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**MEMORANDUM FOR**: Sunshine Canyon Creek – Floodplain Study and Flood Hazard Area Delineation (FHAD) Report

**TO:** Sara DeGroot, P.E., CFM, ENV SP, City of Boulder

**FROM**: Kevin Doyle, Michael Baker International

**SUBJECT**: Review Comments on Hydrologic Analyses for Sunshine Canyon in Boulder County, Colorado

## Background

The City of Boulder contracted Michael Baker to update the floodplain study for Sunshine Canyon Creek in compliance with the Mile High Flood District's (MHFD) Flood Hazard Area Delineation (FHAD) format. As part of this scope Michael Baker reviewed the existing hydrologic studies performed for Sunshine Canyon. This memorandum presents a summary of the past studies completed and recommendations for updates before further hydraulic analysis based on this hydrologic data.

### Hydrologic Analysis Report

This review focuses on the document titled "Hydrologic Analysis Report: St. Vrain Watershed Riskmap Flood Study; Boulder County and Weld County, Colorado" prepared by Anderson Consulting Engineers, dated July 17, 2012 (Anderson Study). This study was part of MAS No. 47 for Risk Map Flood Study for St. Vrain Creek Watershed in both Boulder County and Weld County, Colorado under contract to the CWCB. The purpose is to conduct detailed hydrologic analysis to determine peak discharges for the 10, 25, 50, 100, and 500yr storm events.

### Sunshine Canyon Creek

The Sunshine Canyon Creek Drainage Basin is located approximately 2.5 miles south of the Lefthand Creek Drainage Basin, immediately west of the City of Boulder. The drainage basin is 1.9 square miles. It is generally bounded by the Twomile Canyon Creek Drainage Basin on the north, the western limit of the City of Boulder on the east, the confluence with Boulder Creek on the south, and the Fourmile Creek Drainage Basin on the west. Nearly the entire drainage basin lies within the Mile High Flood District (MHFD) boundary. Most of the Sunshine Canyon Creek Drainage Basin lies west of the hogback and the Boulder city limits. Land use near the basin outlet and east of the hogback is a mix of low to medium density residential housing and shrub and brush rangeland. West of the hogback land use is largely



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evergreen forest mixed with shrub and brush rangeland and limited low-density residential housing. The entire Sunshine Canyon Creek Drainage Basin drains into Boulder Creek near the western boundary of the City of Boulder. The main conveyance corridor within the Sunshine Canyon Creek Drainage Basin is Sunshine Canyon Creek, extending from its headwaters in the Roosevelt National Forest east to its confluence with Boulder Creek near the western edge of the City of Boulder. Two minor left bank tributaries confluence with Sunshine Canyon Creek near its downstream end.

**Review Approach**

The general review approach began with the Anderson Study. The review followed the steps of analysis presented in the report and verified assumptions and calculations were accurate based on the data available. These assumptions and calculation methods were compared to guidance from MHFD to ensure they were adequate. When possible, results were compared to other sources of data and calculations which were not presented in the Anderson Study.

The Anderson Study acknowledges previous studies “FHAD, Boulder and Adjacent County Drainageways” and “FIS, Boulder County, Colorado and Incorporated Areas”.

No published effective FEMA flows exist for Sunshine Canyon so these were not included in the Anderson Study or this review.

The Anderson Study made comparisons for the 100yr event between 1987 FHAD, USGS Regression (StreamStats), and CWCB Regression (SPL-3, Central Foothills Subregion). A summary of discharges from all studies is summarized in Table 1.

In addition to the comparisons made in the Anderson Study, this review also compares the values found in the report titled “Boulder Creek Hydrologic Analysis; Phase 2: Boulder Creek above St. Vrain Creek”, published by CH2MHILL for Colorado Department of Transportation, dated June 10, 2015. This analysis was performed to update flood risk for flooding sources impacted by the 2013 flood as part of the Colorado Hazard Mapping Program (CHAMP). The HMS model created for this report includes a flow calculation on Sunshine Creek at the confluence with Boulder Creek. The 1-Percent-Annual-Chance peak discharge at this location is reported as 437 cfs. It should be noted that this analysis created a hydrologic model for the entire 450 square mile Boulder Creek watershed and focused calibration efforts on the discharges for Boulder Creek. Small watersheds like Sunshine Creek (1.9 square miles) were analyzed as a single watershed with a single runoff curve number. Comparisons to the results of more detailed analysis like the 1987 FHAD and the 2012 Anderson study that focused on Sunshine Creek should be given more weight than the results of this analysis.

The final comparison made in Table 1 is that of the results using the updated version of CUHP. More details on this are discussed in the “Updated Hydrologic Modeling” section of this memo.

**Table 1. Summary of 1-Percent-Annual-Chance Discharges**

| | 1987 FHAD | USGS Regression | CWCB Regression | CHAMP (2015)* | Anderson Study (2012) | Anderson Study with Updated CUHP | Anderson Study with Updated CUHP & Atlas 14 Precipitation |
|---|---|---|---|---|---|---|---|
| 1-Percent Annual-Chance Peak Discharge (cfs) | 1,159 | 480 | 1,080 | 437 | 1,520 | 1,405 | 1,384 |

*Not representative of project study area

## Background Data

The background data presented in the Anderson Study was reviewed for accuracy of assumptions. This included general watershed data including location, drainage area, land use, main conveyance, and tributaries. This data was found to be accurate.

## Design Storms

The Anderson Study developed the 10-, 4-, 2-, and 1-percent-annual-chance precipitation based on NOAA Atlas and Rainfall chapter of the Urban Drainage and Flood Control District (MHFD) Drainage Criteria Manual, Volume I. The 2-hour storm duration was chosen based on drainage size. This methodology is acceptable based on the MHFD Criteria. Precipitation values were distributed using the 2-hour design storm distributions listed in the MHFD criteria manual. This process was reviewed, and all results appear accurate.

## Hydrologic Modeling

The Anderson Study used both the Colorado Urban Hydrograph Procedure (CUHP, Version 1.3.3) and the U.S. Environmental Protection Agency's Storm Water Management Model (EPS-SWMM, Version 5.0, Build 5.0.022). These are acceptable models for hydrologic analysis; however, the version of CUHP used is an outdated version. A significant update to CUHP was performed in late 2016. In the "Updated Hydrologic Modeling" section of this memo the current version of CUHP (2.0.1) was used to produce new hydrologic data for SWMM inputs. Results of this new modeling are presented for comparison to the Anderson Study results.

### Subbasin Delineation

The Sunshine Canyon Creek Drainage Basin was divided into 7 subbasins. Boundaries were modified to provide concentration points at road crossings and confluences with tributaries. A review of these subbasins confirmed the basins were delineated accurately and the final basins meet MHFD criteria.

**Precipitation Losses**

Estimation of precipitation losses in the Anderson Study was based on standard values as prescribed by the MHFD. NRCS Soil Surveys for the Boulder County Area, Colorado were used to determine Hydrologic Soil Groups (HSGs) of the drainage area for Sunshine Canyon Creek. These HSGs and MHFD data were used to determine Horton soil infiltration rates and decay coefficients. Subbasins containing more than one HSG were area-weighted and subsequent infiltration values determined. A review of soil maps and MHFD data determined the methodology and calculations for HSGs and infiltration rates appear to be accurate.

The percentage of each subbasin that is impervious was determined through a visual inspection of 2011 aerial photography, land use/land cover classifications, and descriptions of soil types, specifically rock outcropping percentages within each soil type. Information obtained from these sources, along with engineering judgment, provided the final determination of impervious percentage for each subbasin. Review of the above methodology confirms these determinations appear accurate.

**Subbasin Runoff and Channel Routing**

Direct runoff for all subbasins within the Sunshine Canyon Creek Drainage Basin was determined using CUHP. CUHP requires the input of seven parameters: (a) subbasin area; (b) subbasin length; (c) distance to centroid; (d) subbasin slope; (e) percent impervious; (f) pervious and impervious depression storage values; and (g) Horton soil infiltration parameters. Subbasin lengths, distances to centroids, and subbasin slopes were determined manually using the local quadrangle mapping and the 10-meter DEM. Channel routing within EPA-SWMM was computed using the Kinematic Wave Method.

Model input requires several parameters: (a) channel length; (b) maximum channel depth; (c) Manning's roughness coefficient; (d) channel shape; (e) channel bottom width; and (f) channel side slopes. Channel lengths were determined using the local quadrangle mapping. Maximum channel depths were established so as not to surcharge channel routing elements. Manning's roughness coefficients were estimated based on land cover present in the 2011 aerial photograph as well as field reconnaissance efforts, and corresponding publications for the determination of n-values. All channels were assumed to be trapezoidal in shape; bottom widths and side slopes were determined from the local quadrangle mapping. Longitudinal channel slopes were determined in EPA-SWMM based on elevations assigned to nodes (concentration points) bounding the channel reach.

EPA-SWMM model was used to determine peak flows for 10-, 4-, 2-, 1-percent-annual-chance of occurrence events.

Review of the EPA-SWMM model inputs and results confirm the results listed in the Hydrologic Report appear to be accurate. A different method was used to determine results for the 0.2-percent-annual-chance discharge.

**0.2-Percent-Annual-Chance Discharges**

The Anderson Study accurately reports the 1987 FHAD does not include analysis of the 0.2percent-annual-chance-discharge. The Study used hydrologic analysis results from 10-, 4-, 2-, and 1-percent-annual-chance event simulations to determine discharges for the 0.2-percent-annual-chance event. This was done using a discharge versus log exceedance probability plot for each location in the watershed analysis.

These plots were reviewed, and all inputs and results appear accurate based on the chosen methodology.

## Hydrologic Modeling Results

The Anderson Study compared computed discharges for several calculation methods and references as described above and summarized in Table 1. Additional details about the methodologies used for comparison is provided below.

**USGS Regression Equations**

The Anderson Study made a comparison between the results presented in this study and the information presented in "Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado," Capesius and Stephens, U.S. Geological Survey, 2009. The analysis used StreamStats and notes the USGS regression equations compute peak discharges between 49- and 70-percent lower than the current study and previous master drainage planning study estimates. The Hydrologic Report also notes, in general, the USGS regression equations provide limited discharge estimation capabilities based on high prediction errors and a general lack of gage data, particularly in the Plains Region.

**CWCB Regression Equations**

The Anderson Study makes a second comparison of the modeling results using information presented in "Guidelines for Determining 100-Year Flood Flows for Approximate Floodplains in Colorado, Version 6.0," Department of Natural Resources, Colorado Water Conservation Board, June 2004. The calculation of peak flow for Sunshine Canyon Creek at the confluence with Boulder Creek was reviewed and appears to be accurate based on available data.

**FEMA Discharge-Area Curve**

The Anderson Study made a third comparison of the modeling results by comparing them to the results of nearby gage data. The source of gage data is an undated letter from FEMA to the MHFD; a facsimile transmittal of the letter and figure (dated April 23, 1998) is included in the Anderson Report. The 1-percent-annual-chance discharges computed by Anderson were plotted versus associated drainage areas on the gage results figure. The 1-percent-annual-chance peak discharges computed for Sunshine

Canyon Creek as part of the Anderson Study fell within the range of base flood discharges for the given gaging stations.

The Anderson Study concludes that based on this third comparison as well as reasonably close correlations to the CWCB regression results, it can be assumed that the hydrologic modeling results presented in this study appear to be reasonable.

These points of comparison were checked and appear to be plotted correctly. The claim that they fall within the range of discharges for the given gaging stations appears to be accurate.

### Updated Hydrologic Modeling

The biggest concern was that the Anderson Study used a (now) outdated version of CUHP. The most recent version(s) of CUHP have generally produced lower discharges than the version Anderson used. For this reason, a new analysis was completed using the latest version of CUHP (Version 2.0.1) and SWMM (Version 5.1.014) with the same inputs. The Anderson Study also used outdated precipitation data so the new analysis incorporated precipitation data from NOAA Atlas 14.

This process began with the original CUHP files from the Anderson analysis (CUHP 2005 files). The most recent version of CUHP allows for import of CUHP 2005 Files. After importing the Anderson files, the Output Workbook and CUHP/SWMM Interface file paths were updated and the raingage data was updated with the Atlas 14 data. The CUHP is then run to produce new results (SWMM input files) for each storm event.

The newly created CUHP output files are input to the Anderson SWMM files and SWMM run for each storm event to produce results. No variables or model options were changed for CUHP or SWMM before the models were run.

Per City of Boulder request, this analysis also includes the 2yr and 500yr recurrence intervals which were not included in the Anderson Study. These intervals were added by making new CUHP and SWMM files (copying all pertinent information from the Anderson Study files) and following the sequence described above.

The lower portion of the watershed in the City of Boulder is fully developed. The upper portion of the watershed in Boulder County is zoned as Forestry. Based on conversations with the County, no significant development or change in zoning is anticipated for the upper portion of the watershed. As a result, the watershed is considered fully developed and a separate future conditions analysis was not performed.

## Summary and Recommendations

Review of this hydrologic analysis suggests the inputs, assumptions, and methodology of the Anderson Study are sound. The results of the study are higher than other estimation methods but are not unreasonable. The results using the updated version of CUHP with the Anderson inputs produce lower discharges and appear more reasonable. It is recommended that the hydraulics analysis of Sunshine Canyon be completed using the Anderson Study run with the most current version of CUHP and SWMM. The discharges listed in Table 2 should be used in the analysis.

**Table 2. Summary of Recommended Discharges**

| | 2-YR | 10-YR | 25-YR | 50-YR | 100-YR | 500-YR |
|---|---|---|---|---|---|---|
| Sunshine Canyon @ Mouth | 38 | 179 | 621 | 946 | 1384 | 2346 |