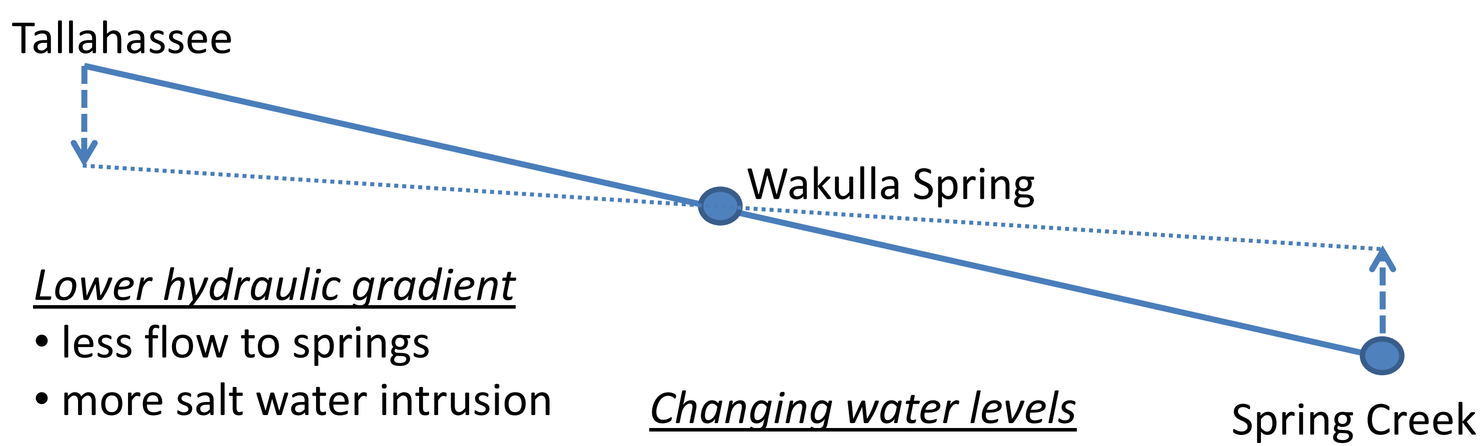
2006: Wells – Wakulla Spring
10.4 miles / 66.5 days (830 ft/day)
10.4 miles / 56 days (980 ft/day)

2006: Turf Pond – Wakulla Spring
10.9 miles / 56 days (1,030 ft/day)

2008 & 2009: Lost Creek – Spring Creek & Wakulla Spring
7.5 miles / 5 days (~1.5 miles/day) – 7.75 miles / 47 days (~870 ft/day)

What We've Learned?

- Pumping reduces groundwater levels in the north (aquifer pressure)
- Gradient (slope of the water table) is getting shallower
- It so shallow in the dry periods that high tide reverses the flow direction at Spring Creek.



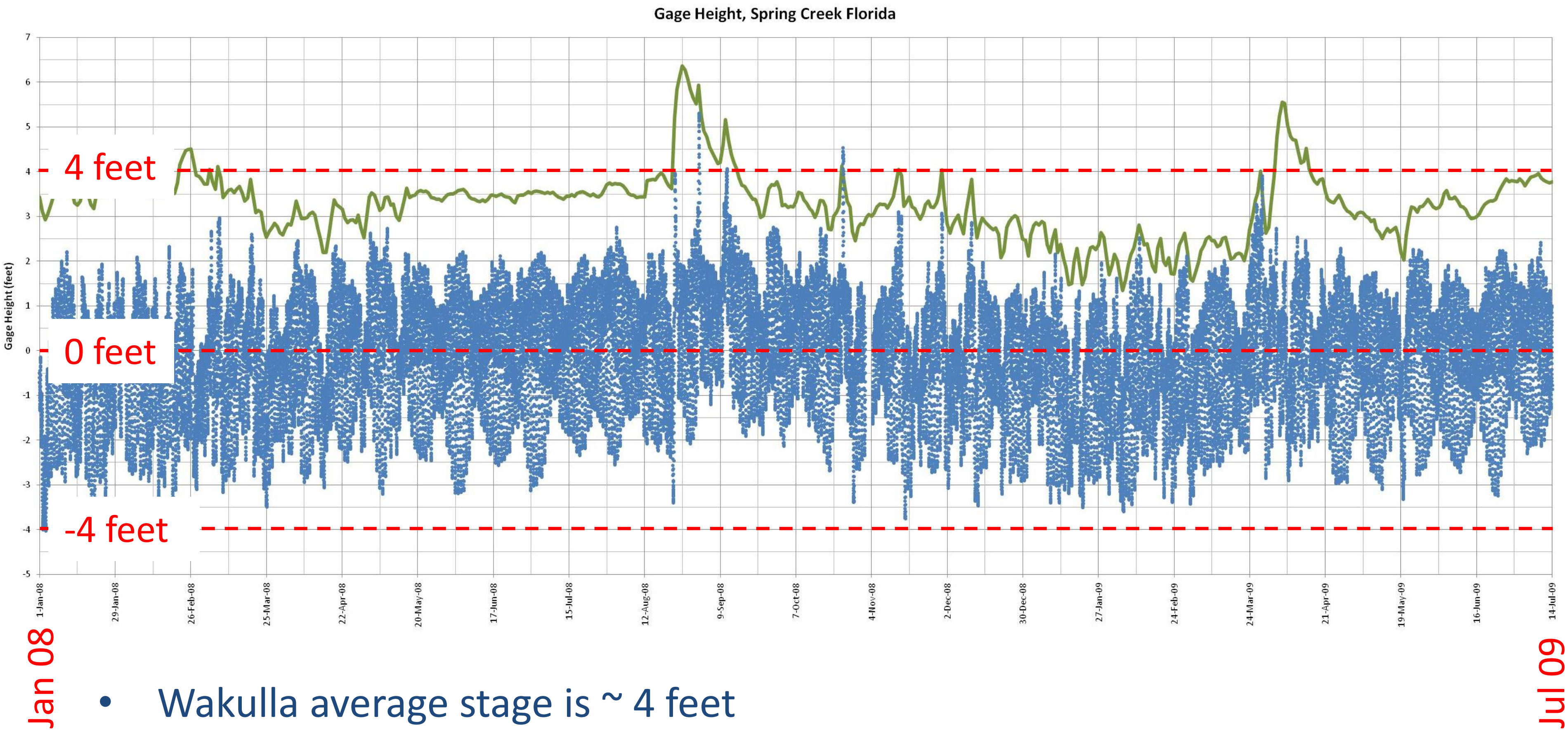
Lower hydraulic gradient

- less flow to springs
- more salt water intrusion

Changing water levels

- depressed conditions in north
- deeper unsaturated zone
- elevated conditions in south
- reduced unsaturated zone

What We've Learned?



- Wakulla average stage is ~ 4 feet
- Tides can reduce the gradient between Wakulla & Spring Creek to significantly less than 1 foot.
- Must maintain groundwater levels at ~>3feet to maintain flow at Spring Creek

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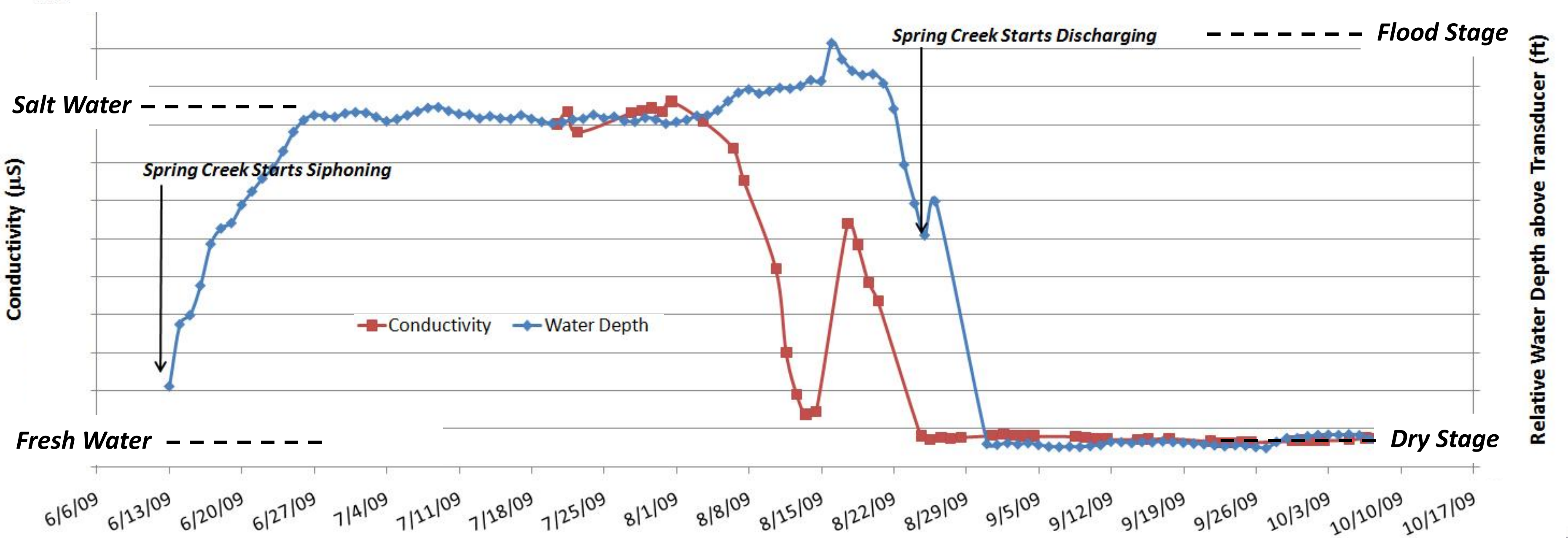
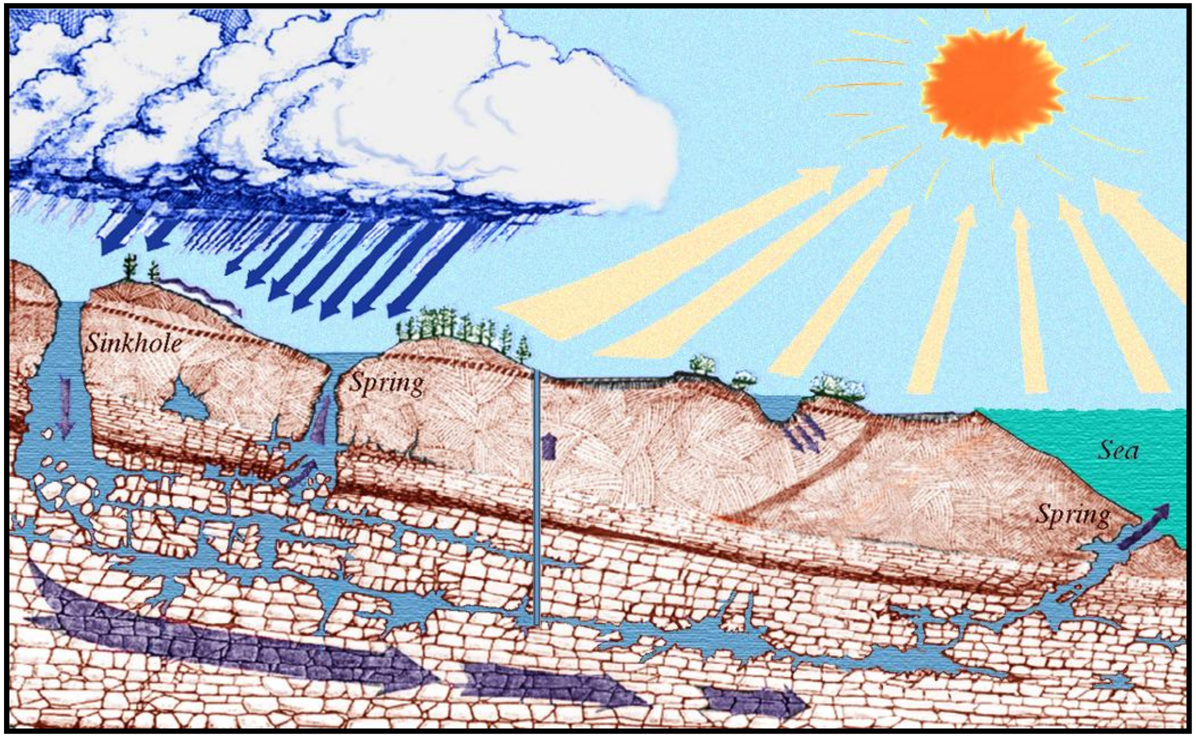
Consequences of Change…

- When Spring Creek stops flowing, water backs up into the aquifer matrix in the southern part of the WKP.
- Salt water travels rapidly for long distances (>= 2 miles to Punch Bowl Sink) in days.
- Sinkhole water levels rise to flood stage.
- When Spring Creek starts flowing, water levels drop precipitously and water in conduits returns to fresh water conductivities.



Balancing the Budget…

How much groundwater do we have?



<u>Water Budget</u>

- Sustainable
  total use = recharge
- Surplus Storage
  total use < recharge
- Declining Storage
  total use > recharge
- ***Just like your check book***

- Water is in constant motion moving from rain to the sea.
- Many different users (humans, plants, animals, rivers, streams, springs, estuaries, etc).
- Groundwater withdrawals intercept part of that flow and return it along a different path (typically surface flow).
- Quality & Quantity are impacted by how much we use, how we impact the quality of recharge, and how the water flows underground.

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Significance of a Water Budget

Inputs – Outputs = Change in Storage

- How do you know how much money you can spend?
  - Income
  - Fixed expenses
  - Balance = surplus money = available cash to spend
  - *Credit – provides immediate benefit but adds to fixed expenses*
- Water availability is governed by the same basic rules
  - Income = rain
  - Fixed expenses = all current extractions
  - Available cash = storage
- One difference
  - There is no such thing as a water surplus
  - Every drop of water entering the Wakulla Springshed is already being used
  - Management of that water falls to deciding which users will be impacted by new extractions & devising creative ways of recycling the extracted water

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And the Bottom Line…

- If trends continue (groundwater level declines):
  - the duration of Spring Creek reversals will increase,
  - the coastal ecosystem will decline due to salt water intrusion, and
  - water clarity at Wakulla will continue to decline.
- Reducing upland groundwater pumping in the Wakulla Springshed would raise groundwater levels and reduce the duration of Spring Creek reversals.
- Protecting Wakulla's flow and clarity requires that we:
  - identify and map the sprngshed boundaries
  - define Wakulla's groundwater budget
  - determine how extractions impact that budget
- To do these things we need to:
  - continue and expand data collection (flows and levels)
  - develop better predictive models that simulate what we know to be the key hydrologic features: caves, springs, swallets
  - educate the public on where their spring water comes from
  - convince our water resource managers to use better tools and maintain a balanced groundwater budget

Where do we go from here?

Aquifer / Spring Triage

- Stop the bleeding
  - Recognize that we cannot keep pumping groundwater
- Make all users monitor extraction
  - Find out how much we’re pumping
- Encourage reuse and recharge
  - The more we put back the better
  - Keep it clean
- Get public engaged
  - i.e. Texas radio stations
  - Tiered rate systems
- Need to build and use better models
- Find a way to make all this happen now!
  - Once we give it away, it will be very very hard to get it back

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More Information

- www.geohydros.com/FGS/
- http://www.geohydros.com/publications.html

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