Chatfield Watershed Model
Data Compilation Technical Memorandum

prepared for
Chatfield Watershed Authority

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1.0 INTRODUCTION

The purpose of this memorandum is to provide a summary of Chatfield Watershed Model (CWM) Phase I work process and products. Phase I of the CWM project (Project) consisted of an initial data compilation workshop meeting with CWA members, compilation, organization, and QA/QC of data provided, review and compilation of external datasets considered to be useful to the Project, and preparation of this memorandum.

The goal of the data compilation and review effort is to provide an accurate and comprehensive data set for input to the model, including:

(1) characterize processes in the watershed; and

(2) inform model input datasets and parameterization.

The initial model data compilation workshop meeting was held on June 17th, 2015, and provided a forum for Leonard Rice Engineers, Inc. and Lynker Technologies, LLC (The Modeling Team) to explain the types of data that are needed for the modeling effort and to request additional data inputs for the model.

Following the data compilation meeting, the CWA provided stream water chemistry data and land use information. The Modeling Team reviewed the data and studies provided, and procured data from CWA members and governmental entities, including the NOAA, USGS, and EPA. Additional data included point source discharges, flow and hydraulic information, spatial information (land use), and historical weather data. This memorandum summarizes data that were obtained from all sources and summarizes how the data are stored and will be utilized in model population and calibration.

2.0 DATA COMPILATION REQUEST & DATABASE MANAGEMENT

2.1 Initial Data Request

Multiple entities have collected data within the Chatfield watershed for many years. The data compilation effort included an initial request to the CWA and other entities to provide available data to support the watershed modeling effort. Following the data compilation kickoff meeting, the Modeling Team selected an initial period of record from 1990 through 2015. This period was selected based on our understanding of historical data availability. Modeling requires calibration over a number of years, and it is important to have enough data so that filling and assumptions are limited, and so that overlapping periods of record are available for stream chemistry and discharge information. Following the initial data compilation effort, due to limited metadata for older datasets, climate data availability, and limited point source discharge data prior to 2001, the period of record was revised to include 2001 through 2015. This still provides a long enough period of record to calibrate and validate the model.

The initial request to the CWA and its member organizations was for water chemistry data, land use data, hydrologic and hydraulic information, model files and qualitative information that may be helpful to the watershed modeling effort. In addition to the raw data, other documentation was requested to include supporting documents such as sampling and analysis plans, data summary reports and summaries of data QA/QC that had previously occurred.

The water chemistry data request included total suspended solids, total phosphorus, orthophosphorus, total nitrogen, nitrate, nitrite, ammonia, total kjeldahl nitrogen, conductivity, dissolved oxygen, temperature, pH, flow, dissolved oxygen, specific conductance, alkalinity, total organic carbon, biochemical oxygen demand, carbonaceous biochemical oxygen demand, and attached algae biomass and chlorophyll-a.

To the extent that data were provided in a database-friendly format, other parameters and data collected prior to 2001 will be stored in addition to the requested parameters list. Sections 3 through 10 of this memorandum summarize the data and files received from the CWA or obtained through additional research. Section 11 provides recommendations for additional sampling, data collection, and special studies that would benefit the watershed modeling effort. This memorandum is not intended to serve as a sampling and analysis plan. Additional site evaluation and planning should be conducted to determine specific locations and parameters to collect to best support this watershed model in the future and the CWA's other objectives.

A Google Drive framework was established for storage of data files, and files were subsequently organized by type of data.

The data request is located at the following link:

https://drive.google.com/open?id=1Bi9e8Mnz8FY_voMDrT6tWhcNwgiRU-bcv6kr8Sn6t8A

A Google Sheets file was established for those entities sharing data electronically to document their data uploads. That file is located at the following link:

https://drive.google.com/open?id=1RdK23pCQqjOpt-BtrgQ9DXCGeyt11L0dSdAaIPEusT4

Initially, data were submitted using the google dive folder by PCWRA, Denver Water, and the CWA. Additional data were provided by e-mail by Denver Water and the CWA. The Modeling Team reached out directly to point source dischargers in the watershed, and received data from the PCWRA, Lockheed Martin, Roxborough Water & Sanitation District, and Perry Park Water and Sanitation District.

Additionally, Tetra Tech provided support by answering questions regarding data qualifiers and data quality, and by formatting datasets.

LRE and Lynker evaluated data, requested further information where needed, and added a final set of data files to the Data Compilation Google Drive folder located at the following link:

https://drive.google.com/open?id=0B5vHUBJCONpRfmd6TDExYlVCVERSbHM2QVV0d1VoN3NSQkxvUGdCallyd3VFNVhHd203YWM

2.2 Data Processing and Model Database

A relational database is used to manage and compile the water quality data relevant to the Chatfield Watershed Model. Specifically, a server-based PostgreSQL database has been established in a Linux environment. PostgreSQL, like most relational database systems, uses SQL (Structured Query Language) for database querying and maintenance. The data have been normalized to a set of tables with unique keys that are able to represent relationships within and between tables. Please see Appendix A (attached) to view the entity relationship diagram for the Chatfield Water Quality database core tables.

The data normalization for each dataset includes determining the unique lists of parameters, methods, locations, units, data sources, quality control flags, and groups. All equivalent characteristics are "mapped" to the chosen official characteristic description. For example, "Degrees Celsius" and "deg-C" may both be mapped to "°C" where "°C" is the official unit name for temperature. Result records then include the corresponding indices for each record's parameter, method, location, unit, source, flags, and groups.

Some information obtained from the data compilation effort is better summarized as ranges of values; for example, where soil chemistry data were reviewed within the Cherry Creek watershed, studies were not specific to the Chatfield watershed, and generally, a very limited number of samples were collected. Ranges will inform model calibration parameters, but will not be used directly in the modeling effort as water chemistry data from the watershed will be, and were therefore not stored in the model database.

2.3 Data Types

The datasets summarized herein are organized in a structure that is consistent with model development needs. Major data categories include stream water chemistry, point source water chemistry and flow data, nonpoint source water chemistry and flow data, soil chemistry, stream flow and hydrology data, hydraulic data, climate data, and land use data.

3.0 STREAM WATER CHEMISTRY SOURCES

Stream water chemistry is necessary for a watershed model in order to provide a calibration and validation check on simulated results. The focus of the modeling effort is on total phosphorus, orthophosphorus, and total suspended solids; however data for additional parameters that are useful for calibration or that may influence nutrient fate and transport have also been compiled. A table of surface water quality sampling locations is included in Appendix B.1.

3.1 Chatfield Watershed Authority Water Quality Data

Chatfield Watershed Authority data derive from a number of sources. Nutrient and other water chemistry information have been obtained from water quality samples collected by consultants and member entities for over 30 years. The following summaries contain information regarding each data source that was provided to or obtained by LRE. The summaries include descriptions of data formatting and data QA/QC for data sources that were suitable for use in the watershed model.

CWA Data Call

This compilation was conducted by Tetra Tech in response to a request for South Platte River Basin water quality data by the Water Quality Control Division. It includes data from 2010 through 2015, collected at fourteen locations in the watershed, three in the Reservoir, and two downstream from the Reservoir. The file includes data from Denver Water, GEI, and the Plum Creek Water Reclamation Authority.

Parameters sampled as part of this dataset include flow, total suspended solids, total phosphorus, orthophosphorus, dissolved oxygen, dissolved oxygen percent saturation, alkalinity, pheno-alkalinity, ammonia (total and dissolved), chlorophyll a, coliform, conductivity, depth, E. coli, hardness, nitrate+nitrite, pH, secch i depth, silicon dioxide, sulfate, temperature, total dissolved solids, total suspended solids, total kjeldahl nitrogen, total organic carbon, turbidity, plankton species, aluminum, antimony, arsenic, barium, beryllium, boron, calcium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silicon, silver, sodium, thallium, uranium, vanadium, and zinc.

The formatting and metadata for this dataset are excellent. Fields include detection limits, qualifiers, and lab methods. As this dataset was already in the standard “data call” format, very little additional processing was required. After import of the raw dataset to the database, LRE filtered out all records that did not have a medium subdivision of “SW” or surface water. This included records with a sub-division of “CCS,” “DIBlank”, “QA/QC dup,” or “spike”. These subdivision types are associated with laboratory quality control. Field mapping was conducted to standardize parameter names, location names, and units within the database.

Tetra Tech Compilations (2001-2009)

Tetra Tech assisted with compilation of data from the original source files for the period from 2001 through 2009. These files were taken from Commodore Advanced Sciences (2001-2006) and Denver Water (2007-2009). Data are included at two primary locations, Plum Creek at the Titan Rd. USGS gage and the South Platte River at the Waterton Canyon USGS gage. Additional data are also provided for some years for Massey Draw locations.

The combined data files included data for 2001 through 2009 for ammonia, bicarbonate, dissolved calcium, cyanide (WAD), dissolved oxygen, e.coli, dissolved hardness, field flow, dissolved magnesium,

nitrate, nitrite, orthophosphorus, pH, specific conductance, temperature, total alkalinity, total nitrogen, total phosphorus, and total suspended solids.

The dataset includes MDL and PQL information, but other metadata are limited. There appear to be problems with the units in certain years of the compiled files, possibly tied to problems in the source files. As this is a key dataset, those problems will need to be resolved before the data are input to the model. Graphing within the water quality database will be used as a first check to determine where problems are likely.

PCWRA Stream Data (1995 – 2014)

The PCWRA provided its stream water quality data from 1995 through 2014 as a separate file. PCWRA data overlap the Data Call dataset for the 2010-2014 period. These data include sampling results for 1995 through 2014 for locations above the PCWRA outfall (UPS = EPC 14.7, formerly labeled 15.1) and below the PCWRA outfall (DNS = EPC 15.3). After 2012, results are also included for other locations on Plum Creek and its tributaries (EPC 11.1, EPC 20.7, EPC 21.1, EPC 33.6, PC 0.3, PC 3.5, PC 6.7, PC 9.5, WPC 10.9, and WPC 29.7) These results are generally contained in the Chatfield Data Call compilation. However, the historical results at the EPC 14.7 and EPC 15.3 locations were only included in the Data Call after 2012. This file will be relied upon for all PCWRA sampling locations and parameters.

Parameters included in this dataset are alkalinity, BOD, calcium, chloride, conductance, copper, dissolved oxygen, E. coli, flow, hardness, magnesium, manganese, ammonia, total kjeldahl nitrogen, nitrate, nitrate + nitrite, total inorganic nitrogen, total nitrogen, dissolved organic carbon, orthophosphorus, total phosphorus, potassium, sodium, sulfate, sulfide, temperature, and total suspended solids.

This dataset was in a flat file format with good metadata, including sample collection time, detection limits, laboratory method, laboratory analyst, analysis data, and qualifiers indicating data quality. Field mapping was conducted to standardize parameter names, location names, and units within the database.

Centennial WSD (2014-2015)

The Centennial Water and Sanitation District provided sampling data collected in 2014 and 2015. These data were collected at 14 locations. This dataset also included an indication of storm events. This sampling was determined to significantly overlap with GEI data already included in the Data Call files; therefore, it has not been prioritized to be added to the database.

Parameters included in this dataset are alkalinity, BOD_5, chloride, chlorophyll-a, conductivity, dissolved oxygen, e. coli, ammonia, total kjeldahl nitrogen, nitrate + nitrite, organic carbon, pH, dissolved phosphorus, orthophosphorus, total phosphorus, secchi depth, silica, total dissolved solids, total suspended solids, sulfate, temperature, and zooplankton counts. Field sonde measurements were also collected, including temperature specific conductance, total phosphorus, orthophosphorus, chlorophyll-a, pH, and dissolved oxygen.

Master Data Spreadsheets

These Excel files, which were obtained from the CWA website were not in a format that was readily imported to a database. Data formats varied during different years, sites and parameters were stored on multiple tabs in each spreadsheet, and data were in tabular format (not flattened). These files were not included in the model or the water quality database. The data were generally duplicated in other data sources that were provided by the CWA.

GEI Compilation

This compilation was conducted by GEI Consultants in an effort to update loading calculations for the watershed. It includes data from 1983 through 2007. The formatting is good, but the file contains limited sample metadata and also does not include any TSS data. This file was not included in the model or the water quality database. The data were generally duplicated in other data sources that were provided by the CWA after 2001.

Final files that were uploaded to the Water Quality Model database are summarized in Table 1. A list of sampling locations included for each dataset is included in Appendix B.1.

Table 1. CWA Water Chemistry Data File Summary

Date Range	Source	File Name (s)
2001-2006	Tetra Tech Compilation from CAS Source Files	CAS_2001 data_072015.xlsx CAS_2002 data_072015.xlsx CAS_2003 data_072015.xlsx CAS_2004-2006 data_072015.xlsx Combined Into (2001_2009_stacked.xlsx)
2007-2009	Tetra Tech Compilation from DW Source Files	DW_2007 data_072115.xlsx DW_2008 data_072115.xlsx DW_2009 data_072115.xlsx Combined Into (2001_2009_stacked.xlsx)
2010-2015	Tetra Tech Data Call File	CWA-303d-Data-Call_2010-2014.xlsx
1995-2015	PCWRA File	ModelCWAData_Rpt Stream 1995 to 7-14-2015

3.2 Additional CWA studies with stream water chemistry information

Massey Draw

A study was conducted to assess water quality in Massey Draw before (2002-2004) and after (2005-2006) construction of the Massey Draw Watershed and Ecosystem Improvements Pilot Project, which resulted in channel improvements in Massey Draw from Wadsworth Blvd. to C-470. The project collected TP, TSS, and orthophosphorus data. The study contains TP and TSS loading estimates at varying flow rates, as well as BMP effectiveness information. These results are contained in the Master Data spreadsheets on the CWA website, but not in a readily portable format for the database. Some results were compiled into the CAS data files sent by Tetra Tech, however, those files do not appear to contain the results for orthophosphorus, and also do not include data prior to 2004. If additional data from this study are considered to be necessary for the modeling effort, LRE will notify the CWA to determine how best to proceed.

Screening Study

A screening study conducted over the time period from 1999 through 2002. Data are summarized for 1999 through 2001 in the Chatfield Basin Water Quality Data Assessment (TDS Consulting, 2001). 2002 data are included in the 2002 CWA Annual report. This study may be useful to the watershed modeling effort because it included water quality and flow samples at many locations within the watershed on the same sampling dates. Upwards of 20 locations were sampled weekly during the summer months of the sampling study. Data collected as part of the study include TSS, specific conductivity, flow, pH, dissolved oxygen, temperature, nitrate, and total phosphorus. Orthophosphorus was not sampled. Data from this study were not provided to our Modeling Team electronically. These data may be useful for the modeling effort. If additional data from this study are considered to be necessary for the modeling effort, LRE will notify the CWA to determine how best to proceed.

DRCOG Study

The Denver Regional Council of Governments developed a plan to address point and nonpoint sources of phosphorus through 2010 including recommendations for general point and nonpoint source controls. This study also included discussion of a Qual2E model that was developed for the Plum Creek portion of the watershed, including East and West Plum Creek. The Qual2E model included ammonia, nitrate, and BOD (DRCOG 1998). This model was not provided. Since it does not address phosphorus, it may have value for hydrologic and hydraulic inputs, but likely not for water chemistry inputs.

Chatfield Watershed Plan

This report (Tetra Tech 2015) provides an excellent overview of water quality and hydrologic conditions in the watershed, and identifies potential sources of nutrients as well as projects that have been conducted to address nutrients over the years. The appendices of this report also contain summaries of additional studies that may be used to estimate sediment, total phosphorus, total nitrogen, and e.coli loading rates and a hot-spot analysis for septic systems and sediment erosion in the watershed.

3.3 Stream NWIS and Storet Data

Water chemistry data are available from the USGS NWIS and EPA Storet databases. These data may be relied upon as needed for model development to supplement CWA water chemistry data.

NWIS and Storet data were obtained from the Water Quality Portal website, www.waterqualitydata.us. The data were retrieved by 8-digit HUC ID 10190002. Next the locations were clipped based on the watershed boundary layer provided by the CWA.

A comprehensive review of Water Quality Portal data was not conducted at this time. The purpose of downloading the data is to provide an additional resource where known datasets are lacking key information. During the data compilation workshop, it was decided that the NWIS dataset would not be relied upon as a primary data source due to the lack of supporting information with the data. These data may have value however, if other data are lacking or require supplementation. For example, these data may be used to provide tributary water quality concentration information where other data are not readily available.

4.0 POINT SOURCE FLOW AND WATER CHEMISTRY

Point source discharges directly affect water quality in the stream below the point of discharge. In order to develop and calibrate the watershed model and to understand the potential effects of future management actions, it is important to have an understanding of the history of point source discharge locations, flow amounts and water chemistry of the discharges within the watershed. Data were provided by the PCWRA, Perry Park WSD, Roxborough WSD, Lockheed Martin. It is noted that Louviers switched to land application in 2009, and has not observed water in its lysimeters site since that time. The Town of Larkspur did not provide any data.

Other wastewater providers in the watershed include the Sacred Heart Retreat and Ponderosa Retreat and Law Enforcement Center These are septic system discharges, that don't have point source discharges.

A table of point source discharge locations is included in Appendix B.2.

4.1 PCWRA WWTF

The Plum Creek Water Reclamation Authority provided effluent data from 1995 through 2015. These data are collected at routine intervals in accordance with PCWRA's CDPS discharge permit requirements.

Parameters provided in the dataset include alkalinity, $CBOD_5$, calcium, chemical oxygen demand, chloride, conductance, copper, E. coli, total hardness, magnesium, manganese, ammonia, dissolved nitrogen, total-kjeldahl nitrogen, nitrate, nitrate + nitrite, nitrite, total inorganic nitrogen, dissolved organic carbon, total organic carbon, pH, total phosphorus, total potassium, total sodium, sulfate, sulfide, temperature, total suspended solids.

The PCWRA effluent dataset did not require additional formatting. The data were uploaded to the database as is. Field mapping was conducted to standardize parameter names, location names, and units within the database.

4.2 Perry Park WWTF

The Perry Park Water & Sanitation District has two service areas served by two different facilities. Data were provided by the Perry Park WSD for the Waucondah and Sageport facilities. Sageport data were provided from 2005-2008 and 2010-2014. Waucondah data were provided from 2005-2014. The provided data were not available in an electronically manipulable format and were therefore hand entered into spreadsheets. Some transcribed data were questionable and flagged accordingly in the model database.

Due to the additional effort to transcribe non-manipulable data, a subset of parameters provided were transcribed and uploaded to the database. Parameters that were included in the model database are effluent BOD (30d average), TSS (30d average), total phosphorus (30d average), minimum pH, maximum pH, ammonia (30d average), flow (30d average), and flow (daily maximum).

Field mapping was conducted to standardize parameter names, location names, and units within the database.

4.3 Roxborough WWTF

The Roxborough Water & Sanitation District provided data from 2001 through 2007. The data were provided as individual DMR sheets, one for each year, with data tabulated monthly. Data were compiled into a continuous format for upload to the database. Following September 2007, Roxborough stopped discharging to the watershed (personal e-mail from Mike Marcum dated October 8, 2015), and Roxborough's effluent stream has been conveyed by pipeline to the Littleton Englewood WWTF since that time.

Parameters that were added to the model database include daily effluent flow, BOD, TSS, temperature, ammonia, total phosphorus, pH, fecal coliform, residual chlorine, and nitrate+nitrite. Influent data were available but were not added to the model database because they are not needed for modeling purposes.

Field mapping was conducted to standardize parameter names, location names, and units within the database. No additional metadata were provided for these results.

4.4 Town of Larkspur

The Town of Larkspur did not provide any data and indicated that it does not discharge to the watershed (personal e-mail from Julie Vlier dated August 26, 2015).

4.5 Louviers WSD

The Louviers Water and Sanitation District did not provide any data. The facility began discharging to groundwater in 2009, and has not observed any water in its lysimeters since that time (personal e-mail from Julie Vlier dated August 26, 2015). Prior to 2009, the facility did have a surface water discharge but no data were provided.

4.6 Lockheed Martin

Lockheed Martin provided wastewater treatment plant effluent data including monthly total phosphorous, ammonia as N, and TSS data. Monthly flow data were provided from 2000 to 2015; data for all other parameters were provided for the period from 1995 to 2015.

All data were delivered in a readily importable format for the database. The monthly discharge data were in an annual cross-tab format but required minimal processing for uploading to the model database. Field mapping was conducted to standardize parameter names, location names, and units within the database.

5.0 NONPOINT SOURCE FLOW AND WATER CHEMISTRY

Nonpoint pollution sources comprise a significant component of nutrient loading within the Chatfield Basin. Nonpoint sources are diffuse sources including stormwater, groundwater, septic systems, agricultural runoff, precipitation, and atmospheric deposition. Due to the difficulty in directly monitoring these sources, a variety of sources are necessary to develop assumptions for model inputs. Studies from other nearby watersheds, as well as state and national scale data may be substituted for watershed-specific data. As additional local data are collected, the model may be refined in the future.

5.1 Stormwater Data – Regulation No. 85 Gap Analysis Report

Stormwater is an important component of modeling. Flows resulting from precipitation events may reach Plum Creek, the South Platte, and their tributaries either as overland flow, groundwater flow, or as point source discharges from stormwater outfalls. LRE requested stormwater flow and water chemistry data from the CWA modeling subcommittee, but none was provided, and likely very little stormwater nutrient data has been collected in the watershed since monitoring is not currently required.

A large effort funded by the UDFCD and the Colorado Stormwater Council was conducted in 2013 in order to identify existing stormwater information and the needs for additional data collection to quantify nutrient loading contributions from MS4s.

The report was prepared in order to satisfy requirements contained in Colorado's Nutrients Management Control Regulation (Regulation No. 85) for MS4 permittees. It is a valuable resource that contains among other information, a compilation of event-mean-concentration study descriptions and results, The authors concluded:

> *"The overall finding from this Data Report is that there is a significant EMC-based urban runoff data set useful and sufficient for characterizing nutrient loads in urban runoff in Colorado. This report provides statistical characterization of total phosphorus and total nitrogen concentrations by land use, including measures of central tendency and variability, which can be used in a variety of load estimation methods, ranging from simple spreadsheet tools to more advanced models. (Reg. 85 Gap Analysis Report, pg. 1)"*

The report contains total phosphorus, total nitrogen, TSS, results for event mean concentration and dry weather grab sample results by land use. Additionally, correlation statistics were determined for relationships between each set of parameters. Also, ranges of stormwater concentration information are summarized at the national level by Rain Zone and land use. Bochis (2010) determined that Rain Zone 6 could be supplemented for lack of data in Rain Zone 9 (which includes Colorado).

The report includes summaries of the following datasets:

- Denver Regional Urban Runoff Program (DRURP)
- National Urban Runoff Program (NURP)
- Urban Drainage and Flood Control District/International Stormwater BMP Database
- City of Ft. Collins/CSU
- Phase I Stormwater Permit Monitoring for the Denver Metro Area
- Phase I Stormwater Permit Monitoring for Colorado Springs

- Colorado Department of Transportation
- Arapahoe County Water and Wastewater Authority
- Bowles Metropolitan District/Grant Ranch

5.2 CWA Groundwater Chemistry

A groundwater study was conducted in the Chatfield basin from 1990 through 2000. The results of this study are documented in the "Chatfield Basin Water Quality Data Assessment report (TDS Consulting, 2001). The CWA master data source files also contain well data at multiple locations within the watershed for April, May, Jun of 2001, 2002. It is our understanding that data files may be available that contain intermittent groundwater data from 1990-2001 (Chatfield Basin Water-Quality Data Assessment).

The study includes water chemistry data from 6 alluvial wells along Plum Creek for parameters including temperature, specific conductance, dissolved oxygen, total nitrogen, total phosphorus, orthophosphorus, and some intermittent nitrate data. Locations for these wells were not provided. Locations may be estimated based on hard copy maps provided within the spreadsheet data summary files or annual water quality reports prepared for the CWA (see 2002 CWA annual report); however precise locations would be ideal. A table of wells and scanned maps is included in Appendix B.3

These data were not provided in an easily portable database format. If these GW data are to be stored in the WQ database, additional processing will be required. If the data are considered to be important for modeling purposes, they will need to be converted to a flat-file format for storage in the database and processing.

5.3 USGS NWIS Groundwater Chemistry

Water chemistry data are available from the USGS NWIS and EPA Storet databases. These data may be relied upon as needed for model development to supplement CWA water chemistry data.

NWIS and Storet data were obtained from the Water Quality Portal website, www.waterqualitydata.us. The data were retrieved by 8 digit HUC ID 10190002. Next the locations were clipped based on the watershed boundary layer provided by the CWA.

A comprehensive review of Water Quality Portal data was not conducted at this time. The purpose of downloading the data is to provide an additional resource where known datasets are lacking key information. During the data compilation workshop, it was decided that the NWIS dataset would not be relied upon as a primary data source due to the lack of supporting information with the data. These data may have value however, if other data are lacking or require supplementation. For example, these data may be used to provide groundwater quality concentration information where other data are not readily available.

5.4 Agricultural Runoff

Agricultural runoff often contains elevated levels of nitrogen and phosphorus due to application of fertilizers to croplands, and also due to animal waste that may contact stormwater or leach nutrients to the groundwater table. The CWA did not provide any site specific data for agricultural runoff nutrient concentrations. Results of a study in Cherry Creek (Novotny & Chesters) indicated cropland runoff concentrations of 0.02 mg/L to 1.7 mg/L for total phosphorus, predominantly from soil loss.

5.5 Septic Systems Spatial Data

Septic systems can be a significant source of nutrients to groundwater. Areas with many septic systems, particularly when they are located adjacent in close proximity to waterbodies, may be a source of nutrients to the watershed. Since phosphorus is readily adsorbed to sediments, nitrate from septic systems tends to be of greater concern as distance to surface waterbodies increases. A GIS layer was provided by the CWA that includes the locations of individual sewage disposal systems (ISDS). The file was provided in ArcMap format, and no additional processing is required.

Additionally, a “Hot-spot study” (Gorman 2013) was conducted for the watershed, which relied on GIS processing of soils and hydrologic information and distance to surface waterbodies to determine risk of septic loading of nitrates to nearby waterbodies.

5.6 Precipitation Water Chemistry

Rainfall may contain small amounts of nitrogen and phosphorus. No data were provided by the CWA; however based on a compilation of research conducted in Cherry Creek (Ruzzo, 2002), it was determined that precipitation accounts for dissolved phosphorus concentrations of 0.02 mg/L to 0.04 mg/L (per Novotny & Chesters, 1981). Additional sources of data may be reviewed during model development.

5.7 Atmospheric Deposition

Dry atmospheric deposition may also account for small amounts of nitrogen and phosphorus. These nutrients build up on land surfaces between rainfall events and wash off when storm events produce runoff. No data were provided by the CWA; however, based on a compilation of research conducted in Cherry Creek (Ruzzo, 2002), it was determined that atmospheric deposition accounts for dissolved phosphorus concentrations of 0.02 mg/L to 0.04 mg/L (per Novotny & Chesters, 1981). Additional sources of data may be reviewed during model development.

6.0 SOIL CHEMISTRY AND SOIL LOSS

Soil erosion is likely a significant source of phosphorus loading to the Chatfield watershed, particularly from Plum Creek, where the stream channel consists of sandy sediments and many reaches of the stream are unstable. The CWA did not provide any soil chemistry data; however several studies have been conducted in the adjacent Cherry Creek Watershed Basin.

6.1 Cherry Creek Basin Data

Several studies have been conducted in the adjacent Cherry Creek Basin to obtain information about nutrient concentrations in the soils. The primary source of this information was a literature review conducted by CH2M Hill in 2009 in conjunction with the study "Phosphorus Removal Potential by Implementation of the East Plum Creek Stream Restoration Project." (CH2M Hill 2009) The full references were not reviewed for this effort, but key findings regarding nutrient concentrations of soils in the adjacent Cherry Creek Basin were compiled.

The review of past studies indicates that there is a large amount of variability in phosphorus concentrations in the soils. Results from individual studies are summarized below:

- Soil measurements ranged from 0 to 3.9 mg/kg (C. Halepaska & Associates, 1999) and from 1 to 60 mg/kg (CSU Extension)
- Streambank measurements were typically much higher, ranging from 310 to 580 (C. Halepaska & Associates, 1999) and 950 mg/kg (CH2M Hill, 1997)
- Ruzzo, 2002 – Indicated undisturbed soil orthophosphorus concentrations up to 3.9 mg/kg, with an average value of 1.5 mg/kg. These results were from grab bag samples from Castlewood Canyon, north east of Castle Rock, across 4 soil types. (per John C. Helepaska and Associates, Inc. 1999)
- Phosphorus concentrations increase from 1.5 mg/kg in native soils in Cherry Creek, in the upper watershed, to greater than 580 mg/kg in channel sediments near the Cherry Creek Reservoir

6.2 RUSLE Model for Chatfield Basin

A soil erodibility study was conducted (Gorman 2013) to determine areas in the watershed at high risk for soil erosion. This study relied on the RUSLE method, which consists of factors for rainfall and runoff, soil erodibility, slope length and steepness, cover and management, and conservation practices. The underlying inputs to this study and the conclusions may have utility for model development and calibration.

7.0 FLOW AND DIVERSION DATA

Streamflow data and diversion data are necessary for model hydrologic calibration. It is helpful to have flow data at model boundaries (upstream headwater conditions and downstream "pour" points), as well as at the mouths of major tributaries to the main channels. A good understanding of flows throughout the watershed enables a better accounting of load partitioning, which improves model calibration. Sub-daily streamflow data is also useful for assigning runoff coefficients and ensuring that stream hydraulic information is accurate. Sources of flow and diversion data in the Chatfield watershed include USGS data, Urban Drainage and Flood Control data, and CDSS diversion data.

7.1 USGS Data

Flow records were obtained from USGS gages in the basin using Colorado Decision Support System TSTool. Flow records were compiled for the modeling period. Flow locations and periods of record are summarized in Appendix B.4. TSTool flow files will be filled by regression and other statistical approaches where necessary. Files can be exported as CSV files for linking to the model.

7.2 Field Flow Measurements

Field flow measurements have been conducted in conjunction with water quality monitoring by the PCWRA, Denver Water, and GEI. Field flow measurement locations and periods of record are the same as stream water quality sampling locations summarized in Appendix B.1

7.3 CDSS Diversions

Key daily surface water diversion structures are included in the water balance can be pulled from HydroBase and formatted for use in the model using TSTool. Below is a summary of the key structures located in Water District 8 that have irrigated acreage, water budget information, and diversions that should be considered in the model water balance (from Appendix A of the SPDSS Consumptive Use Analysis Report).

No.	Structure ID	Structure Name	2001 Acreage	Comments
292	0801001	AURORA INTAKE	0	Carries water to Aurora Reservoir and Aurora Demand Nodes, Primary DivSys with 0801001
293	0801002_D	DENVER CONDUIT NO 20	0	Primary DivSys with 1005. Carriers to Marston Reservoir and Marston WTP for Denver Demand Nodes
294	0801004_D	HIGHLINE CNL	589	Primary DivSys with 1007
295	0801008	CITY DITCH PL	55	Also carries to Englewood Demand Node (or WD 8 Municipal Demand Node)
296	0801009_D	NEVADA DITCH	93	Primary DivSys with 1011 and 1462, plus carries to municipal demand
297	0801013	ENGLEWOOD INTAKE	0	Carries water to Engelwood Demand (or WD 8 Municipal Demand)
298	0801014	ARAPAHOE POWER PLANT	0	Industrial water for power plant
299	0801015	EPPERSON DITCH/PUMP	0	Alternate point to Denver (Harriman Ditch) - Irrigates outside golf course demand
300	0801016	LACOMBE POWER PLANT	0	Industrial water for Zuni power plant
301	0801017	DENVER FOOTHILLS PL 26	0	Carries to Foothills WTP - Denver Demand Nodes
302	0801124	HAYLAND DITCH	15	
303	0801125	FAIRVIEW DITCH	145	
304	0801127	OLD TIME DITCH	15	
305	0801128	GARDEN DITCH	15	
306	0801235	RED ROCK DITCH	16	
307	0801237	SPRING CREEK DITCH	70	
308	0801240	RATCLIFF DILLON DITCH	70	
309	0801241	DAKAN DITCH	70	
310	0801362	JOHN JONES DITCH	71	
311	0801400	ALDERMAN DITCH	27	
312	0801403	HEISER DITCH	77	
313	0801404	MCCRACKEN DITCH	103	
314	0801405	SMITH DITCH	33	
315	0801406	SCHREIBER DITCH	11	
316	0801412	SIXTY SEVEN DITCH	94	
317	0801413	CRAWFORD DITCH	27	
318	0801414	BIRMINGHAM DITCH	7	
319	0801416	GOODRICH DITCH	46	
320	0801417	ROCKY RIDGE DITCH	0	Historical acreage, 0 in 2001
321	0801492	IZZARD DITCH	23	
322	08AURORA_I	AURORA INDOOR DEMAND		Receives water from Aurora Intake and other sources
323	08AURORA_O	AURORA OUTDOOR DEMAND		Receives water from Aurora Intake and other sources
324	08DENVER_I	DENVER INDOOR DEMAND		Receives water from S. Boulder Divr Conduit, Denver Conduit 20, Denver Foothills Pipeline 26, and other sources

A straightline diagram indicating the locations of diversion structures in included in Appendix C.

7.4 UDFCD

The Urban Drainage and Flood Control District (UDFCD) collects flow data throughout the Denver metropolitan area as part of its ALERT system. Three stations within the Chatfield watershed collect flow data pertinent to the watershed model on East Plum Creek and West Plum Creek. Station locations are summarized in Appendix B.4

8.0 STREAM HYDRAULICS AND SEDIMENT TRANSPORT

Hydraulic information is an important component for the watershed model. Stream channel geometry (slope, channel width, and side slopes) and channel characteristics (such as manning's n) are primary drivers of travel time, stream depth, velocity, and peak flow rates. These factors drive nutrient functions such as settling of solids, and periphyton growth (i.e. due to depth/light limitation). One challenge with hydraulic information for Plum Creek is that the streambed is in a constant state of flux. Unless permanent structures are installed, there is no accurate way to maintain consistent rated sections on a long-term basis. Hydraulic information for the watershed includes cross-section information contained in the Castle Rock HEC model, PCRWA field cross-section measurements, and USGS stream rating information.

8.1 Castle Rock HECRAS Cross-Section Data

The Town of Castle Rock has developed a HECRAS model in conjunction with its August 2013 Amended Flood Hazard Area Delineation (FHAD) Study that encompasses the portions of East Plum Creek that are located within the limits of the Town of Castle Rock. Hydraulic information was developed based on 2-foot topographic data, with cross-section spacing at less than 1500 feet. (Castle Rock FHAD Study, 2013)

8.2 PCWRA Cross Sections

PCWRA provided field cross-section measurements that were taken during routine sampling events from April 2013 through November of 2014 at its monitoring locations, including EPC 33.6, EPC 21.1, EPC 15.3, EPC 15.1, EPC, 11.1, WPC 29.7, WPC 10.9, PC 9.5, PC 6.7, PC 3.5, and PC 0.3. These measurements provide one of the only sources of detailed channel geometry for the Plum Creek Basin outside of the Castle Rock HECRAS model.

8.3 USGS Stream Rating Information

The USGS maintains stream rating information for active flow measurement gages. The following gages have rating tables, available on the USGS NWIS website. Rating data are available at the following USGS gage locations:

- 06709000 Plum Creek Near Sedalia
- 06709530 Plum Creek at Titan Rd. Near Louviers
- 06708800 East Plum Creek above Haskins Gulch near Castle
- 06708600 West Plum Creek Near Perry Park

Additionally, for other USGS stations that do not have rating tables, rating curves may be developed based on the relationship with field measured flows and gage heights. Hydraulic information may be supplemented with high resolution digital elevation model data, where necessary.

8.4 South Platte Data from Post-Fire Report

Two stream cross sections were measured in Waterton Canyon, downstream from Strontia Springs Reservoir and upstream from Chatfield Reservoir. (See Table 2-3 of "Analysis and Mapping of Post-Fire Hydrologic Hazards" Report).

8.5 High Resolution Digital Elevation Models

USGS 10-meter resolution Digital Elevation Model (DEM) data is available in the Chatfield Watershed for this project. This resolution DEM is optimal for hydrologic routing at the scale of the Chatfield watershed. It has been thoroughly checked to ensure that there are no spurious errors (e.g. pits and spikes) within the DEM structure that might impact realistic routing of overland flow. We have utilized flow routing algorithms within ArcHydro to ensure we can handle routing challenges in areas of more complex topography using this DEM.

9.0 CLIMATE

9.1 NCEI Data

There are several climatological sites accessible from the National Centers for Environmental Information (NCEI) formerly the National Climatic Data Center (NCDC). The five sites expected to be used for modeling purposes include Kassler near Chatfield Reservoir, Roxborough State Park, Sedalia, Strontia Springs Dam, and Castle Rock. Additionally there is one site in Castle Rock with sub-daily precipitation which can be used as needed based on the model time step. A summary of sites including which sites have daily data and which sites have sub-daily data is shown in Appendix B.5

9.2 UDFCD Data

The Urban Drainage and Flood Control District maintains many climate monitoring locations throughout the Denver Metropolitan area. The Modeling Team reviewed the locations and requested climate data from the UDFCD. The Modeling Team requested five-minute data for three stations within the watershed for the period from 2000-2015, including Tomach Rd. (2990), East Plum Creek @ HW 105 (2010), West Creek Wx (3020). Parameters requested included flow, stage, precipitation, air temperature, relative humidity, barometric pressure, and wind. Unfortunately, the period of record at these locations was limited to 2010-2015. Originally, it was intended that these sites could be used as climate inputs to the model. However, upon receipt, due to the shorter period of record, it is anticipated that they will serve instead to supplement NOAA climate data, and will provide useful information for disaggregating daily data to hourly for the model, as well as to potentially simulate individual storm events within the model. A table of locations is included in Appendix B.5.

9.3 Prism Data

PRISM daily gridded precipitation data was used to analyze the annual precipitation volumes within the watershed. The HSPF model requires hourly precipitation so daily data has been disaggregated to hourly using the closest available hourly precipitation sites.

- Roxborough State Park (COOP 057249) will be used to represent the precipitation for the mountainous regions of the watershed.
- Castle Rock (COOP 051401) will be used to represent the precipitation and temperature for the Plum Creek lowlands.
- Kassler (COOP 054452) will be used to represent the lowland areas around Chatfield Reservoir
- Strontia Springs (COOP 058022) will be used to represent the precipitation in the lower mountainous regions.

Temperature and snow data is available at these four stations and will be used as inputs to the HSPF model. Other datasets required by the HSPF model for in-stream water quality processes, and snow modeling include wind, dew point, and cloud cover which will be used from the Centennial Airport since this data has less availability. Other inputs to the HSPF model include solar radiation and potential evapotranspiration, which will be calculated from cloud cover and temperature, respectively.

10.0 LAND USE

10.1NLCD Data

The National Land Cover Database (NLCD) 2011 land use map covers the entire Chatfield basin watershed area. This dataset provides more refined detail than the CWA land use layer, and based on our analysis, is more accurate. This dataset will be the primary source of land use data for the watershed model.

A supplemental memorandum providing a comparison between the NLCD and CWA land use datasets is included with this memorandum as Appendix D.

The land use data as well as the soils data will be used to develop the hydrologic response units (HRUs) within the watershed model. The HRUs are parameterized according to their base features and are then grouped together to describe a subwatershed within the model.

The National Land Cover Database (NLCD) 2011 dataset has been combined into eight land use types comparable to those provided by the CWA. The land use types are open water, low intensity developed, high intensity developed, forest, grassland and shrubs, pasture/hay, cultivated crops, and wetlands.

10.2 CWA Data

The Chatfield watershed encompasses portions of Douglass County, Jefferson County, El Paso County, and the town of Castle Rock. Current and future land use mapping was provided by the CWA. The CWA data will be used to refine urbanized area land use information within the NLCD coverage, particularly in and around Castle Rock, based on more recent developments that have been constructed. The future land use coverage will also be used to identify expected future land use changes.

10.3Soils Data

SSURGO and STATSGO soils data have been analyzed and will be used to parameterize the layers within the model. For simplicity, hydrologic soil groups (HSGs) will be combined into low runoff potential (A and B) and high runoff potential (C and D). This is common practice utilized by the USGS when building HSPF models.

10.4 CDSS Irrigated Lands and SPDSS State CU Consumptive Use

Statewide irrigated lands GIS coverages are available through the Colorado Decision Support System (CDSS). These GIS coverages provide more specific information than the CWA and NLCD land use coverages regarding agricultural uses; specifically crop patterns and irrigation methods, are provided for each irrigated parcel. The files are snapshots in time, and are available for the years 1956, 1976, 1987, 1997, 2001, 2005, and 2010.

Additionally, consumptive use estimates have been developed for major (key) irrigation structures as part of the State's South Platte Decision Support System (SPDSS) using StateCU within Water District 8 (CWA Boundary). StateCU provides a monthly summary of irrigated crop consumptive use, diversions, canal losses, and unlagged return flows that is important to the overall watershed water balance.

Using the list of key structures in the basin from SPDSS and the daily surface water diversions from HydroBase a summary of major municipal and irrigation surface water diversions can be summarized for use in the model.

The irrigated acreage coverages provide a timeline of crop irrigation in the Chatfield basin. Each parcel in the data set is tied to a surface or ground water structure, a cropping pattern, and an application method (flood or sprinkler). These coverages can supplement the land use information and provide a mechanism to summarize nutrient loadings from agriculture throughout the basin over time.

In addition, when the irrigated acreage coverages are paired with the SPDSS StateCU analysis, a spatial and temporal estimate of evapotranspiration, consumptive use, and unlagged return flows from agricultural practices can be used in the overall water balance for the model. Data can be pulled and summarized from StateCU for input into the model using TSTool.

11.0 RECOMMENDATIONS

Recommendation: Implement a systematic data management approach

A consistent approach to data management ensures that data collected over time can be readily added to the water quality model for adjustment of the model calibration and model updates with minimal data processing required. Recommended data management practices for the CWA and its consultants collecting water quality data, and processing water quality information include:

- Develop a standardized list of data fields that should be completed for each sampling event
- Data qualifiers (flags) indicating data quality a sampling site logs should be enhanced and maintained. A formal set of data qualifiers that is used consistently by all entities and their consultants collecting and storing data would help to confirm data quality and accuracy.
- Develop a standardized data format that is consistent with fields in a centralized water quality database. The Model Database may serve as a template.
- Develop a schedule to routinely update and enter new data into the centralized location
- Standardize sampling location names, parameter names, fraction, and speciation codes, and units prior to entry into the database. This could be handled within the database, but it is much simpler to standardize pre-loaded data.

Recommendation: Conduct storm event sampling

All water quality data that has currently been added to the water quality database is limited to discreet sampling events. It is our understanding that the CWA has two ISCO samplers available to deploy within the watershed in the next year. One is expected to be deployed at the Waterton Canyon USGS location, and one within the lower portion of Plum Creek. The Modeling Team, along with Chris Carson (PCWRA) and Al Baker (Centennial WSD), conducted a site visit on August 13, 2015 to review potential locations on Plum Creek where stormwater sampling could be conducted. Only two of the four sites identified prior to the visit could be accessed. One was under a bridge that was undergoing construction, and one was on gated private property. Due to the shifting streambed, adequate locations are constrained by places with permanent structures (bridges) that confine the channel. Additionally, sites must be accessible and provide a safe location for sampling equipment to be stored away from potential vandals. Of the sites visited, the Louviers Main St. Bridge site was the most promising. It is premature for the Modeling Team to recommend a specific location. However, storm event concentration and flow data would be useful for model calibration.

This type of sampling can be conducted as time-paced volume-paced, pollutograph sampling, or composited time or volume-paced sampling. Ackerman (2011) concluded that pollutograph sampling is the most accurate with lowest bias, but also the most expensive. Volume-paced microsampling was recommended where accuracy is desired, but cost is limiting (Ackerman, 2011). Without real-time flow monitoring, automated volume-paced sampling would not be possible. We note that storm event sampling is considerably expensive due to field personnel time and lab analysis for many samples.

Recommendation: Conduct tributary sampling

A tributary sampling program, including flow and water chemistry, is recommended to help determine native or baseline sediment loads from different parts of the basin, and confirm hydrologic inputs to East Plum Creek, West Plum Creek, and the South Platte River. If budget is limited for additional permanent sites, this program could expand upon the synoptic "assessment" monitoring that was conducted in the late 1990's and early 2000's.

Recommendation: Conduct special sampling as projects are completed

If stream restoration projects or BMPs in the watershed are completed, water quality and flow data above and below these locations will be useful to refine model calibration over time and to determine the effectiveness of different project types at removing nutrient loads. The Massey Draw special sampling is a good example of this type of effort.

Recommendation: Conduct sediment sampling for nutrient water chemistry within the Chatfield basin

Sediment sampling in the watershed and streambanks, similar to studies conducted in the Cherry Creek Basin, should be considered in order to provide data regarding sediment nutrient concentrations.

Recommendation: Implement additional flow gaging at key water chemistry sampling locations

If feasible, channel surveys and channel ratings be completed and maintained at the ungaged cross sections and staff gages installed. This will allow high flows to be calculated when field personnel cannot access the sampling sites. It is recommended that staff gages be installed at key ungaged sampling locations for reference when completing monthly stream surveys. This will provide a better metric of streamflow conditions than high, low, average qualitative estimates which can be subjective.

Recommendation: Implement winter sampling protocols

Icing prohibits winter sampling at several sampling sites in some months. Winter sampling protocols should be examined to determine how data collection during these low flow periods can be improved.

Note that as model development continues, recommendations specific to spatial data gaps and parameter gaps will be refined and delivered with the final modeling report. At this point, recommendations are for preliminary consideration and planning purposes.

12.0 REFERENCES AND DATA SOURCES

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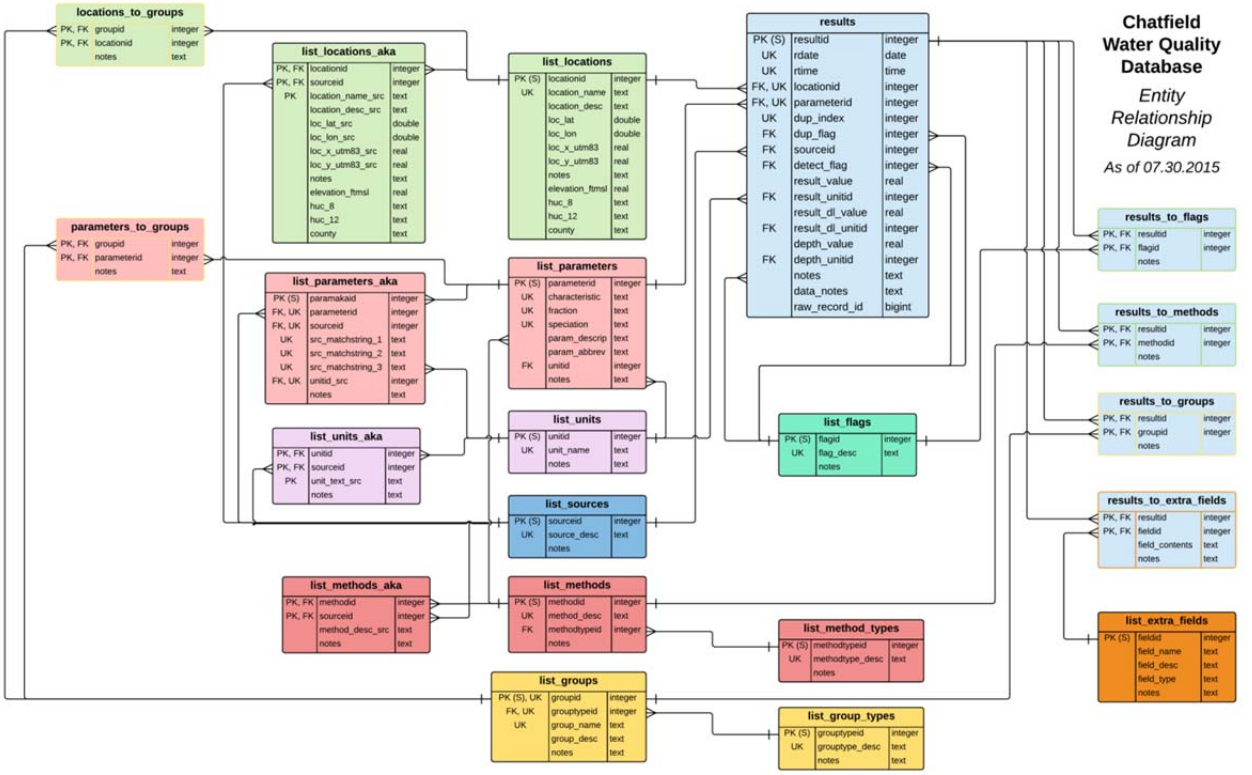
Appendix A – Model Water Quality Database Structure



Appendix B – Sampling and Measurement Locations

Appendix B.1 Stream Water Chemistry Sampling Locations Table

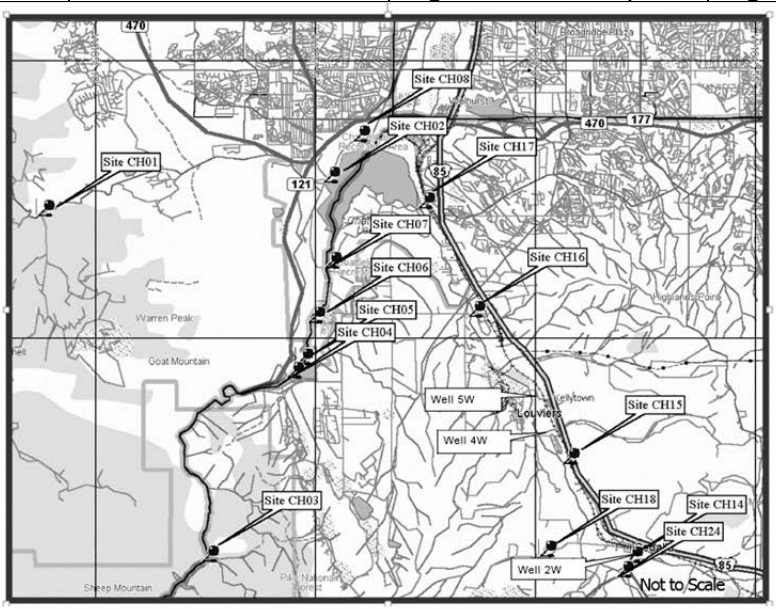
Org.	Name	Description	Latitude	Longitude	Notes	Elevation	HUC	County		TP	TSS	Ortho-P
PCWRA	EPC 11.1	E. Plum Confluence with Plum Cr	39.4324	-104.9645			10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
PCWRA	EPC 14.7	E. Plum d/s of PCWRA (Previously mislabeled as EPC 15.1)	39.4252	-104.9113	Previously mislabeled as EPC 15.1, Corrected by Chris Carson on 7/20/15 by email to Mark Mitisek		10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
PCWRA	EPC 15.3	E. Plum u/s of PCWRA	39.4219	-104.9014			10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
PCWRA	EPC 21.1	E. Plum Cr at Castle Rock	39.3634	-104.8642			10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
PCWRA	EPC 33.6	E. Plum u/s of Larkspur	39.2187	-104.8867			10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
PCWRA	EPC 20.7	E. Plum Cr at Castle Rock (Post-October 2014, replace 21.1 station)	39.3681	-104.8633	Post-October 2014, replaces EPC 21.1		10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
PCWRA	PC 3.5	Plum Cr at Titan Rd, u/s of Reservoir	39.5074	-105.0244			10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
PCWRA	PC 6.7	Plum Cr at Louviers	39.4704	-104.9990			10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
PCWRA	PC 0.3	Plum Creek at Chatfield Reservoir (NEW)	39.5393	-105.0489			10190002	Douglas		04/2014-12/2014	04/2014-12/2014	04/2014-12/2014
PCWRA	PC 9.5	Plum Cr at Sedalia	39.4385	-104.9826			10190002	Douglas		05/2013-12/2014	05/2013-12/2014	05/2013-12/2014
PCWRA	WPC 10.9	W. Plum confluence with Plum Cr	39.4294	-104.9679			10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
PCWRA	WPC 29.7	W. Plum u/s of Perry Park	39.2415	-104.9584			10190002	Douglas		04/2012-12/2014	04/2012-12./2014	04/2012-12/2014
GEI	WS-LP-010	S. Platte River influent above Chatfield Reservoir	39.5206	-105.0792	site is below Waterton Canyon gage		10190002	Douglas		01/2010-12/2014	01/2010-12/2014	01/2010-12/2014
GEI	WS-LP-023	Plum Creek influent above Chatfield Reservoir	39.5391	-105.0488			10190002	Douglas		01/2010-12/2014	01/2010-12/2014	01/2010-12/2014
USGS/DWR	DWR PLAWATCO	South Platte River at Waterton (previously USGS 06708000)	39.4883	-105.0922	location from USGS NWIS site							
USGS/DWR	USGS 06709530	Plum Creek at Titan Road near Louviers, CO (DWR alias PLUTIRCO)	39.5074	105.0245	location from USGS NWIS site							
CAS	Massey Draw in Chatfield State Park		no coords.	no coords.	see map in CAS 2001 files for rough location					8/2002-9/2004	8/2002-9/2004	
CAS	Massey Draw at C-470		no coords.	no coords.	see map in CAS 2001 files for rough location					1/2005-12/2006	1/2005-12/2006	
CAS	Massey Draw at Wadsworth		no coords.	no coords.	see map in CAS 2001 files for rough location					3/2005-12/2006	3/2005-12/2006	
CAS		Plum Creek at Titan Road near Louviers	39.5074	105.0245	location assumed at USGS gage based on later data files w/ location info					01/2001-12/2006	01/2001-12/2006	01/2001-12/2006
CAS		South Platte River at Waterton	39.4883	-105.0922	location assumed at USGS gage based on later data files w/ location info					01/2001-12/2006	01/2001-12/2006	01/2001-12/2006
DW		Plum Creek at Titan Road near Louviers	39.5074	105.0245	location assumed at USGS gage based on later data files w/ location info					01/2007-12/2009	01/2007-12/2009	01/2007-12/2009
DW		South Platte River at Waterton	39.4883	-105.0922	location assumed at USGS gage based on later data files w/ location info					01/2007-12/2009	01/2007-12/2009	01/2007-12/2009
	Mapped together @ Titan Rd.											
	Mapped together @ PC just abv. Res											
	Mapped together @ Waterton Canyon gage											

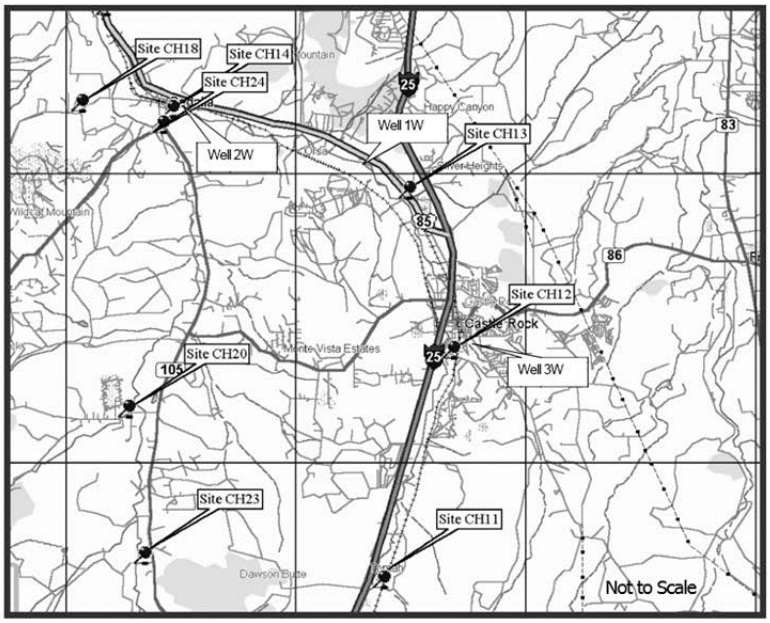
Appendix B.2 Point Source Discharges Sampling Locations Table

Name	Description	Latitude	Longitude
Larkspur, Town of	CO-0035891	39.2306	-104.8802
Louviers, Town of	CO-0027359	39.4853	-105.0061
Perry Park (Sageport)	CO-0043044	39.2573	-104.8938
Perry Park (Waucondah)	CO-0022551	39.2629	-104.9764
Plum Creek Wastewater Authority #1	CO-0038547	39.4249	-104.9042
Roxborough Park	CO-0041645	39.4844	-105.0972
Lockheed Martin	CO-0001511	39.4953	-105.0972

Appendix B.3 Groundwater Sampling Locations (see maps below)

Location ID	Location Description	Latitude	Longitude
1W	North of Castle Rock	No Coords. – to be digitized from map	No Coords. – to be digitized from map
2W	Near Sedalia	No Coords. – to be digitized from map	No Coords. – to be digitized from map
3W	Near Castle Rock	No Coords. – to be digitized from map	No Coords. – to be digitized from map
4W	S. of Louviers	No Coords. – to be digitized from map	No Coords. – to be digitized from map
5W	N. of Louviers	No Coords. – to be digitized from map	No Coords. – to be digitized from map





Appendix B.4 Flow Measurement Locations Table

Station Name	Station ID	Latitude	Longitude	Start Year	End Year	Drainage Area (sq. mi.)	Elevation (ft)
SOUTH PLATTE RIVER AT WATERTON, CO	USGS 06708000	39.4883	-105.0928	1926	2014	2621	5487.57
EAST PLUM CREEK AT CASTLE ROCK, CO	USGS 06708750	39.3844	-104.8622	1985	1989	103	6152 (estimated from Google Earth)
PLUM CREEK NEAR SEDALIA, CO	USGS 06709000	39.4383	-104.9830	1942	2014	275	5723.14
PLUM CREEK NEAR LOUVIERS, CO	USGS 06709500	39.4844	-105.0025	1947	1990	302	5588.09
PLUM CREEK AT TITAN ROAD NEAR LOUVIERS, CO	USGS 06709530	39.5074	-105.0245	1984	2015	316	5523.09
EAST PLUM CREEK ABOVE HASKINS GULCH NEAR CASTLE ROCK, CO	USGS 06708800	39.4230	-104.9046	1999	2015	116	5963.24
WEST PLUM CREEK NEAR PERRY PARK, CO	USGS 06708600	39.2595	-104.9519	2009	2015	26.9	6343.61
COTTONWOOD PARK	UDFCD 2870	39.558	-104.786	N/A	N/A	N/A	N/A
HAPPY CANYON	UDFCD 2880	39.5102	-104.8715	N/A	N/A	N/A	N/A
EAST PLUM CREEK	UDFCD 2820	39.424	-104.908	N/A	N/A	N/A	N/A
E. PLUM CREEK @ COLUMBINE	UDFCD 2800	39.2825	-104.8947	N/A	N/A	N/A	N/A
PINE CLIFF RD.	UDFCD 2810	39.372	-104.966	N/A	N/A	N/A	N/A
EAST PLUM CREEK @ HW 105	UDFCD	39.1897	-104.924	N/A	N/A	N/A	N/A

Appendix B.5 Climatological Sampling Locations Table

NCEI Daily Climatological Sites

Station Name	Station ID	Sub-watershed	Latitude	Longitude	Start Year	End Year	Variables
KASSLER, CO US	GHCND:USC00054452	South Platte	39.49	-105.0952	1918	2015	temperature, precipitation, snow depth
ROXBOROUGH ST PARK, CO US	GHCND:USC00057249	South Platte	39.4286	-105.0702	1995	2015	temperature, precipitation, snow depth
SEDALIA 4 SSE, CO US	GHCND:USC00057510	Plum Creek	39.4036	-104.9522	1956	2015	precipitation, snow depth
STRONTIA SPRINGS DAM, CO US	GHCND:USC00058022	South Platte	39.4344	-105.1208	1984	2015	temperature, precipitation, snow depth
CASTLE ROCK, CO US	GHCND:USC00051401	Plum Creek	39.4105	-104.9058	1893	2015	temperature

NCEI Sub-daily Precipitation Site

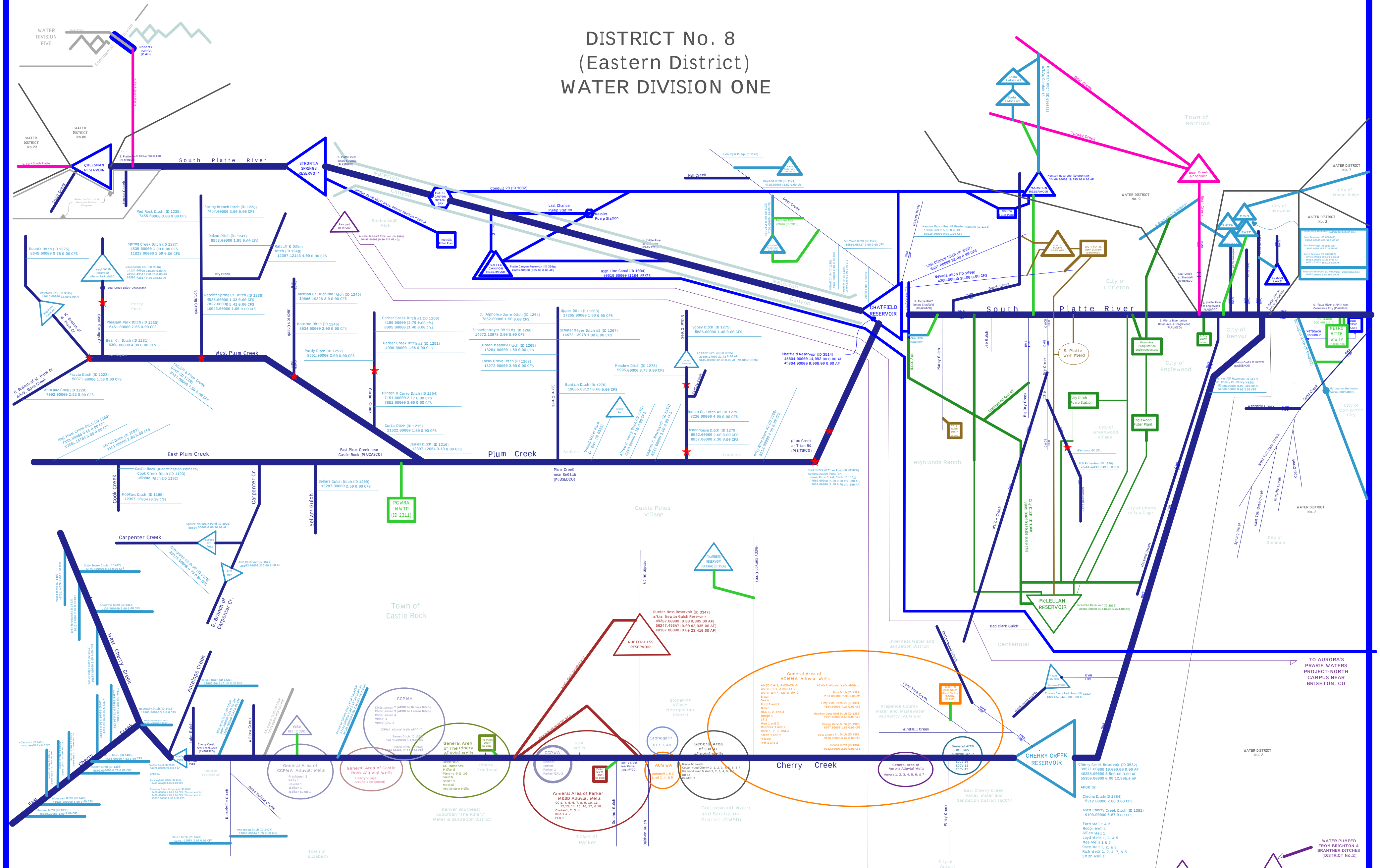
Station Name	Station ID	Sub-watershed	Latitude	Longitude	Start Year	End Year	Variables
Castle Rock, CO	COOP:051401	East Plum Creek	39.4105	-104.9058	1971	2014	15-minute precipitation, hourly precipitation

UDFCD Climatological Sites

Station Name	Station ID	Precip Inc	Precip Accu	Temp	RH	BP	Wind	Lat	Long
Chatfield Dam (1350)	1350	X	X					39.557	-105.078
Highlands Ranch WTP (2710)	2710	X	X	X	X		X	39.562	-105.019
PLUM CREEK AT TITAN ROAD NEAR LOUVIERS, CO (06709530)	06709530							39.5074	-105.0245
Cottonwood Park (2870)	2870	X	X					39.558	-104.786
Willow Creek (2940)	2940	X	X					39.294	-104.794
Spring Valley Road (2930)	2930	X	X	X	X	X	X	39.188	-104.778
West Cherry Head (2920)	2920	X	X					39.13	-104.809
Happy Canyon (2880)	2880	X	X					39.5102	-104.8715
DC Public Works (2950)	2950	X	X					39.406	-104.871
3 East/West Trailhead (3050)	3050	X	X					39.5041	-104.9411
East Plum Creek (2820)	2820	X	X					39.424	-104.908
E. Plum Creek @ Columbine (2800)	2800	X	X					39.2825	-104.8947
Indian Creek (2960)	2960	X	X					39.471	-105.002
Pine Cliff Rd. (2810)	2810	X	X					39.372	-104.966
Tomah Road (2990)	2990	X	X	X	X	X	X	39.295	-104.923
East Plum Creek @ HW 105 (3010)	3010	X	X					39.1897	-104.924
Rampart Range Road (2970)	2970	X	X					39.377	-105.094
West Creek Repeater (3000)	3000	X	X					39.175	-105.034
West Creek Wx (3020)	3020	X	X	X	X	X	X	39.174	-105.034
Fire Station 13 (1370)		X	X					39.5815	-105.1382

Appendix C – Chatfield Watershed (District 8) Straightline Diagram

DISTRICT No. 8
(Eastern District)
WATER DIVISION ONE



DISCLAIMER:

Colorado Division of Water Resources Straightline Diagram Version as of June 2014 by Dean Santistevan & DWR-Division 1 staff. Net amounts are shown (Absolute and Conditional). Example: 03-15-1974 25.5 0.0 CFS; 06-15-1908 69,446 0 AF. Recharge areas are not necessarily geographically placed. Direct flows shown on ditches, storage flows shown in reservoirs and recharge areas

NOTE:

This diagram is subject to change without notice and is a correct and authentic copy from the records and files of the State Engineer for the State of Colorado. Water rights information and structure information included in this diagram are based upon information available to the State Engineer and are believed to be accurate. However, persons seeking to use this diagram in any legal proceeding are responsible for verifying the accuracy of any information included in the diagram.

LEGEND:

ID 1234 — STRUCTURE ID NUMBER (Note: prefix "080" of WDID is omitted for all District 8 structures)
★ — DRY-UP POINTS ON THE RIVER
RIVER, NATIVE WATER IN DISTRICT
TRIBUTARY, NOT IN DISTRICT
DIVERSIONS, CANALS, AND DITCHES
RETURNS TO RIVER
PIPELINE

ACCWA
CCPWA
CENTENNIAL
CITY OF AURORA
CITY OF ENGLEWOOD
CWSD
DENVER WATER
STONEGATE
THE PINERY
TOWN OF CASTLE ROCK
TOWN OF PARKER

MEASUREMENT POINT, UNLESS OTHERWISE NOTED. COLOR INDICATES THE TYPE OF WATER MEASURED (i.e., RIVER, DIVERSION, RETURN, TRIBUTARY)
DWR GAGE STATION
USGS GAUGE

ABBREVIATIONS:

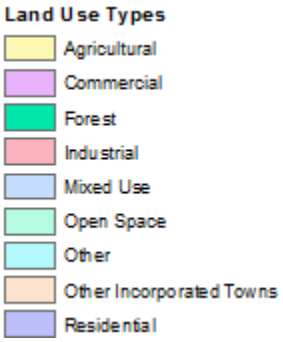
ACWWA = Arapahoe County Water & Wastewater Authority (f/k/a, Arapahoe W&SD)
APOD = Alternate Point of Diversion
AUG RT = Augmentation Return Structure
CCPWA = Cherry Creek Project Water Authority; members include ACCWA, CWSD, Inverness, The Pinery
CWCB = Colorado Water Conservation Board
DIVR = Diversion
DWB = Denver Water Board of Commissioners "Denver Water"
DWB LIRF = In-stream LIRF credit claimed by DWB in Case No. 04CW121
ECCV = East Cherry Creek Valley W&SD
FRICO = Farmers Reservoir & Irrigation Company
ISFR = In-Stream Flow Right
LIRF = Lawn Irrigation Return Flow
MD = Metropolitan District
POD = Point of Diversion
PCWRA = Plum Creek Water Reclamation Authority (f/k/a, Plum Creek Water Authority); members include Castle Rock, Castle Pines MD, Castle Pines North MD, Silver Heights W&SD, Castleton W&SD
PT = Point
SMWSA = South Metro Water Supply Authority; members include ACCWA, Castle Pines MD, Castle Pines North MD, Centennial W&SD, CWSD, Dominion W&SD, ECCV, Inverness, Meridian, Paker, The Pinery, Roxborough MD, Rangeview MD, Stonegate, Castle Rock
UCCWA = Upper Cherry Creek Water Association; members include ACCWA, Aurora, CO Div. of Parks & Wildlife, CWSD, ECCV
W&SD = Water & Sanitation District
WWTP = Waste Water Treatment Plant

Appendix D – Land Use Supplemental Memorandum

October 22, 2015

Chatfield Land Use Memo

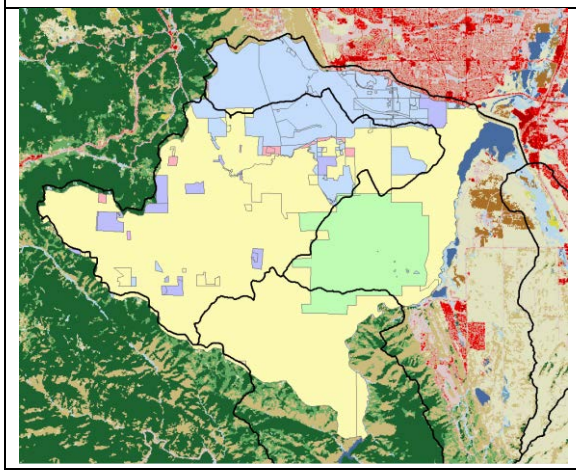
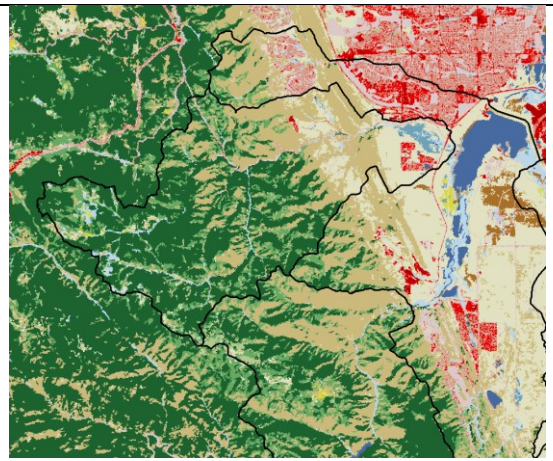
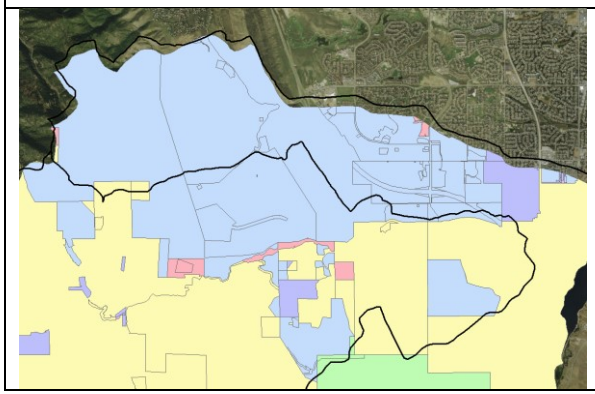
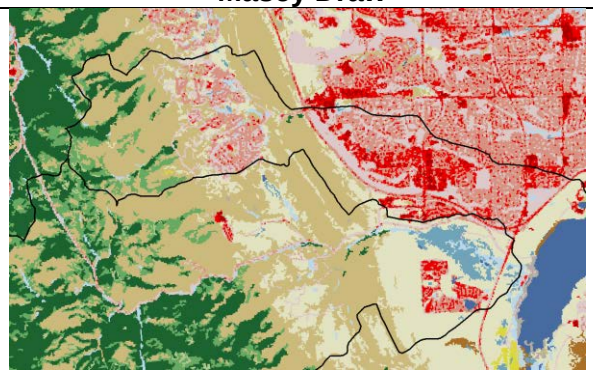
Land use is an important input for the HSPF model as it determines the foundation of the pervious or impervious land within a watershed. In the Chatfield watershed model kick-off meeting it was decided to use the CWA land use data, which consisted of land uses from Douglas County, Jefferson County, the Town of Castle Rock, and El Paso County. However, as this land use map was compared to the NLCD 2011 land use map (and aerial imagery), it was found that many portions did not adequately represent the watershed's true conditions. It was determined that the NLCD 2011 land use should be used for the model, and updated in growing urban areas to best reflect land use in 2015. Specifically, parts of the Town of Castle Rock will need to be updated in the NLCD 2011 layer to reflect the correct land use provided by the CWA. Four examples of differences between the CWA land use, NLCD 2011 land use and aerial imagery are shown in the following pages. The legends for the CWA and NLCD land uses are shown below, respectively. It should be noted that the NLCD land use datasets are the *standard*, when building hydrologic models.



CWA Land Use	NLCD 2011 Land Use

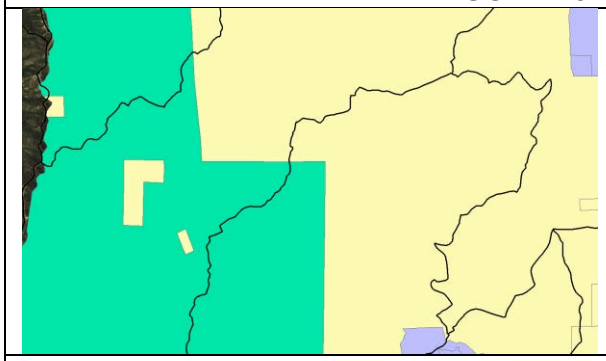
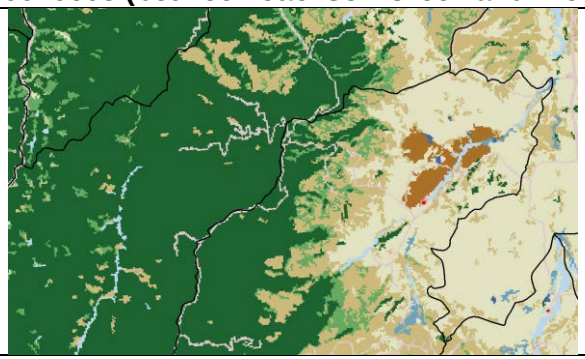
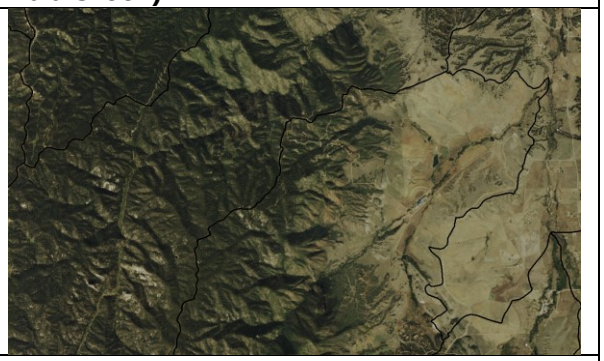
In the northern reaches of the Chatfield watershed, the CWA land use labels forested and shrubs as “agricultural” land use, which does not adequately capture the infiltration properties of this region. The large green section in the CWA land use map is “industrial”, while the aerial imagery shows this is shrubs and forest with some development closer to Chatfield Reservir. The NLCD land use captures these distinctions more closely.

In the Masey Draw catchment, the CWA land use lists nearly the entire area as “mixed use”, while the NLCD lists it as sections of shrub land use interwoven with developed residential. The NLCD land use captures the aerial imagery.

Jefferson County Land Use	NLCD 2011 Land Use	Aerial Imagery
Northern Chatfield Watershed		
		
Masey Draw		
		

These figures show further differences between the CWA land use and the NLCD 2011 land use. In the west Plum Creek watershed, the CWA land use has a coarse representation of “forested” and “agricultural” lands. The NLCD captures the proper extent of the “forested land” as well as the transition to shrub and grassland, while depicting the agricultural operation as dark brown.

In Castle Rock, the NLCD shows the “forested land” on the eastern boundary of the watershed as such, while the CWA land use designates this as “agricultural land”. The aerial image confirms this is forested and shrub land. On the left side of the image the NLCD designates some of the newer developments in Castle Rock as grassland rather than residential. This will have to be updated on the NLCD dataset as it is likely from a newer development.

Jefferson County Land Use	NLCD 2011 Land Use	Aerial Imagery
HUC-12 101900020603 (between Jackson Creek and West Plub Creek)		
		
Castle Rock