

Thermal Mitigation Experience Summer 2022

For FUDR's
"Water Water Everywhere" Virtual Conference
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Thermal Mitigation during Summer 2022: Executive Summary

- Temperatures at Lordville were kept below 75°F except for 4 days. The highest Lordville temperature was 76.5 °F on July 21. Thermal releases were made on all four stressed days.
- 23 thermal release requests were made by NYS-DEC. About 1825 cfs-days of the 2,500 cfs-day bank were used. Thermal releases were made from all three reservoirs, primarily from Cannonsville.
- Had thermal releases not been made, there would have been about an additional 9 days over 75°F at Lordville.
- In retrospect, about 7 of the thermal releases were probably not needed.

Thermal Mitigation History: The protocol has now been successfully implemented for four summers, since 2019

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I. Thermal Mitigation Protocol Background

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What is the Thermal Problem in the Upper Delaware?

- Conservation releases from the NYC dams on the headwaters of the Delaware, including under the FFMP, have historically been unable to keep water temperatures in the upper mainstem at tolerable levels for its wild trout during summer heat waves.
- Under FFMP versions 2008 and 2018, there were 78 days when Lordville temperatures exceeded 75°F. A particular example: During the summer 2010, there were 70 days when the maximum temperature at Lordville exceeded 68°F, and 20 days on which it exceeded 75°F.
- Consequently, after considerable research and activism, a thermal mitigation protocol was added to the FFMP in 2019.

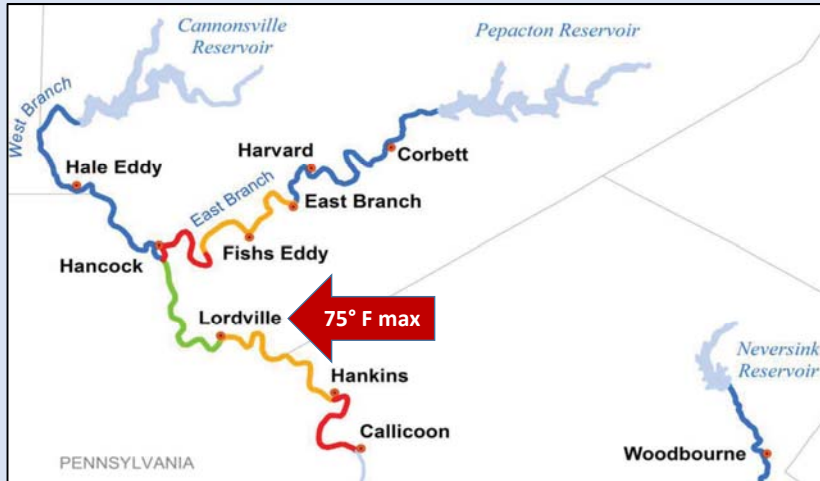
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FFMP 2017's Thermal Mitigation Protocol

- **Objective:** Keep summertime Lordville daily maximum temperatures below 75 °F via timed pulses of cold water from the Cannonsville reservoir when it is anticipated that Lordville temperatures would otherwise exceed the 75 °F limit.
- A thermal mitigation bank 2,500 cfs days of water is available for this purpose. The bank opens June 1, the start of the FFMP water year, and expires on May 31 of the following calendar year.
- The use of the bank is at the discretion of NYS-DEC.
- The DRBC's Subcommittee on Ecological Flows (SEF) has contributed guidelines on the use of the thermal bank. (The fishing community including FUDR and TU have been well represented with Jeff Skelding, Garth Pettinger, Bob Bachman, Jim Serio, and Peter Kolesar among the 13 SEF members.)

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The Geography: Keeping maximum temperatures at Lordville below 75°F aims to protect the Hancock to Lordville reach. It also contributes to keeping the West Branch cool.



Source: Joint Fisheries White Paper, January 2010

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The Reality: Thermal releases are gambles

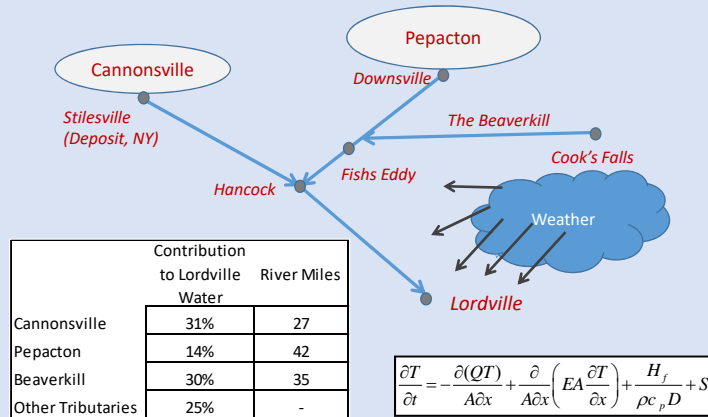
Daily decisions by NYS-DEC are:

- guided by approximate models of river thermodynamics, and imperfect forecasts of weather
- made under stringent time constraints
- work with a very limited amount of water, the 2,500 cfs-day thermal bank.

So, it is quite possible to release water when it is not actually needed, not release water when it is needed, or release the wrong quantity.

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An Engineering/Thermodynamic Schematic of Cooling at Lordville



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The principal factors affecting tomorrow's water temperature at Lordville

- Stream-flows in the West and East Branches, the Beaverkill and in the tributaries
 - The fraction of flow from reservoirs
 - time of travel to Lordville
- Air temperature (today's high, last night's low, tomorrow's forecasts)
- Previous water temperatures
 - yesterday's high temperature
 - this morning's low temperature
 - Cannonsville discharge temperature
- Sky cover (daytime, nighttime)
- Precipitation
- Length of day, sun angle
- Groundwater flux and temperature
- Wind speed, humidity

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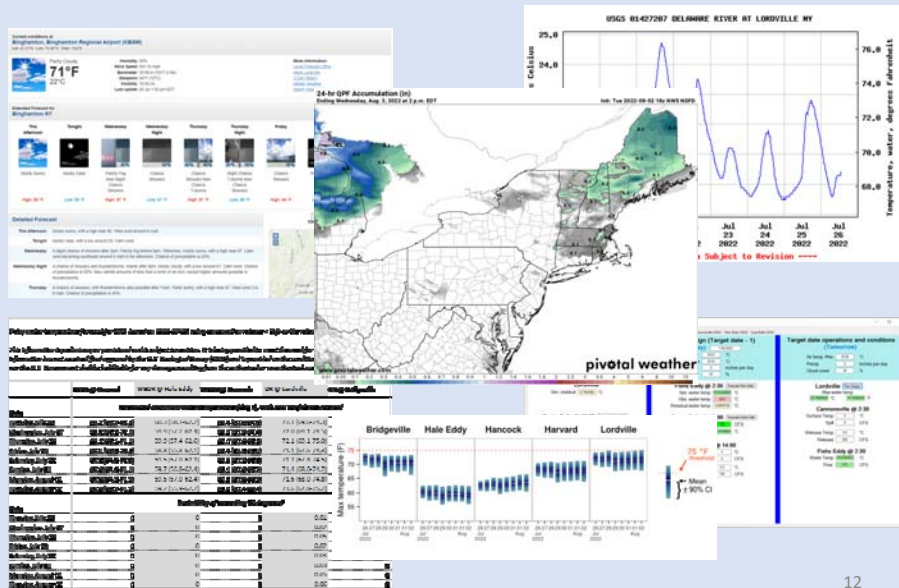
A Typical Scenario faced by the DEC: each day

Yesterday Lordville was at 1070 cfs and 74°F. The Cannonsville release was 621 cfs. Fishs Eddy was at 278 cfs and 78°F. Binghamton's forecasted high and low air temperatures for today and tomorrow are: (81,70); (84,69).

It's now 8 am decision time. What would you do? Release more water? If so, how much and on what specific timing?

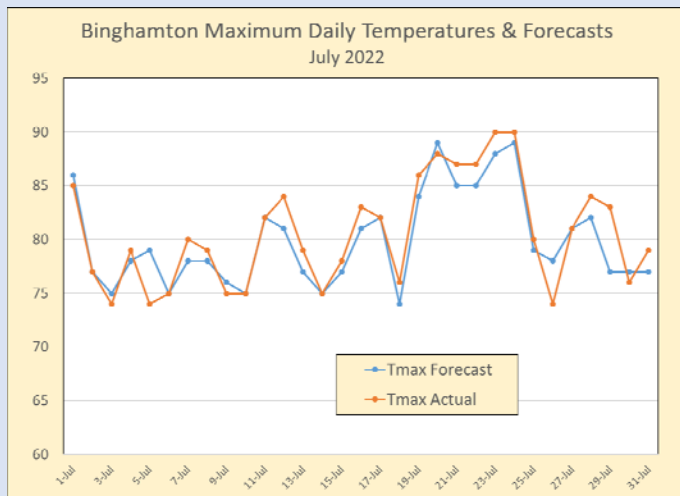
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Information available to NYS-DEC for thermal release decisions



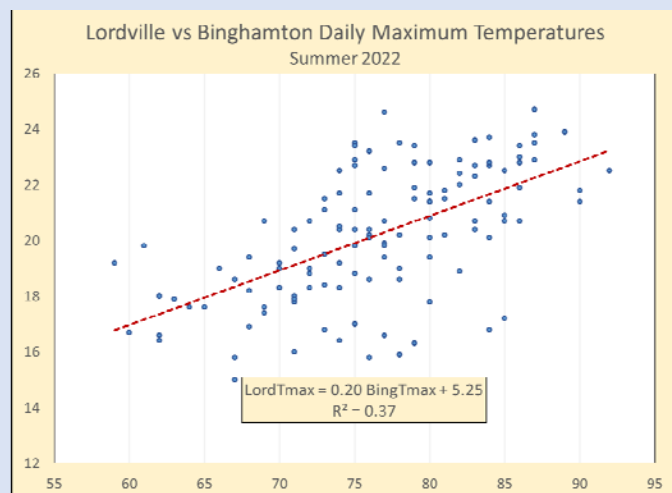
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Accuracy of Binghamton One-Day Ahead Air Temperature Forecasts



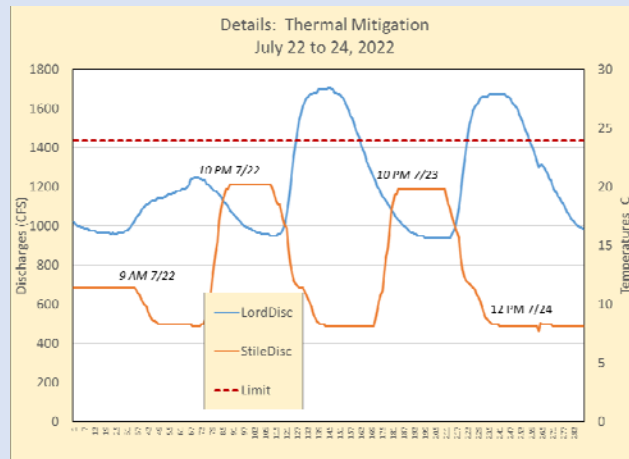
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The Correlation Between Binghamton Air and Lordville Water Temperatures



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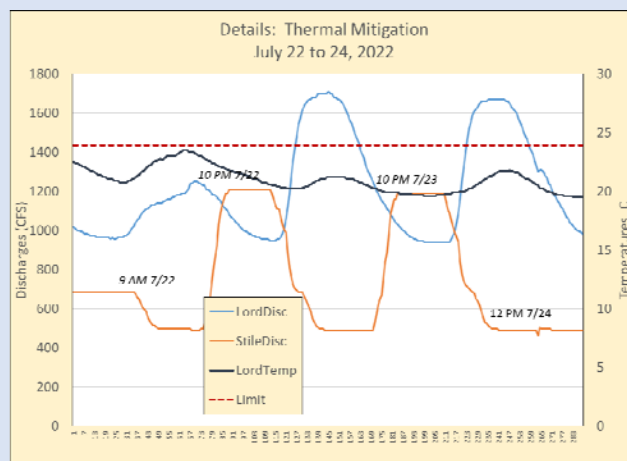
Dynamics of Three July Thermal Releases: Cannonsville Releases & Lordville Flows



Binghamton 1-Day
Ahead Forecasts
7/22 85°F
7/23 88°F
7/24 89°F

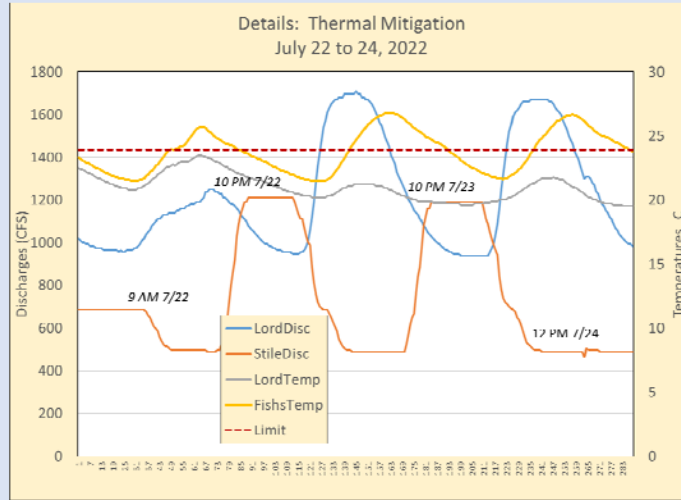
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Dynamics of Three July Thermal Releases: How Lordville Temperatures are affected.



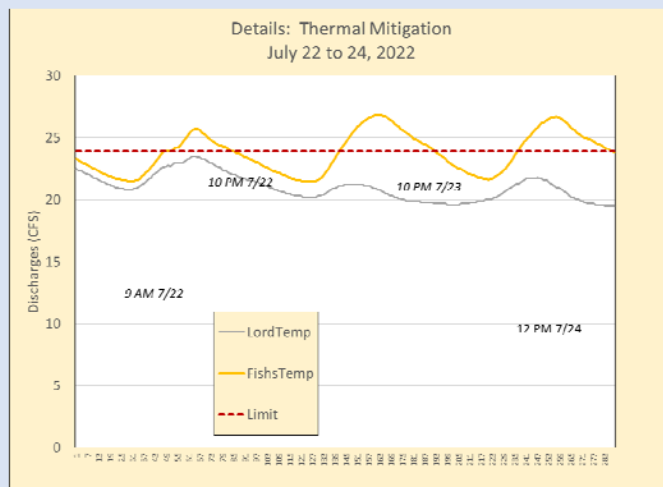
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Dynamics of Three July Thermal Releases: Comparing Lordville and Fishs Eddy Temperatures



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Focus on the Lordville / Fishs Eddy Differences



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II. Statistical Analysis of the Thermal Mitigation Experience over the Summer 2022

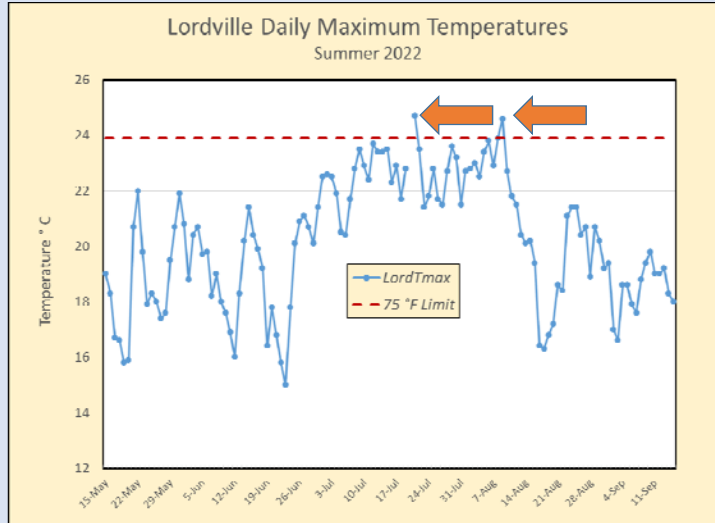
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Overview of Thermal Mitigation Experience: Summer 2022:

- Temperatures at Lordville were kept below 75°F except for 3 or 4 days. The highest Lordville temperature was 76.5 on July 21. Thermal releases were made on all the 'stressed' days.
- 23 thermal release requests were made by NYS-DEC. About 1825 cfs-days of the 2,500 cfs- day bank were used. Thermal releases were made from all three reservoirs, primarily from Cannonsville.
- Had thermal releases not been made, there would have been about an additional 9 days over 75°F at Lordville.
- In retrospect, about 7 of the thermal releases were probably not needed.
- The thermal protocol also kept Lordville daily average temperatures below 72°F and contributes to keeping Hancock daily average temperatures below 68°F.
- The interplay between River Master directed releases made on same day when thermal releases would be called for saved some thermal bank water. **About 650 cfs-days remain in the bank for use in May 2023.**

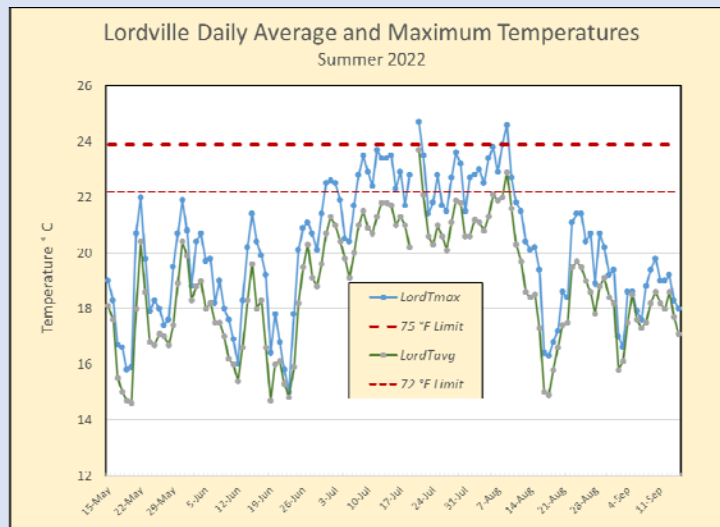
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Thermal Experience: Three or Four Exceedances of the 75°F Limit



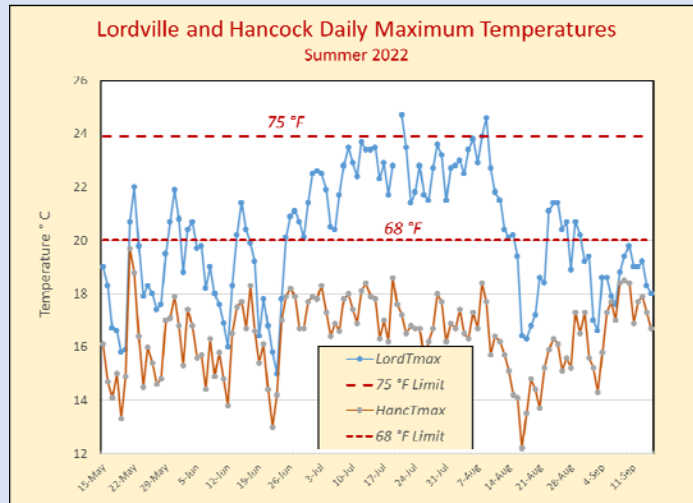
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Controlling Lordville daily maximums also controls the Lordville averages



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Correlation of Lordville and Hancock Daily Maximums



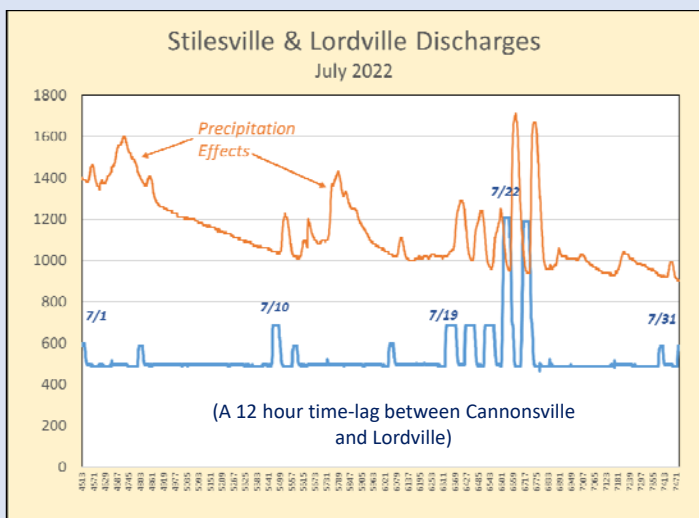
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How to assess the impact of the thermal releases?

- Previous historical research done for SEF has estimated, via regression analysis, that on average an additional 100 cfs pulse from Cannonsville reduces Lordville temperatures by about 0.5°C (0.9°F).
- When releases from Cannonsville and Pepacton are at FFMP's normal levels, Lordville and Fishs Eddy temperatures are highly correlated and almost equal. When thermal releases are made from Cannonsville, the Lordville temperatures drop relative to Fishs Eddy. Thus, Fishs Eddy temperatures serve as a 'control variable' for assessment of the impact of the thermal protocol .

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The Impact of the Cannonsville releases on flows downstream at Lordville: July 2022



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Estimating what would have happened without the thermal releases.

Date	CanPulse	Actual LordTmax	Estimated LordTmax
30-May	200	20.7	21.7
26-Jun	100	20.9	21.4
4-Jul	100	21.9	22.4
12-Jul	100	23.7	24.2
17-Jul	100	22.9	23.4
20-Jul	200	?	?
21-Jul	200	24.7	25.7
22-Jul	200	23.5	24.5
23-Jul	900	21.4	25.9
24-Jul	800	21.8	25.8
31-Jul	100	21.5	22
3-Aug	200	23	24
4-Aug	475	22.5	24.9
5-Aug	200	23.4	24.4
6-Aug	200	23.8	24.8
7-Aug	200	22.9	23.9
8-Aug	475	23.9	26.3
10-Aug	100	22.7	23.2
11-Aug	200	21.8	22.8
26-Aug	240	20.4	21.6
29-Aug	240	20.7	21.9

Estimation Basis: Regression analyses done for SEF indicated that a 100 cfs release from Cannonsville reduces Lordville temperatures by about 0.5 °C.

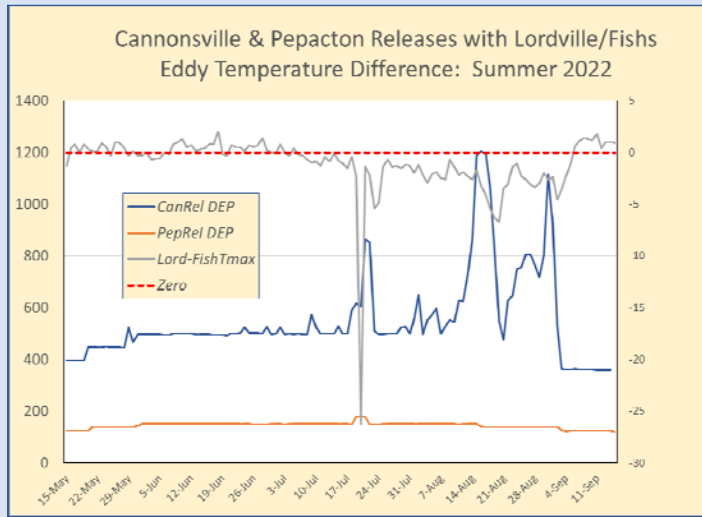
Green indicates that Lordville temperature would have stayed below 23 °C (73.4 °F) on 7 days.

Red indicates that Lordville temperature would have hit or exceeded 23.9 °C (75 °F) on 9 days.

Lordville maximum temperatures were lowered by 2.4 °F on the 21 days when thermal releases were made.

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Evidence that the protocol works: Cannonsville thermal releases reduced Lordville temperatures relative to Fishs Eddy.



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III. Driving Climatological Conditions & Trends

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Weather as a driver of thermal stress:
(Binghamton Air Temperatures)

	Average Daily Maximum			Days Over 80° F		
	June	July	August	June	July	August
2021	77.5	76.2	78.5	12	13	14
2022	72.8	80.5	80.9	6	16	19
Normal	74.0	78.4	76.7	7.7	14.2	10.9

Summer 2022 was warmer than 2021 and warmer than the 30-year 'Normal'. August 2022 was particularly warm, with 19 days above above 80 °F.

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Weather as a driver of thermal stress and lower reservoir storage: Binghamton Precipitation

	June	July	August	Summer
2021	3.29	9.82	6.23	19.34
2022	5.33	2.89	3.32	11.54
Normal	4.69	3.80	4.10	12.59

Drier than the 30-year 'Normal' in July and August

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Comparing Summers 2021 and 2022

	2021	2022
Release Requests	7	23
Water Used (cfs-days)	650	1850
Remaining Bank (cfs-days) Sept 1	1850	650
PCN Reservoir Storage Sept 1 (BG)	252	166
Maximum Lordville Temperature (° F)	76.1	76.5
Stress Days (Over 75°)	2	3 or 4
Stress days Avoided (Over 75°)	2	9
Average Maximum Air Temperature (Binghamton)	77.4	78.1
Binghamton Days Over 80° F	39	41
Binghamton Precipitation (in)	19.3	11.5

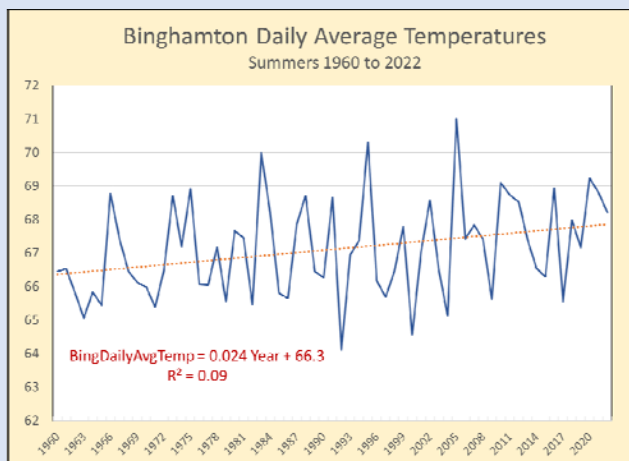
Summer 2022 was tougher than Summer 2021

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Some Local Climate Trends

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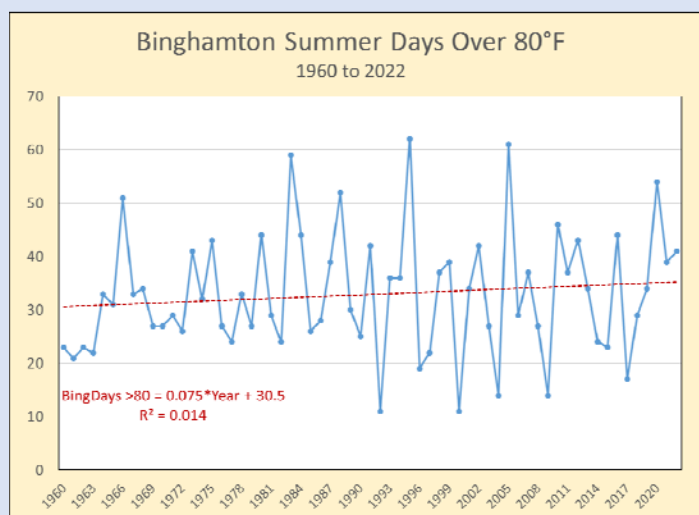
Increasing regional summer average daily temperatures



A decade projection of + 0.24 °F

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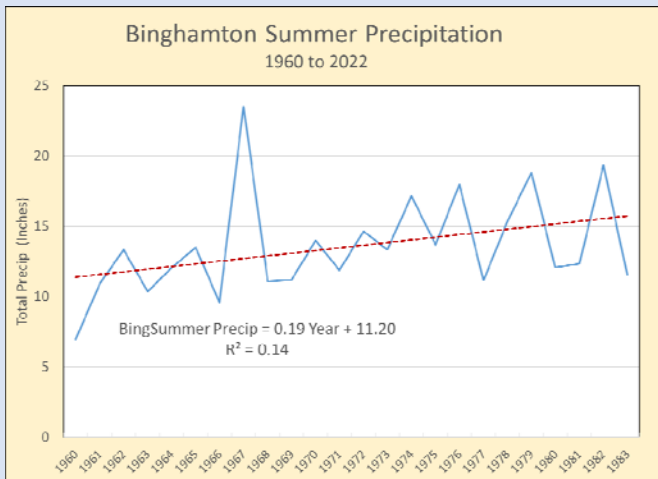
Increasing regional stress producing summer temperatures: Days over 80°F



A decade projection of + 0.75 days

34

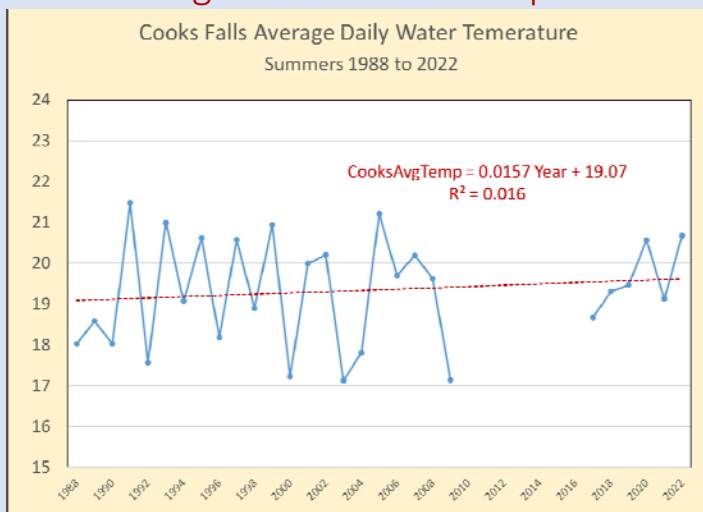
Increasing regional summer precipitation



A decade projection of +1.9 inches

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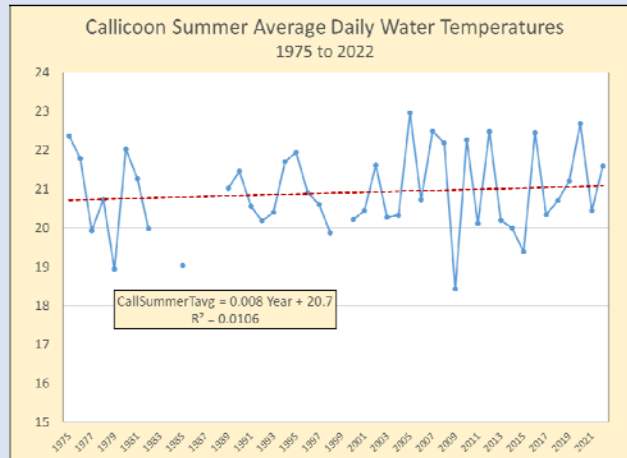
Increasing Catskill water temperatures



A decade projection of +0.15 °C ≈ +0.27 °F

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Increasing Delaware mainstem water temperatures



A decade
projection of +0.08
°C ≈ +0.14 °F

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Some Open Policy & Research Issues (Kolesar)

- Assess the adequacy of the 2,500 cfs–day thermal mitigation bank consistent with the goals identified in the FFMP. There is evidence that the bank could be bigger at little or no risk to other stakeholders.
- Check the effectiveness of short thermal pulses, such as 4, 6 or 8 hour vs 12 or 24 hour pulses etc. Short pulses can save water and control peak temperatures, but would permit higher daily average temperatures.
- Reassess reliance on the “Bank” strategy. The actual water is in the reservoir. What should be done if the bank is empty, but the reservoir is “full”?

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Some Open Policy & Research Issues (Kolesar) (continued)

- Refine the regression-based mitigation calibration models and/or develop thermodynamic models of the impact of reservoir releases on downstream temperatures. Use the best experience data and forecasts now available.
- Evaluate the impact of the thermal mitigation protocol on shad and warm-water species such as smallmouth bass. (Some SEF members.)
- Evaluate the feasibility of other temperature triggers or targets such as a 68°F daily max, a 72°F daily average or two successive days at the 75°F max, etc.

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THE END

Questions?



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Appendix Slides Not Used

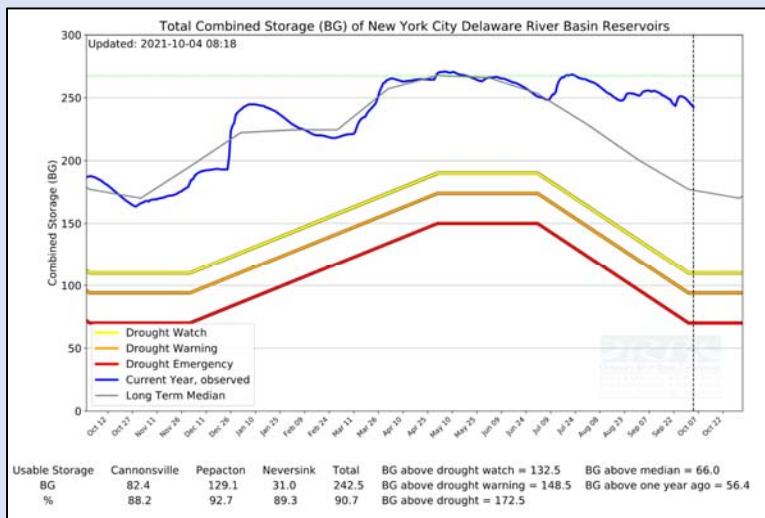
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A comparison with the Summer 2021 thermal mitigation experience: (An easier summer)

- In 2021, 7 thermal relief requests during were made by NYS-DEC. Mitigation releases were made on 6 days, 3 distinct 'thermal episodes', using about 650 cfs-days of water. **About 1850 cfs days remained in the bank for use in May 2022.**
- Lordville temperatures were kept below the 75°F stress threshold except on two days during a June heat wave (76.1 on June 29 and 75.3°F on June 30)
- Using the regression-based calibration of the impact of Cannonsville releases on Lordville temperatures, I estimate that had the thermal releases not been made, Lordville temperatures would have exceeded the 75 °F limit on one or two additional days, and the temperatures on June 29 and June 30 would have been about 0.7°F higher.

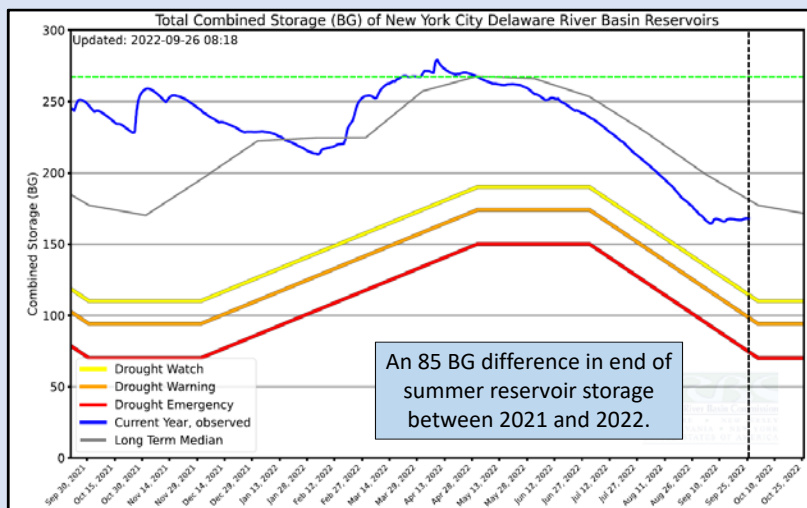
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By contrast, summer, 2021, was much wetter than 2022. Storage was at or above the median through the summer.



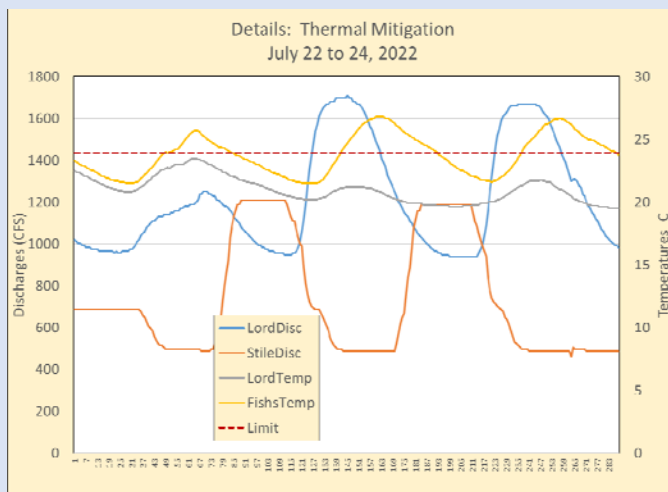
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Low summer 2022 precipitation is reflected in lower than median reservoir storage



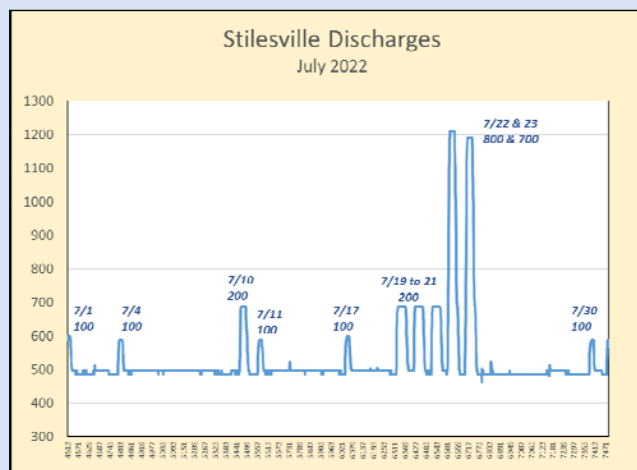
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Dynamics of Thermal Releases



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Cannonsville Thermal Releases July 2022



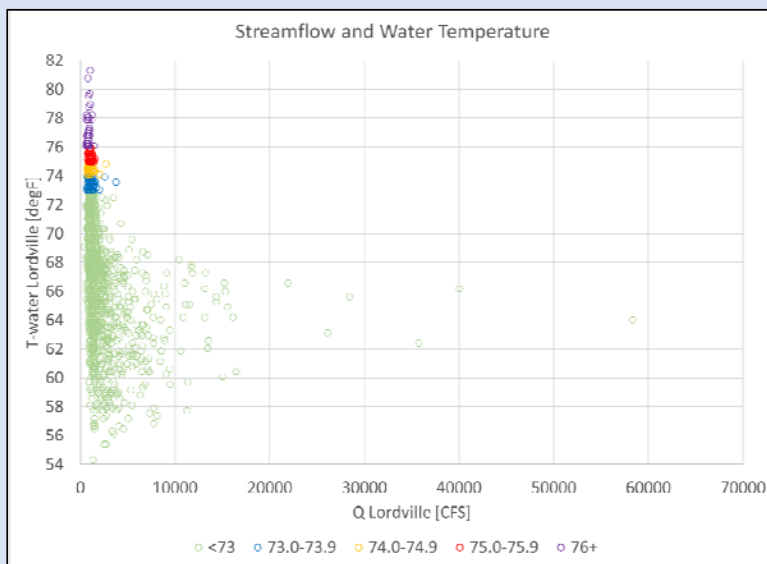
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Principal factors affect today's water temperature at Lordville

- **Streamflow**
 - fraction of flow from reservoirs
 - time of travel
- **Air temperature (today's high, last night's low)**
- Previous water temperature
 - yesterday's high temperature
 - this morning's low temperature
- Sky cover (daytime, nighttime)
- Precipitation
- Length of day, sun angle
- Groundwater flux and temperature
- Wind speed, humidity

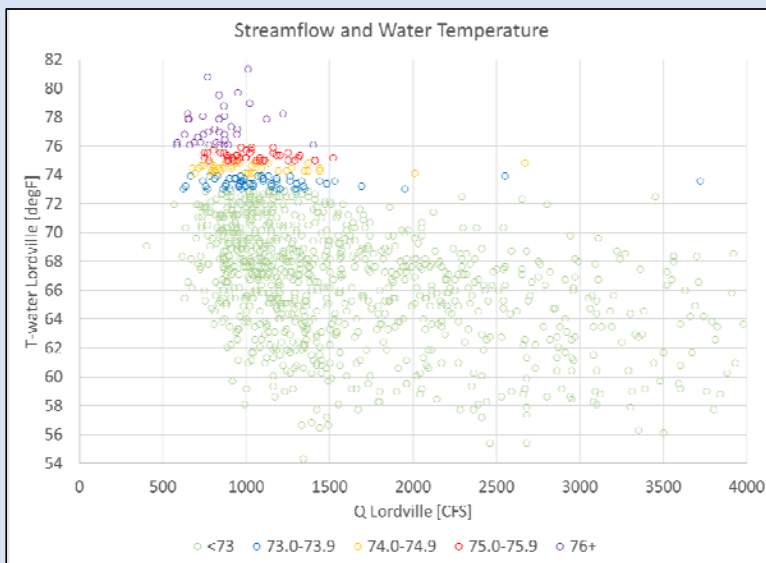
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Water temperature factors



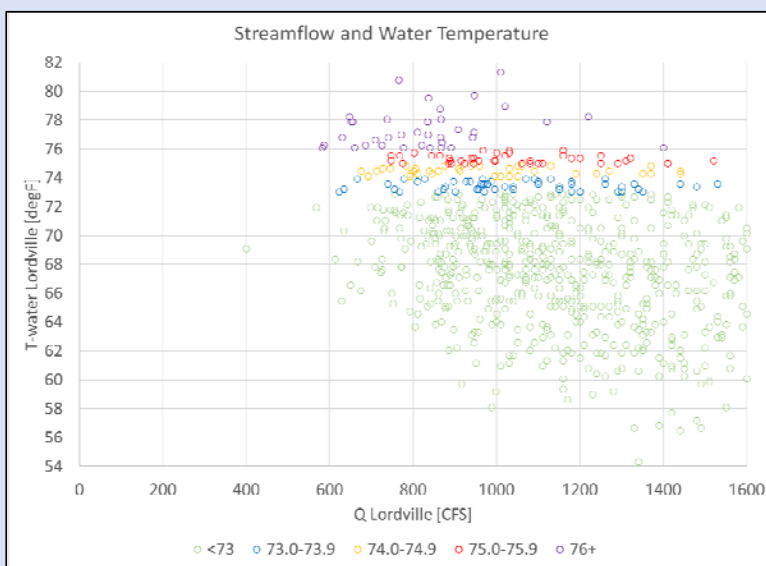
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Water temperature factors



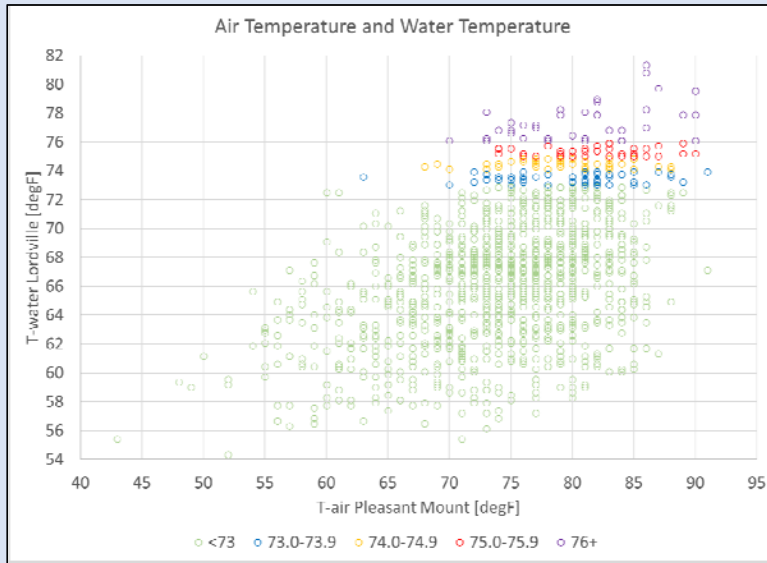
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Water temperature factors



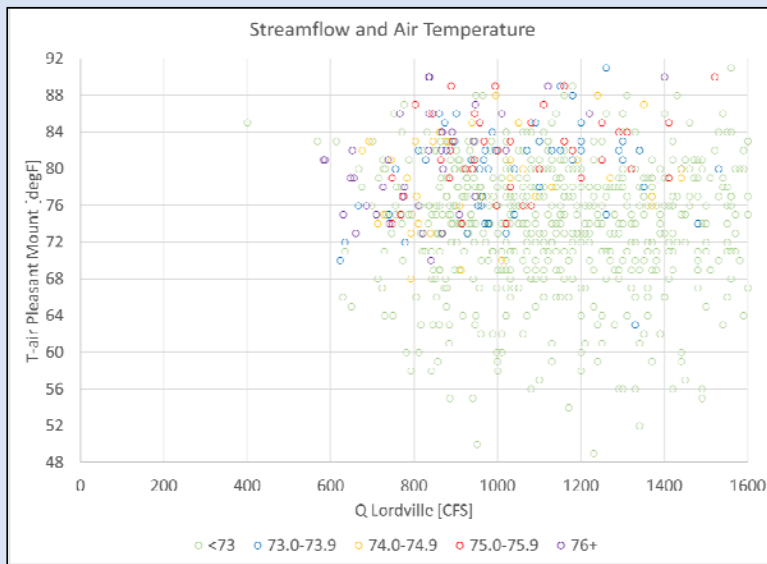
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Water temperature factors



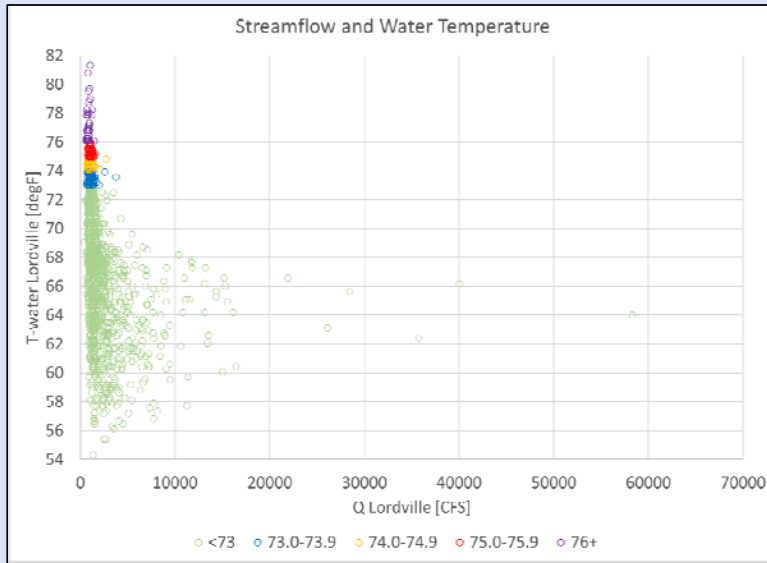
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Water temperature factors



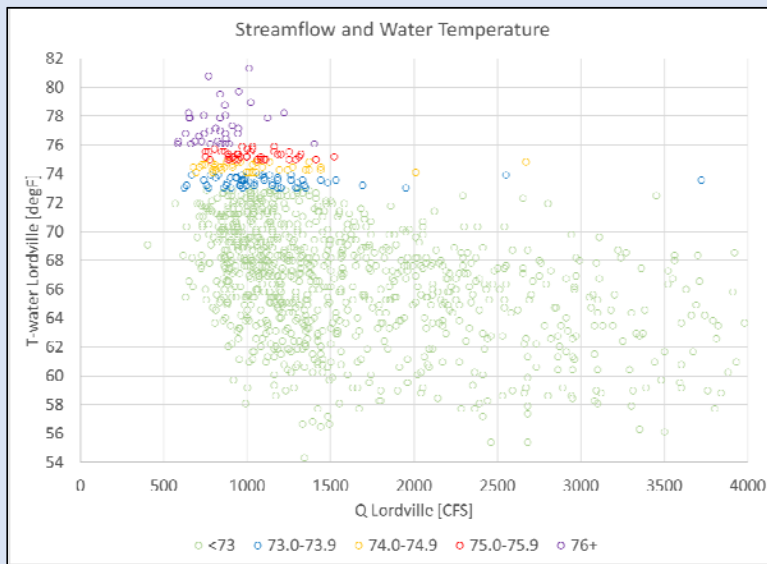
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Water temperature factors



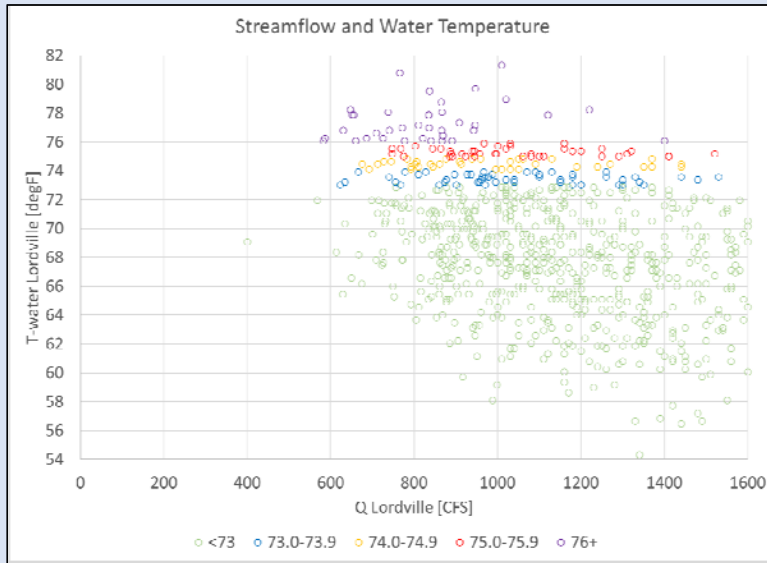
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Water temperature factors



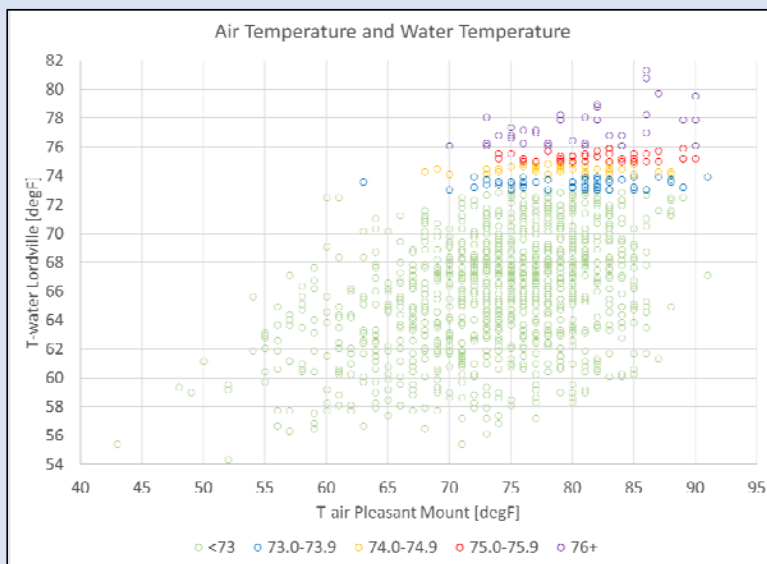
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Water temperature factors



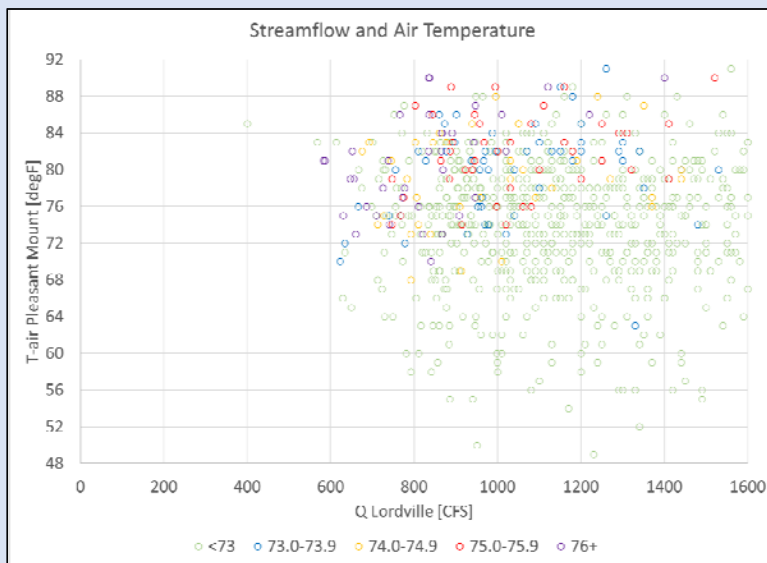
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Water temperature factors



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Water temperature factors



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Weather forecast parameters

Current conditions at
Binghamton Regional Airport (KBGM)
Lat: 42.21°N, Long: 75.98°W, Elev: 1627ft

Partly Cloudy
71°F
22°C

Humidity: 55%
Wind Speed: SW 10 mph
Barometer: 30.06 in (1017.3 hPa)
Dewpoint: 54°F (12°C)
Visibility: 10.00 mi
Last update: 26 Jul 1:53 pm EDT

Extended Forecast for
Binghamton NY

This Afternoon	Tonight	Wednesday	Wednesday Night
Mostly Sunny	Mostly Clear	Patchy Fog then Slight Chance Showers	Chance Showers
High: 80°F	Low: 59°F	High: 87°F	Low: 67°F

Detailed Forecast

This Afternoon Mostly sunny, with a high near 80. West wind around 6 mph.

Tonight Mostly clear, with a low around 59. Calm wind.

Wednesday A slight chance of showers after 2pm. Patchy fog before 6am. Otherwise, mostly sunny, with a high near 87. Calm wind becoming southwest around 6 mph in the afternoon. Chance of precipitation is 20%.

Wednesday Night A chance of showers and thunderstorms, mainly after 6pm. Mostly cloudy, with a low around 67. Calm wind. Chance of precipitation is 50%. New rainfall amounts of less than a tenth of an inch, except higher amounts possible in thunderstorms.

Thursday A chance of showers, with thunderstorms also possible after 11am. Partly sunny, with a high near 87. West wind 3 to 8 mph. Chance of precipitation is 40%.

SKY CONDITION

The sky condition describes the predominant/average sky condition based on the percentage of sky covered by opaque (not transparent) clouds. If a high probability of precipitation (60% or greater) is expected over a majority of the forecast period, then the sky condition may be omitted since it is inferred from the precipitation forecast.

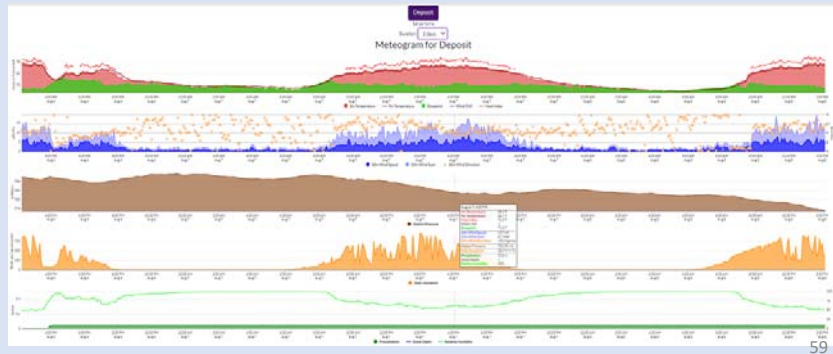
Sky Condition	Opaque Cloud Coverage
Cloudy / Overcast	88-100%
Mostly Cloudy / Considerable Cloudiness	70-87%
Partly Sunny / Mostly Cloudy	51-69%
Mostly Sunny / Partly Cloudy	26-50%
Sunny / Mostly Clear	6-25%
Sunny / Clear	0-5%

Topographic
[Click Map For Forecast](#)

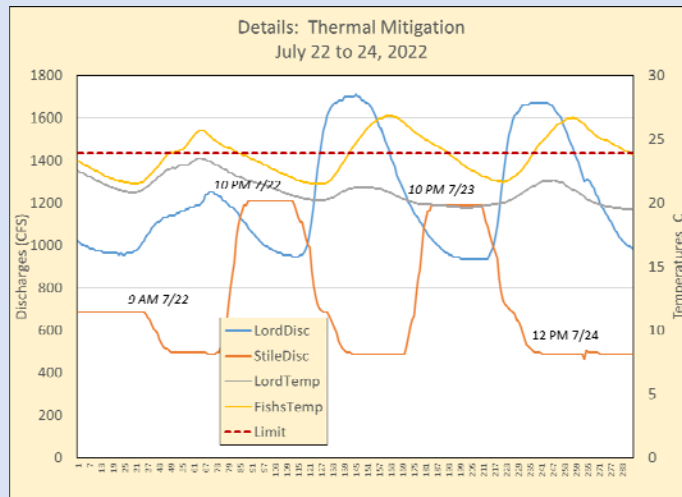
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The sources of release errors

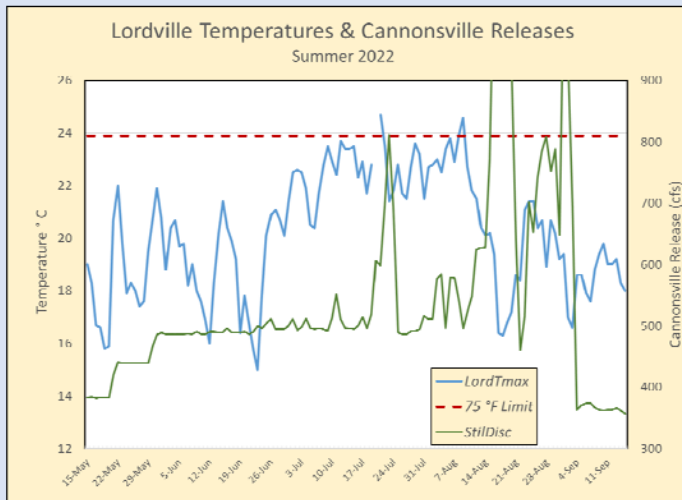
- Forecast error
 - It happens...
- Forecast uncertainty
 - Use midpoint of range? Test edge cases? Judgement calls...
- Model/calculation error
 - Adjust based on yesterday's model error; likely correlated
- Operator error
 - Teamwork! Multiple staff members working in parallel and cross-checking



Detailed Dynamics of Some July Thermal Releases

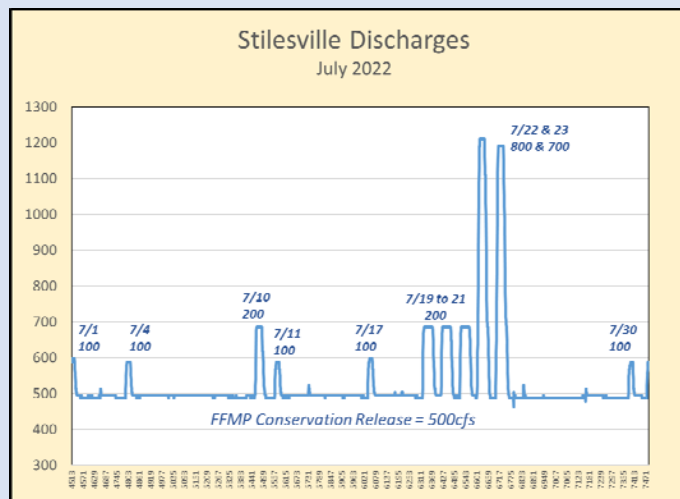


Impact of Cannonsville Thermal Releases on Lordville Temperatures: Summer 2022



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Zoom in on the Thermal Releases of July 2022.



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