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July 16, 2019

VIA EMAIL: Kelsey.lindquist@slcgov.com

Historic Landmark Commission
SALT LAKE CITY CORPORATION
451 South State Street, Room 326
Salt Lake City, Utah 84111

Re: Is it reasonable to claim that the proposed 4th Avenue water treatment plant could be damaged by a cloudburst flood?
4th Avenue Well – HLC PLNHLC2018-00557 and PLNHLC2018-00558
Utah DDW Matter 4th Avenue Well (WS017); Salt Lake City Water System, System #18026, File #11680

Ms. Lindquist:

This letter supplements my prior comments to the Historic Land Commission (the "Commission") regarding how the applicant's (the DPU's) proposed 4th Avenue pump house and chemical treatment plant fails to comply with Salt Lake ordinance requirements because it is inadequately protected against floods. I am aware that the June 6th hearing has been postponed and that further negotiations may result in a revised design being submitted; however, the following authorities and points will be relevant regardless of any pump house design that is considered by this Commission. This supplemental comment concerns whether it is feasible that a cloudburst flood similar to the 1945 Perry's Hollow flood could damage or destroy the proposed Well-Water Treatment building and how likely such a failure event would be.

The key conclusions of this analysis are: 1) rough, initial modeling indicates that cloudburst-fire floods can reasonably be expected to damage the proposed chemical water treatment plant at 4th Avenue. 2) The risk of a Perry's Hollow type flood should be evaluated as a conditional probability and not by committing the base rate fallacy of estimating fire and flood risks as independent events. If the risk of fire and flood are erroneously estimated as independent, the computed risk such a severe flood is once in 1,250 years. Treating fire and flood frequencies as conditional probabilities, I estimate the lower bound of the 100 year rate for severe cloudburst-fire flood that could damage the proposed chemical plant at 2% per 100 years – or 25 times the risk if fire and flood are treated as independent events. This estimate is are more than the traditional acceptable civil engineering risk criteria of 1% per 100 years. This analysis illustrates how the risk of a cloudburst flood-fire might be assessed when evaluating the proposed chemical treatment plant at 4th Avenue and North Canyon Road.

This 2% point-estimate of risk of cloudburst-fire flooding in the next 100 years is in addition to the empirical rate of City Creek high-snowmelt flooding (post-1909) of about 3 every 100 years. The combined risk is 5 events every 100 years.

Introduction and Summary

Severe cloudburst floods have historically occurred in northern Utah associated with our narrow Wasatch Front Mountain Range canyons or valley floor flatlands. Woolley (1946) abstracts 500 such Utah floods beginning with a June 23, 1852 Salt Lake City cloudburst through 1945.[1] A particularly severe subset of cloudburst floods are cloudburst-fire floods. Such when steep canyon hillsides that are denuded by fire are followed by a cloudburst rain event, then conditions similar to southern Utah soils that are not covered by vegetation are present. A severe cloudburst-fire flood, or what would be called flash flood in desert lands, occurs that can send a wall of water and mud down canyon. Northern Utah canyon related cloudburst floods were so severe during the 1910s to 1920s, that Utah State government commissioned a special study.[2]

Rough, initial modeling indicates that cloudburst floods from many scenarios of reasonably expected combinations of burn-acreage, fire-reduced soil porosity, and, severe rainfall events can send water and mud flows down City Creek Canyon sufficient to overwhelm flood control ponds at North Canyon Road and Bonneville Drive and to damage the proposed chemical water treatment plant (Section IV at 18). The risk of such fire followed by cloudburst rain events is unknown and given currently available severe rain and wildfire historical data can only be roughly estimated.

Cloudburst floods and cloudburst-fire floods are rare events. Since 1900, along the Salt Lake northern salient, there have been two cloudburst floods and two cloudburst-fire floods on salient hillsides between Ensign Peak and Dry Fork Canyon that have deposited torrential floodwaters and large muds flows on the valley floor (Section I at 3). But these rare events cause significant damage (*id*). The likelihood of cloudburst-fire floods are a joint probability distribution of the probability of a moderate and large acre fire occurring and the probability of a severe rainfall event occurring.

Section II reviews what is known about the mean return interval between large, mid-sized, and small acre fires along the Wasatch Front Mountains, generally, and Salt Lake City, specifically. For the Los Angeles basin, Schoenberg, Peng, and Woods (2002) quantified the risk of wildfires by acreage for fires greater than 100 acres along the northern foothills that surround that desert city.[3] As expected, the frequency of wildfires decreases as burn acreage increases.

Based on currently available Utah information, it is not possible to construct a Schoenberg-like probability distribution for wildfires in the Salt Lake City foothills (Section II at 6). An extensive, ongoing research effort by the United States Forest Service ("USFS") and the Utah State Division of Forestry, Fire and State Lands provides on historical Wasatch Front Mountain Range wildfires and the mean-return-time-interval of fires greater than 1,000 acres

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[1] Woolley, R. R. (1946). Cloudburst Floods in Utah: 1850-1938. Washington, D.C. at 96-120 (url: http://pubs.er.usgs.gov/publication/wsp994).

[2] Utah Flood Commission. (1931). Torrential floods in Northern Utah, 1930. Logan: Agricultural Experiment Station, Utah State Agricultural College. On file at Special Collections, Marriott Library, University of Utah. (url:.http://www.lib.utah.edu).

[3] Schoenberg, F.R., Peng, R., and Woods, J. (2002). On the Distribution of Wildfire Sizes. Whitepaper. url: http://www.biostat.jhsph.edu/~rpeng/papers/firesize.pdf . Schoenberg and colleagues found that fire frequency declines as acreage increases by a Pareto distribution.

(Section II.A).[4] New analysis is presented here based on the experience of the Salt Lake City Fire Department fighting small sub-1-acre fires (Section II.C at 9). Missing is historical data on the rate of mid-range fires less than 1,000 acres and more than 1-acre (Section II.B at 9). Without that information, a Schonberg-like estimate of wildfire return times is not possible.

Section III at page 11 reviews what is known about likely frequency of severe cloudburst rainfall events in Salt Lake City. For the valley floor, the baseline risk is a severe 1.5 inch rainfall occurs about every 100 years (Section III.A). New analysis presented here based on two methods (power law and Gumbel distributions) estimates the frequency of such severe rainfall events in City Creek Canyon based on data from automated weather recording stations at Louis Meadows and Lookout Peak which are operated by the United States National Resources Conservation Service ("NRCS") (Section III.B at 12).

Even if fire and cloudburst flood risks could be quantified, it would be improper to reason that they are extremely rare events that occur on the scale of more than once every 500 years. For example, assuming the rate of a 1.5 inch cloudburst rainfall is once every 100 years and the risk of a large acre fire in City Creek is 3 times every 100 years, it would be improper to conclude that the joint risk of these events is 4.5 joint events every 1,000 years (0.015 per 100 years times 0.03 per 100 years = 0.0045 or 4.5 per 1,000 years). A reasonable assumption is that the lower humidities at ground level and the ability of the atmosphere to hold larger amounts of water that causes severe summer thunder storms are both related to the higher summer temperatures during periods of drought. That there have already been two such events within the last 104 years indicates that the risk of wildfire and flood are somehow dependent on each other or third unknown factors and are not independent.

Because the two causes are not independent, deciding, for example, that the risk of a cloudburst flood impacting the proposed treatment plant is less than 1 in 500 years would be a *base rate fallacy* (Section V at 2218). Conditional probability is a better way to quantify the risk, *e.g.-if* the risk of a cloudburst-fire flood is 2 in 100 years, and a 500 acre wildfire occurs, *then* the risk of a subsequent cloudburst and flood is one-half. The overall risk is then 2% x 50% or 1%.

The implication of the risk of cloudburst-fire floods for the Commission's consideration of the 4th Avenue chemical treatment plant is that the Commission will have to engage in fact-finding as to the extent and severity of that risk based on its administrative judgment. Expert opinions – and this writer is not an expert in these matters – will be unable to provide a concise opinion on this risk due to the lack of weather and fire data discussed above. However, the background information provided in this letter can aid the Commission in making that factual determination (Section VI at 24).

I. HOW MANY CLOUDBURST AND CLOUDBURST-FIRE FLOODS HAVE OCCURRED ALONG THE SALT LAKE SALIENT SINCE 1900?

Table 1 and Figure 1 lists and shows the four historical severe cloudburst events that have occurred between the Ensign Peak area and Dry Fork Canyon between 1900 and the present.

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[4] United States Forest Service. 2010. Monitoring-Tends-in-Burn-Severity (MTBS) database. LANDFIRE program. url: https://www.landfire.gov/version_comparison.php ; Utah State Division of Forestry, Fire, and State Lands. (2016). Forest Action Plan 2016 Five-Year Update. url: https://ffsl.utah.gov/forestry/forest-action-plan/ .

Two those events were cloudburst-fire events – one in 1915 and another in 1945. A hypothetical scenario of a 388 acre fire at Pleasant Valley in City Creek, discussed in Section IV, is also illustrated.

Table 1 - Four Cloudburst Floods Along the Salt Lake City Salient Since 1900. Source: Addenda "A" and "B".

Flood Date	Flood Location	Flood Description	Related Fire Date	Related fire location	Description
Sept. 25, 1916	Dry Fork Canyon to 2nd Ave and 9th East	"Solid ten-foot wall of water rushing water . . ."	Aug. and Nov. 1915	Dry Fork to Upper City Creek; Lower City Creek 4 to 7 sq. miles burned	In Aug. "four miles of east side of Canyon burned." In Nov., fire spread from Dry Fork to upper City Creek.
Sept. 24, 1918	West Capitol Hill to 200 West	Up to 1 foot of mud.	Not applicable (NA)	NA	NA
Aug. 31, 1931	West Ensign Peak	Floods mixed with mud completely buried cars on highway	NA	NA	NA
August 20, 1945	Perry's Hollow to M Street and 200 South	Wall of water and mud carried cars and gravestones to North Temple.	Aug. 1, 1944	388 Acres at the top of Perry's Hollow-City Creek ridgeline.	Craddock refers to "Fully 80 percent of the area, including all but patches of the headwater slopes and portions of the lower benchlands, was burned last fall" (at 58).

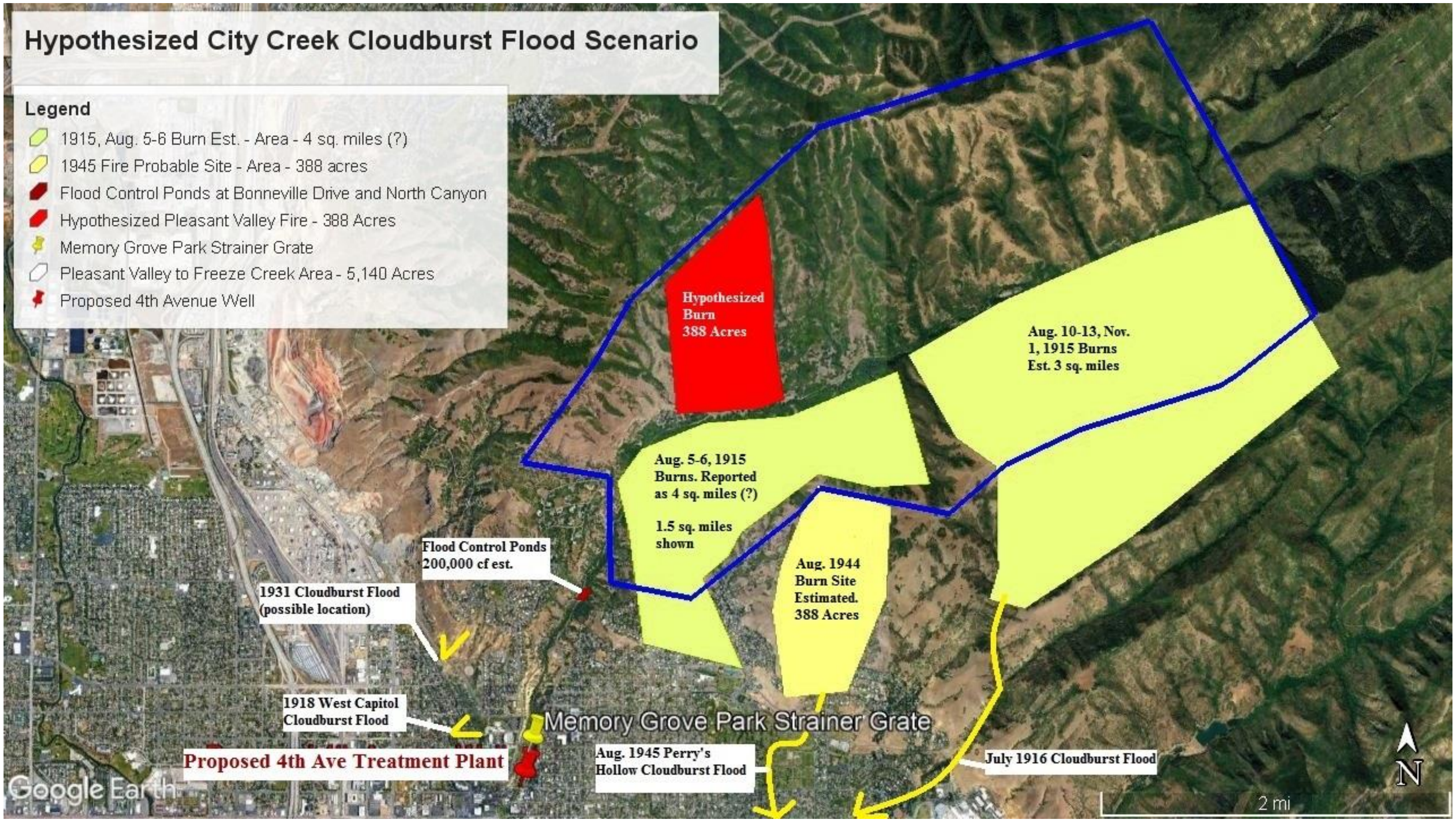

Figure 1 - Two Cloudburst Floods and Two Cloudburst-Fire Floods with Burn Areas (Yellow) with a Hypothesized Burn in City Creek Canyon (Red). Source: Table 1, Addenda "A" and "B".

These events span about 120 years. This implies that cloudburst floods occur in City Creek and on the Salt Lake Salient every 30 years (120 ÷ 4) and that cloudburst-fire floods with high waters and mudflows occur once every 60 years (120 ÷ 2). Cloudburst-fire floods are the result of two rare events: a wildfire followed by a cloudburst rain event during a following season.

II. WHAT HISTORICAL LARGE AND SMALL FIRES HAVE OCCURRED ALONG SALT LAKE FOOTHILL MOUNTAINS?

With respect to the latter fire event, the best estimates for the mean-return-interval for large 1,000+ acre fires on the Salt Lake salient west of Freeze Creek is between 31-35 years for grasslands and 51-60 years for Gamble's oak woodlands (Figure 3). For the montane upper City Creek canyon, the mean-return-interval is about 16-20 years for Aspen community slopes on the north side of Little Black Mountain and 26-30 years for the mountain's north facing Douglas Fir community (*id*).

A. <u>What large acreage fires greater than 1,000 acres have occurred?</u>

Since the 1980s, the USFS has tracked all wildfires in the United States that burned more than 1,000 acres. That fire data is tracked and archived in the agency's "Monitoring Trends in Burn Severity" (MTBS) database.[5] Since 1986, there have been 9 wildfires in the urban Wasatch Front Mountain Range west-facing canyons. That includes the 1988 Affleck Park fire to the south of Lookout Peak that burned approximately 9 square miles. Table 2 and Figure 2 lists and shows the location of those fires. Historical humidity data is shown for four of those fires.

Table 2 – Fire Characteristics and Fire Return Intervals for 9 Wildfires Greater Than 1,000 acres on Wasatch Front West Facing Canyons – Brigham City to Spanish Fork - from 1986 to 2018 shown in Figure 2. USFS MTBS 2019; MesoWest.

Year	Fire	Acres	Date	Return Time (yrs)	Relative Humidity	Temp (F)	Temp and RH from location
2012	Quail	2,041	7/3/2012	9.0	9.6	96.8	SLC AP 2
2003	Farmington	2,070	7/10/2003	1.0	11.7	95.0	Ogden AP
2002	Springville	2,320	6/30/2002	0.9	10.5	98.6	Provo AP
2001	Mollie	7,850	8/18/2001	5.0	11.0	95.0	Mud Springs, Lehi
1996	Vivan Complex	3,084	8/5/1996	1.0			
1995	Perry Canyon	3,123	8/15/1995	0.9			
1994	Trojan 2	3,136	9/10/1994	6.0			
1988	Affleck Park	5,748	9/2/1988	1.1			
1987	Squaw Peak	1,415	8/5/1987	n/a			
	Median	3,084		1.1	10.8	95.9	
	Average	3,421		3.0	10.7	96.4	
	Total Burned	30,787	**Region Total**	422,400	**Burned Percent**	7.3%	**Years** 32

[5] url: https://data.fs.usda.gov/geodata/edw/datasets.php?xmlKeyword=monitoring+trends+in+burn+severity .

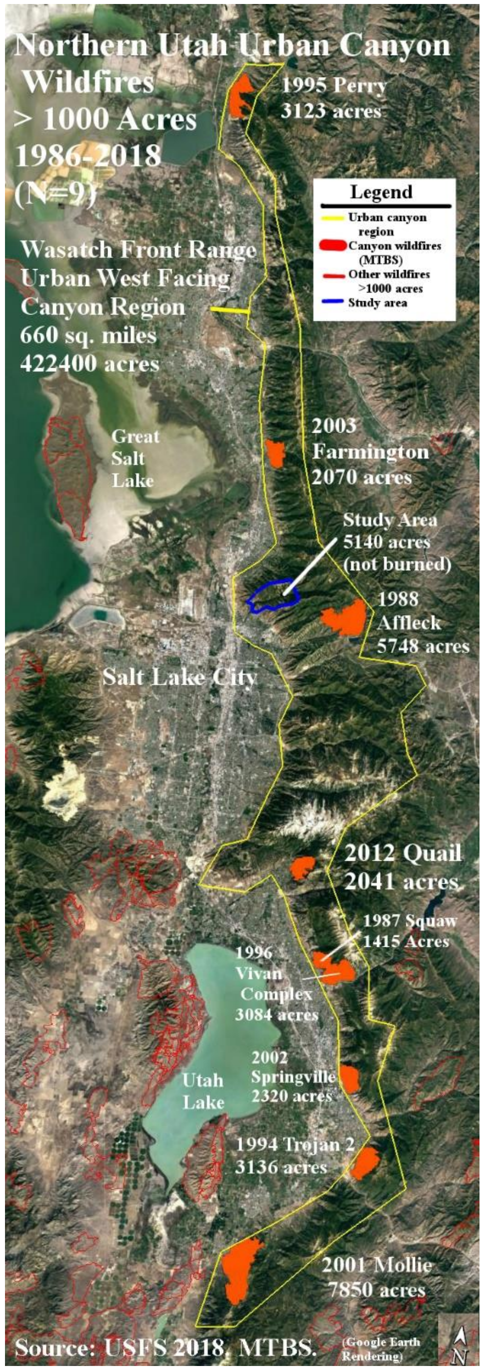

Figure 2 - Northern Utah Wildfires Greater Than 1,000 Acres: 1986 to 2018. Source: USFS 2019. Monitoring Trends in Burn Severity (MTBS) GIS database. Rendering: GoogleEarth.

During the 32 years between 1986 and 2018, 7.3% of the urban west facing canyons of the Wasatch Front Mountain Range burned in fires greater than 1,000 acres (Table 2). That point estimate indicates that the entire area will burn in approximately 32 years.

The west (left) side of Figure 2 shows many more 1,000+ acre fires on the west side of the Great Salt Lake, at Antelope Island, in the Herriman area, and along the Lakeside and NNN mountains. Those fires are outlined in red color without red fill. This is consistent with the biological community of those principally grassland and low-elevation grass-covered mountains. In contrast, there are fewer fires on the eastern high-elevation Wasatch Front canyons. Biology matters.

The USFS and allied agencies perform much more sophisticated analysis of the mean-fire-return-interval in its LANDFIRE program. That program use remote satellite imagery to categorize biological communities in a geographic region. Using its MTSB data, the USFS can then statistically assign wildfire-return intervals for all lands in the United States. Figure 3 is an excerpt from the 2010 national MTSB database for the City Creek and Salt Lake City salient.[6]

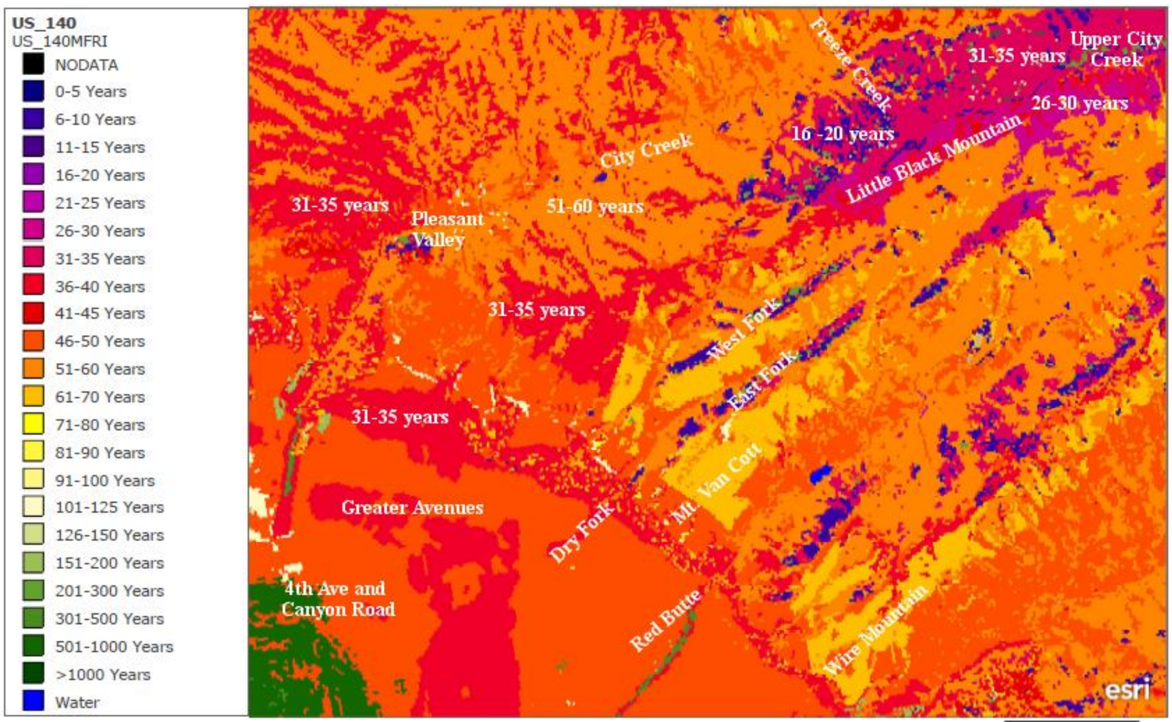

Figure 3 - Mean Fire Return Interval (Years) for City Creek Canyon and the Salt Lake Salient from USDA USFS 2010 LANDFIRE Program, File US_140MFRI.[7] Source: USFS. Rendering: ESRI ArcGIS.

The fire-return-intervals estimates are based on the background occurrence of fires. Departures from larger natural areas can occur from human activity, *e.g.* - an increased incidence from human caused fires and a reduced incidence from better fire-fighting response closer to populated

[6] This 2010 data is the last final MTBS version. Provisional data for 2014 exists that changes Figure 3 estimates. The final approved 2010 data is used here.

[7] url: https://www.landfire.gov/version_comparison.php .

areas.[8] The Utah State Division of Forestry, Fires and State Lands prioritizes fire response strategies based on a nine-point management scale that considers both the propensity for a region to burn and its proximity to large urban populations.[9] The City Creek and Salt Lake County canyons are rated “7” and “8” on the 9-point scale for fire risk and impacts and in the highest three point category for wildfire risk (*id* at 21).

Addendum B at page 29, below, lists historical newspaper accounts for fires reported or estimated at more than 1,000 acres in the Salt Lake City Creek to Emigration area. Fourteen events occurred between 1886 and 1951. After 1951, large fire reports drop off due to a gap in the newspaper review scope during 1980 to 1991 and due to modern improvements in fire-fighting techniques.

B. <u>What medium acreage fires between 1,000 acres and 100 acre have occurred?</u>

I was unable to obtain a catalogue of northern Utah fires less than 1,000 acres but more than 100 acres in a timely manner. The Utah State Division of Forestry and-or the Utah Interagency Fire Center is believed to have such a database that is comparable to the UFSF MTBS database. The absence of a fire catalogue prevents preparing a mean-fire-return-interval study similar to the 2002 Schoenberg, Peng, and Woods study for Los Angeles.

Addendum C, at page 33 below, abstracts 12 historical newspaper reports of such mid-sized Salt Lake City fires between 500 and 100 acres that occurred between Ensign Peak and Dry Fork.

As discussed in Section IV, fires that burn acreages between 250, 400, and 1,000 acres as a matter of mechanics can generate cloudburst-fire floods capable of reaching the 4th Avenue chemical treatment plant. That table includes the July 2008 175 acre fire behind Ensign Peak near the radio towers and the July 2018 100 acre fire that raced up Columbus Avenue below Ensign Downs.

C. <u>How often does the Salt Lake City Fire Department fight small fires along the foothill benches?</u>

In November 2017, I obtained a fire response database from the Salt Lake City Fire Department for the period 2012 through October 2017. The data was in the form of an Excel spreadsheet. By geo-plotting those fires, 39 foothill bench fires shown in Figure 4 were located between Beck Street and Emigration Canyon. This indicates that the Salt Lake City Fire Department responds to about 8-9 foothill bench fires of less than 10 acres per year.

Addendum D, at page 35 below, abstracts 30 historical newspaper reports of small-sized Salt Lake City fires between of less than 100 acres that occurred between Ensign Peak and Dry

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[8] *See* Safford, H. D., Van de Water, K. M. (January 2014). Using Fire Return Interval Departure (FRID) Analysis to Map Spatial and Temporal Changes in Fire Frequency on National Forest Lands in California. U.S.F.S. Pacific Southwest Research Station. Research Paper PSW-RP-266.

[9] Utah State Division of Forestry, 2016 Forest Action Plan, n. 4, above.

Fork. That abstract includes an August 6, 2016 10 acre fire observed by this writer, and the August 30, 2017 seventy-five acre fire on the Bountiful side of the City Creek ridgeline.

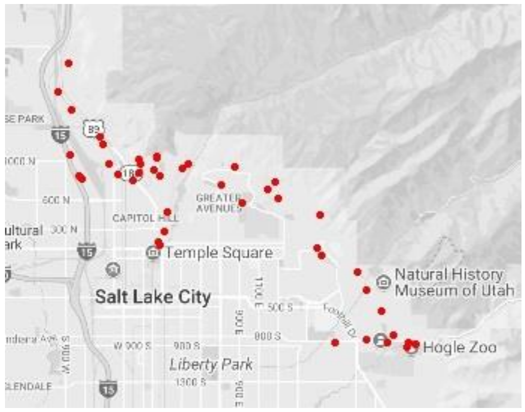

Figure 4 – Location of Thirty-nine Small Foothill Bench Fires less than 1-acre in size fought by the Salt Lake City Fire Department 2012-2017. Source: SLC Fire Dept. GRAMA Production to K. Fisher, Nov. 2017.

The 2017 Bountiful "Summerwood" fire prompted Mayor Biskupski to close entry to City Creek Canyon.

D. <u>Can wildfire-fighting technology abate Salt Lake City wildfires greater than 1,000 acres?</u>

Table 2 at page 6 above is instructive as to what causes wildfires and large wildfires in particular. Average daily summer humidity in Salt Lake City is 22% during the daytime. As seen in the table, large fires occur when summer daytime humidity drops to below 11%. This is the lesson of California's July 2018 Carr Fire near Redding, the Paradise, California November 2018 Fire, and the San Fernando Valley November 2017Fire that destroyed hundreds of homes. In the Carr Fire, humidity dropped to 10% over several hot summer afternoons. When humidity dropped to 9%, the forest ignited in fire that could not be controlled by modern fire-fighting techniques.

Although the City Fire Department and the Utah Interagency Fire Center have done an amazing and admirable job of controlling fires at Salt Lake City's urban interface, at some point, the large variations in northern Utah's weather will cause humidity to drop. Then a large, difficult to control fire, like Salt Lake's 1988 Affleck Park fire, can occur in City Creek. Fire-fighting technology cannot completely control nature; it should not be assumed that the fire return times shown in Figure 3, above, can be completely abated.

The next part of the joint probability that can create cloudburst-fire events is extreme rainfall.

III. WHAT IS THE RATE OF CLOUDBURST RAINSTORMS AROUND SALT LAKE CITY?

A. What is the severe rainstorm rate on the valley floor?

A recent local example of a cloudburst flood was the July 2017 event in which 2.5 inches of rain fell within one hour was Salt Lake City's eastside neighborhood and that resulted in the City's Mayor declaring an emergency.[10]

Figure 5 – Mayor Biskupski and DPU Director Briefer at July 28, 2017 declaration of cloudburst flood emergency. YouTube.com. (url: https://www.youtube.com/watch?v=aE86VK43tII

The Mayor characterized the cloudburst flood as "unprecedented". It was. But cloudburst floods are also a well-known environmental hazard in northern Utah. The Salt Lake County Flood Control Office has prepared duration-based 100 year rainfall prediction maps.[11] For the east bench neighborhoods, the 30 minute duration map predicts a 100 year rainfall level of 1.20 inches and the one-hour duration predicted rainfall is about 1.5 inches. The Watershed Planning and Restoration Office extreme rain chart provides a point-estimate for a one-hundredth year 1-hour rainfall event of between 1.5 and 1.65 inches for a City Creek Canyon cloudburst:

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[10] Biskupski , J. Mayor. July 28, 2017. Press Conference: Mayor Biskupski Declares Local Emergency in SLC. Video. YouTube.com. (url: https://www.youtube.com/watch?v=aE86VK43tII , DPU Director Laura Briefer appears to the Mayor's left); Fox News (Channel 13, SLC). July 28th, 2017. Mayor Biskupski declares local emergency after SLC flooding. Fox News. (url: https://fox13now.com/2017/07/28/mayor-biskupski-declares-local-emergency-after-slc-flooding/).

[11] TRC North American Weather Consultants Meteorological Solutions, Inc. and Flood Control Engineering, Salt Lake County. (August 1999). 100 Year Return Frequency Maps – 15 Minute to 24 Hour Duration. (url: https://www.slco.org/flood-control/rainfall-maps/). *See* Excerpt, Figure 6, *infra*, at page 9.

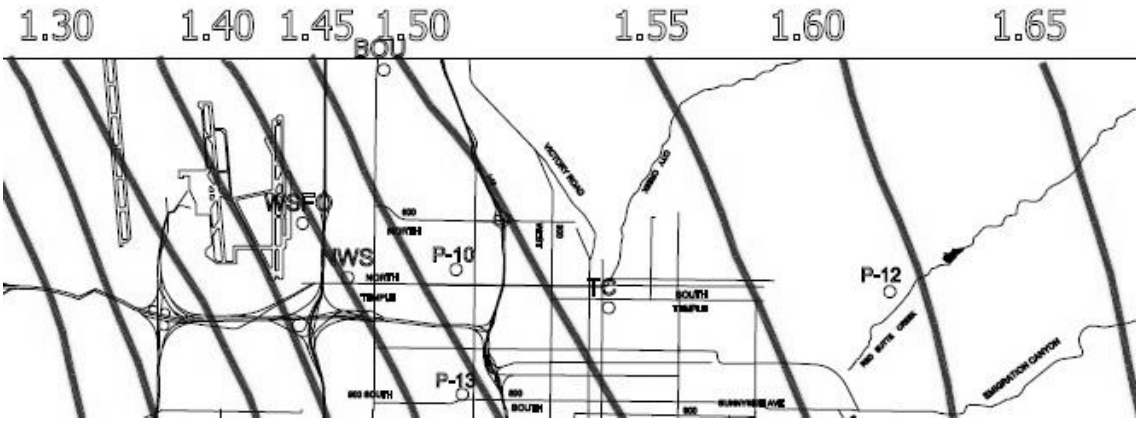

Figure 6 - Excerpt from Salt Lake County Rainfall Map –Inches of Rain, Duration 1 Hour, 100-Year Event (August 1999). n. 11.

Empirical cloudburst flood events shown in Figure 1 and Addenda A suggest this 100-year frequency estimate may be too low. During the 100 years between 1916 and 2016, there were three possible events of that magnitude in the 1.50-1.55 band – the 1918 West Capitol and the 1931 Beck Street cloudburst floods. In the 1.55-1.65 band, there were also three possible events between 1916 and 2016 – the 1916 Dry Fork flood, the 1945 Perry's Hollow flood, and the July 28, 2017 City eastside flood.

While the spatial location of cloudburst floods in each band are random, Figure 6 shows that there is a progression of intensity from the valley floor to the Wasatch Front Mountains. Mountains make weather. Other metrological data from the National Oceanographic and Atmospheric Administration (NOAA) indicates that the return times for severe storms in the mountains are higher than those of the valley floor.

B. <u>Is the cloudburst rainfall event rate higher in City Creek Canyon?</u>

It is often said that "mountains make weather." Higher elevations force clouds to rise and as a result, they release rain. It is reasonable to expect more cloudburst events at higher elevations such as the mid-City Creek Canyon's Pleasant Valley or in the upper canyon between Grandeur Peak and Lookout Peak. To test this commonplace, I obtained data for April 2003 to the present from SNOTEL automated weather recording stations at Louis Meadows and Lookout Peak in City Creek Canyon which have been operated by the United States NRCS.[12] Automated readings are taken every hour, the including temperature and one-hour duration accumulated rain and snowfall.

The elevation of the valley floor at 300 West and North Temple which appears in the Salt Lake County 100-year rainfall contour line of 1.5 inches is 4,280 feet. The Louis Meadows SNOTEL station is at an elevation of 6,700 feet; the Lookout Peak SNOTEL station is at an

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[12] NRCS. 2019. Lewis Meadows (SNOTEL Station 972) Site Information and Reports. url: https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=972&state=ut; NRCS. 2019. Lookout Peak (Station 596) Site Information and Reports. url: https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=596&state=ut ; NRCS. 2019. NRCS Report Generator 2.0. url: https://wcc.sc.egov.usda.gov/reportGenerator/ .

elevation of 8,161 feet. Are there more 1.5 inch rainfall events than once every hundred-years at the higher stations?

The 288,413 raw hourly observations for these stations for the period April 1, 2003 to July 4 2019 were cleaned for instrumentation errors and station downtime.[13] The stations recorded accumulated rainfall and snow since the instrument last reset in minimum increments of 0.1 inches. Hourly incremental values had to be derived by taking the difference of the current and preceding observation. Temperature was also reported hourly. For the Louis Meadows station, 6.5% of raw observations were excluded as instrumentation errors, and, for the Lookout Peak station, 13.5% of raw observations were coded as instrumentation errors.[14] Next, data was recoded to change snow, snow-sleet, sleet, and evaporative events as "not a rainfall" event. After cleaning and recoding, 15.4 years of valid hourly observations for the Louis Meadows station and 14.24 years of valid hourly observation data for the Lookout Peak station remained in 259,584 hourly observations as summarized in Table 3.

Table 3 - Characteristics of Data Cleaning and Recoding

	Louis Meadows		**Lookout Peak**		**Both**	
	Count	**Percent**	**Count**	**Percent**	**Totals**	**Percent**
Total Observations	144,237	100.0%	144,176	100.0%	288,413	100.0%
Instrument & Other Errors	9,372	6.5%	19,457	13.5%	28,829	10.0%
Subtotal Cleaned and Recoded Observations	134,865	93.5%	124,719	86.5%	259,584	90.0%
Zero rainfall events	120,909	89.7%	113,063	90.7%	233,972	90.1%
Rainfall events => 0.1	13,956	10.3%	11,656	9.3%	25,612	9.9%
Checksum	134,865	100.0%	124,719	100.0%	259,584	100.0%

For those cleaned and recoded observations and the Louis Meadows station, 13,596 observations involved hourly rainfall precipitation in the range of 0.1 inches to 1.2 inches. For cleaned and recoded observations and the Lookout Peak station, 11,656 observations involved hourly rainfall precipitation in the range of 0.1 inches to 3.0 inches. With respect to the low percentage of total rainfall events (N=25,612, 9.9%) with precipitation greater than or equal to 0.1, recall that most of the annual precipitation at these mountain sites is in the form of snow. Snow-only events were recoded as "not rainfall" events with a rainfall precipitation equal to zero. Rainfall events involve summer season hourly changes of 0.1 inches and only rarely does more than that amount of rain fall in an hour. In contrast, winter snow can fall in feet over a few hours.

For Louis Meadows, Station 972, the observed frequencies of precipitation over 15.4 years are tabulated in Table 4 in Columns B and C. A fitted power law distribution model (R^2=0.99) appears in Column D. The expected 100-year counts are shown in Column E based on

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[13] SNOTEL Station Analysis Report by K. Fisher, in process.

[14] Typically, both stations' recording devices marked a quality assurance error for either an automatically recorded precipitation or snowfall reading. Each such error event invalidated the current reading and the next subsequent reading that established a new accumulation baseline. At the beginning of each month, both stations reset their sensors, again generating a discontinuity in the incremental hourly reading.

the observational frequencies in Column B. The sum of power law distributed random variables is the sum of the variables with the same power α parameter and a scaled C_0 parameter ($y= C_0x^{-\alpha}$).[15] This means that the 100-year expected observations are the same as the original observations during a shorter interval scaled by 100 years divided by the initial observation duration, *e.g.* – 100 ÷ 15.39 = 6.5). For example, the observed 1.2 inch single event in Column B translates into 6 expected events over 100 years in Column E. The expected and predicted 100-year counts are shown in Figure 7 for a 100-year model (Columns E to F in Table 4).

Table 4 – Louis Meadows SNOTEL Station – Frequency of Observed Hourly Rainfall Events and 100-Year Hourly Predicted Counts (N=134,865 observed Hours)

A	B	C	D	E	F
	Over 15.39 observed years			Over 100 predicted years	
Precipitation (in)	**Count (observed)**	**Percent**	**Count (predicted)**	**Count 100-years (expected)**	**Count 100-years (predicted)**
0.0	120,909	89.652%	120,952	785,350	785,633
0.1	12,793	9.486%	11,690	83,095	75,931
0.2	913	0.677%	2,980	5,930	19,355
0.3	155	0.115%	1,130	1,007	7,339
0.4	57	0.042%	532	370	3,459
0.5	19	0.014%	288	123	1,871
0.6	8	0.006%	171	52	1,113
0.7	3	0.002%	109	19	709
0.8	4	0.003%	73	26	477
0.9	2	0.001%	51	13	334
1.1	1	0.001%	28	6	181
1.2	1	0.001%	21	6	138
1.3			*17*		*108*
1.5			*11*		*69*

[15] This was verified by simulation in the instant matter.

Source: Author and NRCS SNOTEL Reporter 2.0. Notes: Italicized values are extrapolated beyond the range of the observations. Station 972; elevation - 6,700 ft.

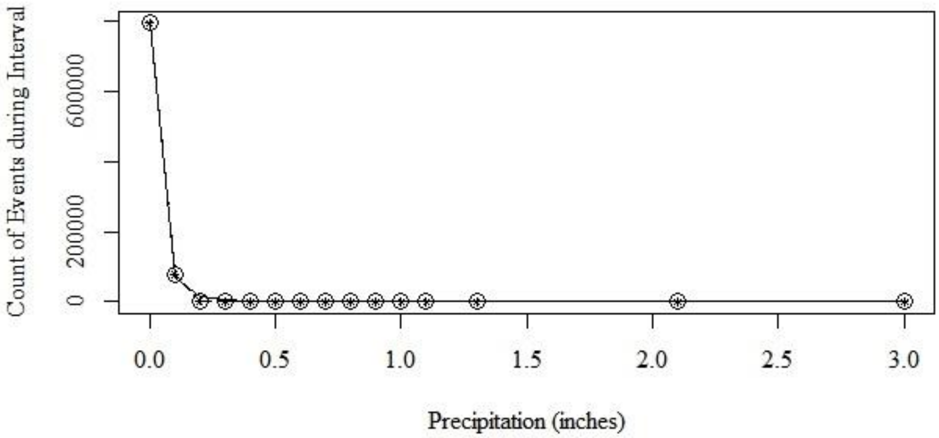

Figure 7 - Louis Meadows SNOTEL Station – Power Law Model of Predicated 100-Year Hourly Rainfall Events. * - Observed; Circles - Predicted. Source: Columns D and E, Table 4.

For Lookout Peak, Station 596, the observed frequencies of precipitation over 14.2 years are tabulated in Columns B and C of Table 5. The observed 1.3 inch single event in Column B translates into 7 expected events over 100 years in Column E (100 ÷14.24 = 7.0). A predicted power law distribution model (R^2=0.99) over 100-years appears in Columns E and F. The 100-year power law model is shown in Figure 8.

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Table 5 – Lookout Peak SNOTEL Station – Frequency of Observed Hourly Rainfall Events and 100-Year Hourly Predicted Counts (N= 124,719 Observed hours)

A	B	C	D	E	F
	Over 14.24 observed years			Over 100 predicted years	
Precipitation (in)	**Count (observed)**	**Percent**	**Count (predicted)**	**Count 100-years (expected)**	**Count 100-years (predicted)**
0.0	113,063	90.654%	113,099	794,131	794,385
0.1	11,130	8.924%	10,120	78,175	71,080
0.2	379	0.304%	2,466	2,662	17,320
0.3	76	0.061%	906	534	6,360
0.4	38	0.030%	416	267	2,924
0.5	18	0.014%	221	126	1,550
0.6	5	0.004%	129	35	906
0.7	1	0.001%	81	7	569
0.8	1	0.001%	54	7	378
0.9	2	0.002%	37	14	262
1.1	1	0.001%	27	7	188
1.2	2	0.002%	20	14	139
1.3	1	0.001%	12	7	81
1.5		0.000%	*7*	*7(?)*	*51*
2.1	1	0.001%	2	7	17
3.0	1	0.001%	1	7	5

Source: Author and NRCS SNOTEL Reporter 2.0. Notes: Italicized values are predicted within the range of the observations. Station 596; elevation – 8,161 ft.

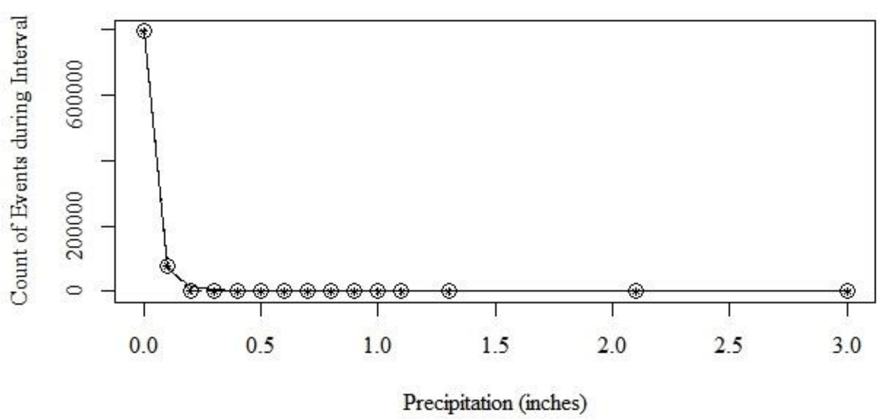

Figure 8 – Lookout Peak SNOTEL Station – Power Law Model of Predicated 100-Year Rainfall Events. * - Observed; Circles - Predicted. Source: Columns D and E, Table 5.

The overall result of this gathering of SNOTEL data and analysis is:

Table 6 - Expected Count of 1.5 inches Rainfall Events every 100 Years by Altitude

Station	Elevation (feet)	Expected Number of 1.5 inch rainfall events per 100-years
Louis Meadows	6,100	6
Lookout Peak	8,161	7

This power-law methodology is not a generally accepted method used by hydrologists for predicting the extreme rainfall frequency. The generally accepted method is to analyze rainfall using the Gumbel distribution method for extreme value events.[16] That method of analysis also indicates that for heavy and extreme rainfalls between 1.0 and 1.5 inches, that are shown in Section IV to be capable of producing cloudburst-fire floods, such events occur on the order of 20 times per 100 years.

The Gumbel distribution method involves determining the maximum rainfall event each year for a number of years. That data is used to estimate the parameters for the Gumbel cumulative distribution that predicts the likely interval of time in which a specified amount of rainfall will be exceeded. Table 7 summarizes the Gumbel distribution computation for the Louis Meadows and Lookout Peak SNOTEL stations.

Table 7 - Max. Exceedance Rainfall (inches) by 4 to 100 Year Intervals and Excepted 100 Year Events Counts for SNOTEL Stations at Louis Meadows and Lookout Peak

		Maximum exceedance rainfall inches (X*)		
Elevation (feet)		6,100	8,161	
Return time years	Expected Count per 100 years	Louis Meadows	Lookout Peak	300 W. N. Temple
4	25	0.9	1.6	
5	20	1.0	1.7	
7.5	13	1.0	1.9	
10	10	1.1	2.1	
25	4	1.3	2.6	
50	2	1.4	3.0	
75	1	1.5	3.3	
100	1	1.5	3.4	1.5

Source: Author and NRCS SNOTEL Reporter 2.0.

Table 6 indicates that as altitude increases, the number of extreme rainfall events increases. Table 7 indicates the frequency (the Expected Count column) of events that are capable of generating cloudburst-fire floods for larger burned acreages can occur quite frequently – as many as 20 to 25 years out of 100 years.

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[16] Hornberger, G.M., Wiberg, P.L., Raffensperger, J.P. and D'Odorico, P. (2012 2nd). *Elements of Physical Hydrology*. Baltimore, M.D.: Johns Hopkins University Press at 36.

If an unfortunate congruence of a wildfire in a burned area of City Creek Canyon and a cloudburst rainfall event occurred, would the surface runoff be sufficient to generate a flood that could reach the proposed 4th Avenue chemical treatment plant?

IV. WHAT ARE THE PARAMETERS OF CLOUDBURST-FIRE FLOODS THAT COULD BE REASONABLY EXPECTED TO DAMAGE THE 4TH AVENUE CHEMICAL TREATMENT PLANT?

A simple model that explores the cloudburst flood event space shows that mechanically, a large cloudburst flood in City Creek could reach 4th Avenue and North Canyon Road. One lay technique for assessing whether cloudburst flooding risk is speculative is simulation. First order simulation is the art of making a first rough approximation for which no better information is currently available or might become available in the future.[17] Such rough simulations are a more rationale decision-making method than relying on simple intuition or by ignoring a material factor.

One approach to evaluating whether physically a cloudburst flood in City Creek Canyon could reach 4th Avenue is to pose the question: "What if a 1945 Perry's Hollow cloudburst flood[18] on the south face of the ridgeline separating the City and City Creek Canyon occurred on near Pleasant Valley below the south facing ridge between City Creek Canyon and Bountiful?" This question defines the perimeters of what flood scenarios might have adverse impacts on the 4th Avenue chemical treatment plant, *assuming that, after a wildfire, a cloudburst flood occurs.*

In the Perry's Hollow 1945 event, 388 acres burned in a 1944 grass fire. This resulted in the soil losing its porosity and ability to hold rain water. After a burn, soil porosity can change from 100% retention or decline to about 10% retention. In the fall of 1945, a cloudburst storm deposited between 1.25 and 1.75 inches (or an average of 1.5 inches) in one hour with possible intermittent bursts of between 5 and 8 inches of rain per hour.[19] The resulting cloudburst flood sent a 2,400 c.f.s. wall of water and mud down Perry's Hollow, breached the city cemetery wall, and then carried gravestones and 500 lb. boulders down M and N Streets to South Temple. In response to this flood during the 1980s, the City constructed a combined-road flood control structure on Chandler Drive.[20]

What would happen if a 1.5 inch per hour cloudburst storm of 1 hour duration occurred over a 388 burned acres on the north slope above Pleasant Valley in City Creek Canyon? This hypothesized scenario is illustrated in Figure 1 at page 5, above.[21]

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[17] Weinstein, L. and Adam, J. A. (2009). Guesstimation: Solving the World's Problems on the Back of a Cocktail Napkin. Princeton University Press; Harte, J. (1988, 1st Ed). Consider a Spherical Cow: A course in environmental problem solving. Univ. Science Books.

[18] Craddock (1946). Salt Lake Telegram, August 20 and 27, 1945 (Available through https://go.newspapers.com/; copy in author's possession).

[19] n. 18, above.

[20] Map location – url: https://goo.gl/maps/m4QNHVuoqUxNsJjE7 .

[21] *See* Addenda "A" and "B" for supporting references to historical cloudburst floods shown in Figure 2.

The resulting volume of cloudburst flood water would be about 2,112,660 cubic feet.[22] If soil porosity is 100%, the ground would absorb all the water. But if as occurred in Perry's Hollow, soil porosity is 10%, then 90% of the rainfall, or 1,901,394 cubic feet would then proceed to flow downhill and out the City Creek stream bed (2,112,660 times 0.90). This complementary 90% is the "solidity" of the soil.**[23]** The 2,112,660 cubic feet of rain water is falling through an imaginary horizontal plane above a slope. The slope beneath that horizontal plane has more area and would absorb more water proportional to its area. The typical slope on the north half of City Creek Canyon is 20%. Thus, 1,901,394 cubic feet of water is adjusted downwards to 1,786,726 cubic feet.**[24]**

By comparison, an Olympic-sized swimming pool contains about 88,000 cubic feet of water. The outdoor 50 meter pool at the Steiner Aquatic Center is an Olympic pool.[25]

The slope above the north face of Pleasant Valley is similar to the Perry's Hollow headwaters. Initially, the flow of the hypothesized cloudburst flood would be similar – about 2,400 cubic feet per second. The flow would slow as it approached the more flat terrain at North Canyon Road and Bonneville Drive.

At North Canyon Road and Bonneville Drive, there are two small flood control basins constructed in response to the 1983 floods – each about 15 feet deep with a triangular shape of about 100 feet by 200 feet – at the intersection of Bonneville Drive and North Canyon Road.[26] Based on the oblique pyramid formula, I roughly estimate volume of these basins at 100,000 cubic feet each.[27] These basin are principally designed as strainers and not to retain flood waters.[28]

When the hypothesized floodwaters of a 1.5 inch per hour cloudburst storm that sends 1,786,726 cubic feet of water down canyon reaches these structures, their 200,000 cubic feet capacity would be quickly overwhelmed, leaving 1.6M cubic feet of water to travel down canyon. Even if one-half of 1,786,726 cubic feet of water was absorbed prior to reaching these

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[22] 388 acres * 43560 sq-ft per acre * 1.5 inches * 1 foot per 12 inches per hour = 2,112,660 cubic feet.

[23] "Solidity" is the complement of "Porosity". Porosity refers to the percentage of water that is retained by the ground,.*e.g.* a surface with 40% porosity retains 40% of water that falls on it in a given duration. This implies that the surface has 100%-40%=60% solidity.

[24] "Adjusted Volume CF" means the net volume of water is reduced proportional to the degrees of slope. 20% is the working slope angle of the south-facing, northern half of City Creek drainage. 2,111,660*cosine(slope in radians)=2,111,660-0.94=1,985,251 cubic feet.

[25] Map location: url: https://goo.gl/maps/YbFQBsVM8rea7WSG9 .

[26] Map location: url https://goo.gl/maps/ez7uk97yt98Jpz6U8 .

[27] V= 1/3Bh = 1/3*200*15 *100.

[28] Over the last two spring seasons (2018 and 2019), I have observed that even with moderate snowpack run-off, the north basin fills to about three feet below overtopping.

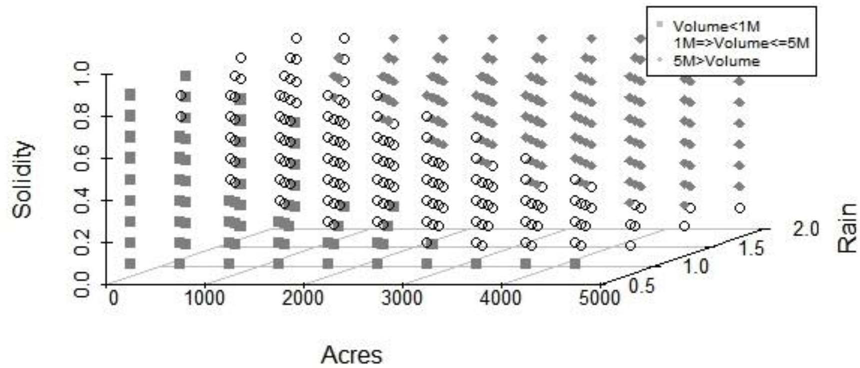

Figure 9 – Cloudburst Event Subspaces. 1M-5M flood water volumes (open circles), low-volume floods unlikely to cause damage (grey squares), and >5M floods with less-likely high burned acreages (grey diamonds). Source: Table 8.

ponds, about 700,000 cubic feet of water would still travel downstream to the next flood control feature – a strainer grate at the south end of the dog wading pond at Memory Grove.[29]

This grate accesses the 1908 City Creek entombment conduit that post-1983 still has an approximate capacity of 100 cubic feet per second. This structure would also be easily overwhelmed by the remaining 1.7M cubic feet of flood water.

Figure 1 (at page 5, above) illustrates only one of many permutations of possible combined wildfires followed by a cloudburst scenario that might occur in the lower Pleasant Valley-to-Freeze Creek City area of the City Creek drainage. A full permutation of all possible scenarios might involve a) 0.5 to 2.0 inches of rain fall in one-half inch increments; b) soil porosity between 10% and 90% in 10% increments; and burned acres from 250 to 4,750 acres in increments of 500 acres each. In those intervals, there are 360 permutated scenarios that are summarized in Table 8 and visualized in Figure 9.

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[29] Map location: https://goo.gl/maps/sLptGo6ezYGptBEq6 .

Table 8 – Characteristics of Possible Cloudburst Flood Scenarios Ordered by Floodwater Volumes - Selected by Minimum Acres or Less than Maximum Solidity† (N=17 of 360)

Volume CF	Slope	Adjusted Volume CF[30]	Olympic Pools	Acres[31]	Rain Inch	Solidity[32]
317,625	20	298,470	3	250	0.5	0.7
544,500	20	511,663	6	250	1.0	0.6
1,089,000†	20	1,023,325	12	250	2.0	0.6
1,089,000†	20	1,023,325	12	750	0.5	0.8
1,089,000†	20	1,023,325	12	750	1.0	0.4
1,089,000	20	1,023,325	12	250	1.5	0.8
1,633,500	20	1,534,988	17	250	2.0	0.9
1,815,000	20	1,705,542	19	1250	0.5	0.8
2,722,500	20	2,558,313	29	750	2.0	0.5
3,675,375	20	3,453,723	39	750	1.5	0.9
4,900,500	20	4,604,964	52	750	2.0	0.9
6,897,000	20	6,481,060	74	4750	0.5	0.8
9,438,000	20	8,868,819	101	3250	1.0	0.8
13,884,750	20	13,047,397	148	4250	1.0	0.9
18,104,625	20	17,012,783	193	4750	1.5	0.7
31,036,500	20	29,164,770	331	4750	2.0	0.9

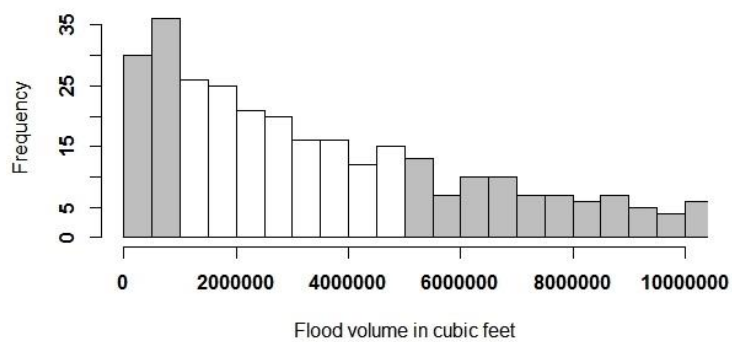

Figure 10 - Frequency of Possible Cloudburst Flood Scenarios (N=360, truncated at 10M cubic feet, max 31.2M cf.; each bar represents 500,000 c.f.; grey bars correspond to shading in Error! Reference source not found.**.)**

Table 8 describes 17 representative scenarios out of the possible 360. Several scenarios can result in the same flood water flow. Where ties existed, the minimum acre entry was chosen

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[30] n.23, above.

[31] "Acres" means the area of an imaginary horizontal surface above a slope. Because rain falls through this imaginary plane on to a sloped surface, the volume of absorbed water is increased, and the net volume of water traveling downhill is reduced, *e.g.* – the "Adjusted Volume CF".

[32] n.24, above.

for inclusion in the table and are marked with †. This procedure resulted in also biasing the representative scenarios with those that had the highest soil solidity. Further acreage ties where the top two entries had the same acreage were resolved by using the entry that had less than the maximum solidity, and those entries are (also marked with †. A potential flow of 1M or 1.5M cubic feet of flood water is abstract to most readers. To provide a more human-based measurand, the "Olympic Pool" column was added, and it expresses the equivalent volume of water stored in a number of Olympic regulation-sized swimming pools.

The event-space visualization in Figure 9 is graphically misleading in that it assumes that the density on each scale is uniform. As noted above, this is not the case. Higher acreage wildfires are less likely than small fires, probably by a Pareto distribution.[33] Higher acreage-high rainfall events are less likely than small acreage-moderate rainfall events. How then can the risk of a Perry's Hollow type cloudburst-fire flood be characterized?

V. THE BASE RATE FALLACY CAN LEAD TO UNDERESTIMATING THE PROBABILITY OF WILDFIRES FOLLOWED BY CLOUDBURST-FIRE FLOODS.

Based on the foregoing analyses of wildfire and severe rainfall events, a commonplace assessment of the joint probability of a wildfire event and a cloudburst flood event would be to multiply the two probabilities. For example, if the risk of a wildfire greater than 1,000 acres is 4 in 100 years (0.01 or 4%, *see* Table 2) and the risk of a cloudburst flood of 1.5 inches is 1.5 inches (Figure 6), then their joint probability is 0.04 times 0.01, or 0.0004, or 4 in 10,000 years or once every 2,500 years. *This reasoning only applies to events that are independent.*

Where two events are *not* independent, applying this reasoning is called the *base rate fallacy*. The base rate fallacy is the failure to consider that the probability of the occurrence of events may be conditioned on the characteristics of some narrower subgroup. The base rate applied to a larger group is erroneously generalized to the subgroup. Rules of probability can clarify such cases by applying Bayes' rules for conditional probability.

In the instant matter, the empirical probability of joint cloudburst fires is about 2 every 100 years (Figure 1 at 5). The empirical rate of extreme rainfall events is about 6 every 100 years (Table 4 at 14).

The rate of wildfires in and near is City Creek greater than 388 acres is unknown, but from the USFS, the probability of wildfires greater than 1,000 acres is about 3 every one-hundred years (1 ÷ mean fire return time of 33 years, Table 2 at 6, Figure 3). During the 20th century, City Creek fires - where newspaper accounts confirm fires with published estimates greater than 1,000 acres - number 8 or about once every 12 years. (1900, 1902, 1905, 1915 Aug (twice), 1916, 1932 in Addendum B). A ninth large acre fire occurred in 1898. The lower USFS frequency of about 3 wildfires per 100 years is used here.

Using rules of probability and knowing that the two rates are dependent, the probability of a wildfire over 388 acres in or near City Creek Canyon can be estimated. First, tests for independence can be applied to verify that the rates of fire and flood are dependent. Two random variables are *independent* if,

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[33] n. 3, above at page 2.

$$P(fire) \times P(flood) = P(fire \cap flood).$$
$$\frac{3}{100} \times \frac{6}{100} = \frac{1.8}{1000} \neq \frac{2}{100}.$$

Another probability rule that tests for independence is,

$$P(fire|flood) = P(flood).$$
$$\frac{2}{100} \neq \frac{4}{100},$$

per Figure 1, where "|" means "given that". These two tests confirm our hypothesis that the two events – wildfires and floods are dependent either on each other or on some other unknown factor.

Another relevant probability rule involves the intersection of two events. The intersection rule states that the intersection or joint probability of two events must be less than the sum of probabilities of each event separately:[34]

$$P(flood\ and\ fire) \leq P(flood) + P(fire).$$

This probability rule can be used to estimate the upper bound of the joint probability of fires greater than 388 acres occurring in or near City Creek Canyon (Figure 1 at 5 and Table 4 at 14),

$$\frac{2}{100} \leq \frac{6}{100} + P(fire \geq 388\ acres).$$
$$P(fire \geq 388\ acres) \geq \frac{4}{100}.$$

From this, the probability of a wildfire over 388 acres in or near City Creek Canyon should be at most approximately 4 wildfires per 100 years. Figure 1 at 5 page, above, shows the location of the four fires greater than 388 acres that occurred in or near City Creek during the 100 years of the 20th century: the August 5-6, 1915 fire, the August 10-11, 1915 fire, the November 1915 fire, and the August 1944 Perry's Hollow fire (*see* Addenda A and B).

The simple form of Bayes Rule regarding conditional probability can also be used to estimate the conditional probability of a flood happening after a fire greater than 388 acres occurs in or near City Creek Canyon,

$$P(flood|fire) = \frac{P(flood \cap fire)}{P(fire)}$$

$$\frac{1}{2} = \frac{\frac{2}{100}\ (fires\ and\ floods)\ per\ 100\ years}{\frac{4}{100}\ fires\ per\ 100\ years} = \frac{1}{2}(floods \mid fires) = 50\%\ per\ 100\ years.$$

This conditional probability means that if a wildfire burns more than 388 acres in or near City Creek Canyon over 100 years, there is a 50% chance that cloudburst flood will follow. The 100 year rate of 4 fires times the conditional probability of 50% equals a 2% probability over the next 100 years for another cloudburst-fire flood event.

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[34] This is sometimes also called the "conjunction fallacy" or "the Linda problem". It is a form of the triangle inequality in probability metric spaces.

It is sometimes useful to visualize these two-category conditional probability problems as a two-way table in order to better understand the impact of a large number of non-event (no rainfall) on the probability of rare events (fire and flood). Once a fire occurs, the "F" column becomes applicable and the probability of a fire and flood becomes one-half of that column:

Table 9 - Two-Way Probability Table for Fire and Floods

		Fire		
		F	$\overline{\text{F}}$	$R \cup R$
Rain-Flood	R	$\frac{2}{100}$	$\frac{4}{100}$	$\frac{6}{100}$
	$\overline{\text{R}}$	$\frac{2}{100}$	$\frac{92}{100}$	$\frac{94}{100}$
	$F \cup F$	$\frac{4}{100}$	$\frac{96}{100}$	$\frac{100}{100}$

If the higher worst case frequency of fires greater than 1,000 acres – 8 fires in 100 years – is used instead, the conditional probability estimate is,

$$\frac{\frac{2}{100}\ (fires\ and\ floods)\ per\ 100\ years}{\frac{8}{100}\ fires\ per\ 100\ years} = \frac{1}{4}(floods \mid fires) = 25\%\ per\ 100\ years.$$

The expected risk *is not* 0.04 times 0.02, or 8 in ten-thousand, or once in 1,250 years.

Using the higher 100 year rate of 8 fires times the conditional probability of 25% also equals a 2% probability for another cloudburst-fire flood event in the next 100 years.

These estimates are more than the traditional civil engineering risk criteria of 1% per 100 years. This is how the risk of a cloudburst flood-fire might be assessed when evaluating the proposed chemical treatment plant at 4th Avenue and North Canyon Road.

VI. HOW CAN THE COMMISSION INCORPORATE THIS INFORMATION IN ITS DECISION-MAKING PROCESS?

Ideally, such an analysis would be done by a hydrologist or requested by one of the many registered professional engineers ("P.E.s") involved in this matter. There is no evidence in the Commission's record regarding flood risk provided by the proponent DPU. The March 2019 staff analysis does not mentioning flooding. Your commentator has provided several letters documenting the risk of high-snow melt flooding, and in this letter and estimate of the risk of cloudburst-fire flooding is provided.

Given that there is no DPU or other expert opinion in the record, the Commission should, based on the preponderance of evidence, conclude that there is a reasonable potential for a cloudburst-fire flood to damage the proposed Well chemical treatment plant. Absent experts, the Commission is left to its own lay devices to decide if the risk is serious and poses a threat to the proposed design. To resolve such factual questions with finality, lay administrative law judges, such as the Commission's members, are retained as quasi-judicial decision makers.

Given the absence of any responsible estimates of flood and fire risk by the DPU, the Commission is within its administrative powers to adopt the cloudburst-fire and snow-melt risks as outlined by your commentator. If these 100 year risk estimates are adopted by the

Commission, the Commission can reasonably conclude that the DPU's failure to submit a safe design as required by Utah Administrative Code R309-540-5, Facility Design and Operation: Pump Stations - Pumping Facilities (effective April 1, 2019)[35] - by including either flood protection walls, by elevating the entire structure at least 3 feet above the last known historic flood levels, or by moving the proposed treatment plant out of the geologic streambed of City Creek - is fatal to the DPU's proposal.

Please feel free to contact me with any questions that you may have by the means listed above.

Very Truly Yours

Kurt A. Fisher

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[35] url: https://rules.utah.gov/publicat/code/r309/r309-540.htm.

Addendum A

Key Historical Salt Lake City Creek Floods and Northern Utah Cloudburst Flooding Documents, Research and Academic Articles[36]

Excerpts from SLC DPU GRAMA production to K. Fisher, June 13, 2019 (url: http://fisherka.csolutionshosting.net/misc/FourthAveWell/20190617ExcerptsfromDPUProductionre4thAveWell.pdf).

> As a result of the 1983 state-wide floods, the DPU's predecessor spent about $1,000,000 repairing flood damage to roads from North Temple and State Street north to Memory Grove. The City replaced 1,040 feet of 6" inch pipeline excavated and damaged by flood waters between 4th Avenue and Memory Grove, 18 subsurface sewer and water connections in the area were destroyed, and the foundations of the old Brick Tank house north of Memory Grove were undermined.

Nicoli, K. and Lundeen, Z. J., University of Utah. (2016). A case study: geomorphic effects of the 2009 Big Pole fire, Skull Valley, Utah (Vignettes: Key Concepts in Geomorphology). Northfield, Minnesota. (url: http://serc.carleton.edu/47063).

> Recent example of the effects of cloudburst flooding in northern Utah. In a large Skull Valley canyon fire covering about 41,000 acres. Such fires decrease soil permeability by 9 to 100 times. *See also* Craddock, below. During subsequent heavy rains in Skull Valley, large sheet flows occurred and craved 1 meter deep rills in the alluvium. Historically, a similar incident occurred a Dry Creek Canyon. In 1915, there was a large 4 square mile fire in the Canyon that spread over the Salt Lake City Salient southern city-facing hillside. *See* Salt Lake Telegram and Tribune, 1915, below. Woolley records that on July 25, 1916, a Dry Creek Canyon cloudburst sent a 4 to 10 foot wall of water down City Creek and into city, along with mud, boulders and cattle (below, Salt Lake Tribune July 25, 1916).

Wirth, Craig (KUTV News). May 12, 2014. Remembering the flood of '83. KUTV News. At min. 1:35. (url: https://www.abc4.com/wirth/wirth-watching-remembering-the-salt-lake-city-flood-of-83/204262974)

Salt Lake Tribune, and Smart, C. (2011, Apr 29). River on State Street unlikely in 2011, official says. Salt Lake City Tribune. Salt Lake City, Utah. ProQuest No. 864039697. (Retrospective article in which Salt Lake Councilperson describes sandbagging efforts to control 1952 flood; available through Proquest (https://www.proquest.com/) or copy on file with this author).

[36] In reverse chronological order.

Honker, A. M. (1999). "Been Grazed Almost to Extinction": The Environment, Human Action, and Utah Flooding, 1900-1940. Utah Historical Quarterly, 76(1), 23–47 (url: http://heritage.utah.gov/history/quarterly) (Includes review and photographs of Salt Lake City Creek flooding, in particular, in 1909. Overviews high-snow melt verses cloudburst flooding in northern Utah).

Salt Lake Tribune, June 3, 1983 and July 22, 1983. Reproduced in Salt Tribune. 1983. *Spirit of Survival: Utah Floods of 1983* (Available at Reference Desk, Main Branch, Salt Lake City Public Library and Special Collections, Marriott Library, University of Utah, Call No. F830 .S657).

Boyce, R. R. (1958). A historical geography of Salt Lake City, Utah. Thesis. Masters. Department of Geography, University of Utah at 41 re 1876). (On file at Special Collections, Marriott Library, University of Utah; copy in author's possession).

Salt Lake Tribune. April 30, 1952 (Available through https://go.newspapers.com/, re: floods of 1952).

Woolley, R. R. (1946). Cloudburst Floods in Utah: 1850-1938. Washington, D.C. at 96-120 (url: http://pubs.er.usgs.gov/publication/wsp994)

> Woolley listed numerous cloudbursts floods that have come across the Avenues District and from City Creek and across the proposed Well site and into the downtown: (Woolley 1946). Summer cloudburst floods included: June 13th, 1854 (city streets flooded), September 11th, 1864 (heavy flooding of North Temple from City Creek), August 25th, 1872 (downtown flooded), July 23rd, 1874 (downtown flooded from City Creek), August 1st, 1874 (Lindsey Gardens areas flooded as in 1945), August 8th, 1884 (North Temple flooded from City Creek), July 26th, 1893 (cloudburst flooded basements in city), July 19th, 1912 (1 inch fell in 1 hour filled South Temple with sand and mud from above), July 25th, 1916 (cloudburst sent a 10 foot wall of water into city along with mud, boulders and cattle), July 30th, 1930 (cloudburst over Emigration, Red Butte, and Parley's Canyons washed out highway north of Salt Lake and washed away three homes with damages of 500,000 USD), and August 13th, 1931 (four to 12 inches of water swept through streets and 12 feet of debris washed over road near Beck Hot Springs).

Craddock, G. W. (1946). The Salt Lake City Flood, 1945. Proceedings of the Utah Academy of Sciences, Arts and Letters, 23, 51–61. (On file with the Special Collections, Marriott Library, University of Utah; copy attached).

Salt Lake Telegram, August 20 and 27, 1945 (Available through https://go.newspapers.com/; copy in author's possession).

Salt Lake Telegram, August 1, 1944. "S.L. Fire Burns Grass, Brush." This fire potentially led to the Aug. 1945 Perry's Hollow flood per Craddock (1946) (url: https://newspapers.lib.utah.edu/ark:/87278/s6j97frg/17144631).

Utah Flood Commission. (1931). Torrential floods in Northern Utah, 1930. Logan: Agricultural Experiment Station, Utah State Agricultural College. On file at Special Collections, Marriott Library, University of Utah. (url:.http://www.lib.utah.edu).

Salt Lake Telegram. August 14, 1931. Flood Traps Car on Highway. (A cloudburst flood buried cars on highway to the north of Salt Lake City). (url: https://newspapers.lib.utah.edu/ark:/87278/s6cr728k).

Salt Lake Telegram. Sept. 24, 1918. Property Damaged by Big Cloudburst. (A cloudburst flood swept down West Capitol Hill and buried properties at 200 West in up to 1 foot of mud). (url: https://newspapers.lib.utah.edu/ark:/87278/s6d80jz5).

Salt Lake Tribune. July 25, 1916. Cloudburst Kills Cattle in Canyon. (url: https://newspapers.lib.utah.edu/ark:/87278/s6j10wfd)

> "A cloudburst breaking in Dry canyon during the electrical storm of yesterday emerged from the ravine a solid ten-foot wall of rushing water, carrying with it eight head of cattle and rocks weighing from 1000 to 1500 pounds, swirling them along as lightly as feathers. Following the course of the old waterway, the waters rushed through Popperton place, down Second and Third Avenues, turning on Ninth East to the Second South conduit before the force of the flood was spent. In the residence district of Popperton place and the avenues the telephone poles showed that the water mark to have been four feet."

Salt Lake Tribune. August 6, 1915. City's Watershed Suffers from Fire. (url: https://newspapers.lib.utah.edu/ark:/87278/s6tf17rk/14627562)

Salt Lake Telegram. August 5, 1915. Big Damage Caused by Brush Fire in City Creek. (url: https://newspapers.lib.utah.edu/ark:/87278/s6km0kdd/19586313 , re: 4 square mile brush fire in City Creek Canyon that crossed city-side ridgeline).

Salt Lake Telegram, June 19th, 1903. Salt Lake City in Path of Cloudburst, Should It Break in City Creek. (url: https://newspapers.lib.utah.edu/ar/87278/s6ck2gdq)

Addendum B

Table 10 -Fires Greater than 500 Acres on the Salt Lake Salient and in City Creek Canyon – Historical Newspaper Accounts (N=14)[37]

Year	Month	Size	Article Date	Newspaper	Description/Title/Url
1886	Aug	Large, size unknown; Est. > 640 acres	1886-08-08	Salt Lake Herald	"Fire in City Creek" "Fire been burning for there for the last few days." https://newspapers.lib.utah.edu/ark:/87278/s6vm5jtr/10670880 .
1898	Aug	Est. 6 to 15 sq. miles	1898-08-20	Salt Lake Tribune	"Fire along City Creek". From City Creek sweeping north to Bountiful. "At midnight, the flames extended along the hills for a distance of 6 miles. . . . . At midnight, tankman Brown estimated that the fire would exceed fifteen miles." https://newspapers.lib.utah.edu/ark:/87278/s6x93mw7/12792082 (Note: There is no corresponding Fall 1898-Summer 1899 Salt Lake City cloudburst flood reported by Woolley (1945).)
1900	Aug	Est. 1,000 acres	1900-08-12	Salt Lake Herald Salt Lake Tribune	"Big Fire in the Foothills . . ." Northwest of Fort Douglas travelling into Red Butte Canyon. "When the fire had spent its fury, an area of probably 1,000 acres was left black . . ." https://newspapers.lib.utah.edu/ark:/87278/s6ms4z4x/11117735 "Big Blaze in Hills." "[I]t had spread to Red Butte Canyon on the east and into Dry Fork Canyon a short distance, besides reaching nearly halfway up rugged Black Mountain . . ." https://newspapers.lib.utah.edu/ark:/87278/s69k5n2t/13406975
1902	Aug	4 sq. miles	1902-08-25	Salt Lake Tribune Salt Lake Telegram	"Forest Fire Threatens City." "A forest fire raged in City Creek Canyon north of the city . . . stripping four miles of territory of its vegetation . . ." City Creek Canyon, caused by campers. https://newspapers.lib.utah.edu/ark:/87278/s6st90nv/13469547

[37] Based on author's newspaper review from 1870 to 2018, excluding 1980 to 1991.

Year	Month	Size	Article Date	Newspaper	Description/Title/Url
					"Forest Fire Sweeps 4 Miles of Prairie." "The fire burned fire miles up and down the canyon before it was controlled." https://newspapers.lib.utah.edu/ark:/87278/s6446tnv/16716797
1905	Jul	800 acres (1.25 sq. miles)	1905-07-25	Salt Lake Herald	"Fire in City Creek Canyon." "The blaze . . . began at a point about three miles up the creek from the city and burned over an area about two and one-half miles in length and one-half-mile in width." Started by a camper. https://newspapers.lib.utah.edu/ark:/87278/s6446rxm/11900137
1905	Aug	Large, size unknown	1905-08-3	Salt Lake Telegram	"Brush fire in canyon." "A brush fire originating near Twelfth Street . . . swept northward over the ridge toward City Creek Canyon." https://newspapers.lib.utah.edu/ark:/87278/s6vm8f37/18225319
1912	Jul	Large, size unknown	1912-07-11 1912-07-12	Salt Lake Telegram Salt Lake Tribune	"First Forest Fire of the Summer Starts . . . " Fire on Salt Lake salient between City Creek and Dry Fork Canyons. https://newspapers.lib.utah.edu/ark:/87278/s6v13c5j/18092417 "Fire patrol will protect canyons." "A party of men was successful in conquering a brush fire that raged all yesterday between City Creek and Dry Fork Canyons." https://newspapers.lib.utah.edu/ark:/87278/s6q82mft/18092670
1915	Aug	At least 4 square miles	1915-08-05 1915-08-05 1915-08-06	Salt Lake Herald Salt Lake Telegram Salt Lake Herald	"City Creek Canyon Ablaze." "A grass fire started yesterday on the north bench and crept over the hill into City Creek, where the flames cut into the brush. The flames were about a mile below the high line station . . ." https://newspapers.lib.utah.edu/ark:/87278/s6qr6304/10126956 "Big Damage Caused by Brush Fire in City Creek". "[A] four mile stretch of the canyon on the east side had been burned clean . . . . Destruction of the brush . . . is considered very serious because of the importance of this undergrowth in holding and protecting the winter snows and checking its melting in the spring." https://newspapers.lib.utah.edu/ark:/87278/s6km0kdd/19586313 "Fire sweeps large area." https://newspapers.lib.utah.edu/ark:/87278/s6m341kp

Year	Month	Size	Article Date	Newspaper	Description/Title/Url
1915	Aug	3 sq. miles	1915-08-10 to 1915-08-13	Salt Lake Telegram Salt Lake Tribune Salt Lake Herald	"Forest Fires Rage; Salt Lake's Water Supply Periled." Began in west fork of Dry Fork and spread over Black Mountain and down into City Creek. Fire burned through August 13th, 1915. SLTe. 8-10. https://newspapers.lib.utah.edu/ark:/87278/s6t451n5/19587977 "Large Grass Fire Occurs in Canyon." SLTr. 8-10. https://newspapers.lib.utah.edu/ark:/87278/s6z04khg/14636781 "Flames Menace Water Sources." "About three square miles of timbered land was burned, and the fire is still burning . . ." SLH.8-11. https://newspapers.lib.utah.edu/ark:/87278/s6th9sj7/10128812 "Watershed Saved from Fire." SLTr. 8-11. https://newspapers.lib.utah.edu/ark:/87278/s6f490h2/14628711 "City Creek is in Flames." SLTe. 8-12. https://newspapers.lib.utah.edu/ark:/87278/s6jm3j64/19588334 "Fire Fighters Make Headway in Canyon." SLH. 8-12. "[]one and one-half miles north of High Line station . . ." https://newspapers.lib.utah.edu/ark:/87278/s6pv7r6s/10129011 "Relentless Work Halts Timber Fire" SLTr. 8-12. https://newspapers.lib.utah.edu/ark:/87278/s6rf75dx/14632812 "Flames Driven by Wind May Destroy Zion's Watershed." SLTe. 8-13. "Brought to life by a sudden mountain wind . . ., the forest fire on Black mountain and City Creek Canyon is raging anew." https://newspapers.lib.utah.edu/ark:/87278/s6pc48zw/19588159 "Brush Fire Extinguished". SLH. 8-13. ". . . the brush fire, which has been sweeping a portion of the canyon above the High Line, is practically extinguished." https://newspapers.lib.utah.edu/ark:/87278/s6k370h6/10129223 "Fire in City Creek is Conquered." SLTr. 8-13. https://newspapers.lib.utah.edu/ark:/87278/s6vh706s/14616003

Year	Month	Size	Article Date	Newspaper	Description/Title/Url
1915	Nov	Large, size unknown	1915-11-01	Salt Lake Tribune Salt Lake Telegram	“Fierce Fire Rages in near-by Canyon”. SLTr. Black Mountain spreading into upper City Creek Canyon. https://newspapers.lib.utah.edu/ark:/87278/s64x6k62/14554664 “City Creek Canyon Blaze Extinguished”. SLTe. https://newspapers.lib.utah.edu/ark:/87278/s6pp0d5t/19343612
1916	Sep	Two sq. miles	1916-09-07	Salt Lake Telegram	“Citizen Soldiers Fight Canyon Fire.” Started by soldiers using blank cartridges during combat exercises. https://newspapers.lib.utah.edu/ark:/87278/s6f77m3d/19391742
1928	Sep	Several sq. miles	1928-09-26 to 1928-09-30	Salt Lake Telegram	“Salt Lake Brush Flames Checked at Rotary Park.“. Spreading from Dry Fork Canyon to Red Butte Canyon then over Black Mountain and upper City Creek Canyon. Fire was extinguished by a rain storm. https://newspapers.lib.utah.edu/ark:/87278/s6xh10vn/17900812 “Rainfall Puts End to Danger of Brush Fire.” SLTe. 9-27. Fire was extinguished by a rain storm. 600 soldiers fought fire. https://newspapers.lib.utah.edu/ark:/87278/s6sr084b/17901120 “Citizen Soldiers Fight Canyon Fire.” SLTe. 9-30. Started by soldiers using blank cartridges during combat exercises. https://newspapers.lib.utah.edu/ark:/87278/s6f77m3d/19391742
1936	Aug	More than 1 sq. mile	1932-08-22	Salt Lake Telegram	“2-mile grass fire is fought.” “West of City Creek Canyon” toward Ensign Peak. https://newspapers.lib.utah.edu/ark:/87278/s62v3q9m/16543702
1951	Jul	Large, size unknown	1951-07-02	Salt Lake Telegram	“Forest Fire Rages in S.L. Canyon" Covering a wide area" north of Pleasant Valley. https://newspapers.lib.utah.edu/ark:/87278/s6sb5f9d/17631073

Addendum C

Table 11 - Fires between 500 acres and 100 acres on the Salt Lake Salient and in City Creek Canyon – Historical Newspaper Accounts (N=12)[38]

Year	Month	Size	Article Date	Newspaper	Description/Title/Url
1905	Sep	Large acreage, unknown size	1905-09-14	Salt Lake Tribune	"Big Brush Fire Rages." "The burned area is extensive and the entire canyon became filled with smoke." https://newspapers.lib.utah.edu/ark:/87278/s6252v8j/13792648
1911	Aug	Large acreage, unknown size	1911-08-21	Salt Lake Tribune	"Big Fire is Raging Near Black Mountain." "A timber fire of big dimensions . . . about one mile north of Fort Douglas between Black Mountain and Dry Fork." https://newspapers.lib.utah.edu/ark:/87278/s60v9q24/14266092
1919	Jun	Large acreage, unknown size	1919-06-16	Salt Lake Herald	"Grass Fires Unchecked." Large blaze reported in City Creek Canyon. https://newspapers.lib.utah.edu/ark:/87278/s6h71mqt/10279971
1933	Sep	100 acres	1933-09-05	Salt Lake Telegram	"Black Mountain Fire is Checked." "[A]t the face of Black Mountain at the head of City creek canyon . . ." https://newspapers.lib.utah.edu/ark:/87278/s67w7m7w/16234153
1936	Aug	500 acres	1936-08-24	Salt Lake Telegram	"Forest Fires laid to Matches, Cigarettes." "[O]ver nearly 500 acres in City Creek Canyon …" https://newspapers.lib.utah.edu/ark:/87278/s6z61x6h/16544106
1938	Jul	100 acres 50 acres	1938-07-23	Salt Lake Telegram	"Fire Officials Sound Warning." 100 acre fire at Fort Douglas; 50 acre fire on Ensign Peak.

[38] Based on author's newspaper review from 1870 to 2018, excluding 1980 to 1991.

Year	Month	Size	Article Date	Newspaper	Description/Title/Url
1941	Sep	More than 500 acres	1941-09-01	Salt Lake Telegram	"City Creek Fire Rakes Big Area." SLTe. 9-1. Salt Lake salient at near 13th Avenue and E Street and sweeping over ridgeline into City Creek Canyon. https://newspapers.lib.utah.edu/ark:/87278/s6z90mn8/16941270 "Big Canyon Fire Laid to Youths Trying to Halt Toy 'Sabotage'" SLTe 9-4. https://newspapers.lib.utah.edu/ark:/87278/s6cc27zx/16947504
1944	Aug	388 Acres	1944-08-01	Salt Lake Telegram	"S.L. Fire Burns Grass, Brush." This fire potentially led to the Aug. 1945 Perry's Hollow flood per Craddock (1946) Craddock refers to "Fully 80 percent of the area, including all but patches of the headwater slopes and portions of the lower benchlands, was burned last fall" (at 58). Although the 1944 article does not state the number of acres burned, Craddock estimated the burn size at 388 acres. https://newspapers.lib.utah.edu/ark:/87278/s6j97frg/17144631
1958	Oct	100 acres	1958-10-18	Salt Lake Tribune	"Fire hits [Water]'Shed at City Creek." At Ensign Peak; started by a hunter at the police firing range. Rec'vd from www.newspapers.com. In author's possession.
1992	Jul	150 acres	1992-07-23	Salt Lake Tribune	"Residents Rush to Safety as Brush Fire Sweeps Foothills . . ." 150 acre fire near the Lime Kiln on Tomahawk Drive. ProQuest document ID: 288484519.
2008	Jul	175 acres	2008-07-30	Deseret News	"Crews fighting wildfires in City Creek." Burning close to radio towers behind Ensign Peak. ProQuest document ID: 351641173.
2018	Jul	100 acres	2018-07-24	Salt Lake Tribune	"Grass fire near Salt Lake City's Ensign Peak damages one home. Three firefighters and two residents were injured." https://www.sltrib.com/news/2018/07/24/fire-reported-salt-lake/

Addendum D

List of Small Acreage Fires Less than 100 Acres on the Salt Lake Salient and in City Creek Canyon – Historical Newspaper Accounts (N=30) [39]

• July 24th, 1894, unknown size, City Creek Canyon, Salt Lake Tribune, boys camping.

• May 2nd, 1899, small acreage, City Creek Canyon, Salt Lake Tribune, Abandoned camp fire.

• September 2nd, 1905, size unknown, City Creek Canyon near the Brick Reservoir, Salt Lake Herald.

• April 15th, 1909, unknown size, City Creek Canyons - four miles from downtown, Deseret Evening News.

• On April 29th, 1910, small acreage, City Creek Canyon near Memory Grove, Salt Lake Tribune.

• June 28th, 1918, size unknown, City Creek Canyon, Salt Lake Telegram, Canyon closure ordered.

• August 7th, 1922, size unknown, City Creek Canyon near mile 0.9, Ogden Standard Examiner.

• August 27th, 1926, unknown size, City Creek Canyon at old Brick Reservoir Tanks, Salt Lake Telegram, Destroyed reservoir tanks.

• June 18th, 1930, size unknown, small acreage, Salt Lake Telegram.

• April 25th, 1934, small acreage, City Creek Canyon, Salt Lake Tribune, woman fined for starting a fire.

• July 18th, 1934, Two acres, City Creek Canyon in upper north fork, Salt Lake Tribune.

• July 23rd, 1938, 50 acres, Ensign Peak, "Fire Officials Sound Warning." Salt Lake Telegram. https://newspapers.lib.utah.edu/ark:/87278/s6zw2v3m/16622337

• July 3rd, 1951, 80 acres, "Blaze Blamed on S.L. Boys." Salt Lake Tribune. https://newspapers.lib.utah.edu/ark:/87278/s6c2651d/17633875 and "Fire Blackens 80 Acres." https://newspapers.lib.utah.edu/ark:/87278/s6c2651d/17633883 .

• August 8th, 1940, 20 acres, Salt Lake salient at north of 12th Avenue between H and K Streets, Salt Lake City Tribune.

• July 5th, 1951, unknown size, Ensign Peak - below, Salt Lake Tribune, Started by rifle fire at police gun range.

• July 7th, 1953, 50 acres, Ensign Peak, Porschatis Photographs, Marrriot Library Digital Archive.

• June 24th, 1957, small acreage, City Creek Canyon on east slope below homes near A Street and Ninth Avenue, Salt Lake Tribune.

• June 22nd, 1960, 50 acres, City Creek Canyon, Salt Lake Tribune.

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[39] Based on author's newspaper review from 1870 to 2018, excluding 1980 to 1991. Unlike the two earlier lists, url references are not provided for these small acreage fires.

• July 24th, 1960, small acreage, Ensign Peak, Salt Lake Tribune July 25th, 1960, Started at police range on July 24th day.

• July 14th, 1971, Four acres, City Creek Canyon at western side of Bonneville Drive, Salt Lake Tribune.

• August 4th, 1973, small acreage, City Creek Canyon, Salt Lake Tribune.

• August 27th, 1973, 2 acres, Salt Lake salient north of 18th Avenue, Salt Lake Tribune).

• July 1st, 1997, small acreage, City Creek Canyon at Memory Grove, Salt Lake Tribune.

• September 6th, 2002, 60 acres, City Creek-Bountiful ridge, Salt Lake Tribune.

• On August 25th, 2006, unknown size, City Creek Canyon headwaters, Deseret News and Salt Lake Tribune, Caused by lightning strike.

• August 31st, 2006, 4 acres, City Creek Canyon at Memory Grove sweeping up-canyon to Bonneville Drive and 11th Avenue, Deseret News.

• July 23rd, 2010, 2 acres, City Creek Canyon, Salt Lake Tribune.

• July 23rd, 2011, small acreage, City Creek Canyon at Bonneville Drive and Memory Grove, Salt Lake Tribune, Mentally ill person admitted to starting three fires.

• August 6th, 2016, 10 acres, Ensign Peak, Personal observation.

• August 30th, 2017, 75 acres, Bountiful side of Salt Lake salient, Salt Lake Tribune, Short-term closure of City Creek Canyon ordered. https://www.ksl.com/article/45612452/summerwood-fire-25-contained-city-creek-canyon-remains-closed