TECHNICAL MEMORANDUM

MWH

BUILDING A BETTER WORLD

To:	Valerie Esparza Helen To	**Date:** **Revised:**	February 26, 2016
From:	Miko Aivazian, MWH Matthew Huckaby, MWH Adnan Anabtawi, MWH	**Reference:**	10507917
Subject:	Devils Gate Dam to Eaton Water Conservation Pipeline Study Water Conservation Model Constraints Technical Memorandum		

1 Introduction

The Water Conservation Model (WCM) is developed as part of the Devil's Gate Dam to Eaton Water Conservation Pipeline Study. The WCM is used to:

- Determine the best use of stormwater tributary to Devil's Gate Reservoir for water conservation;
- Quantify the volume of stormwater that can be feasibly conserved; and
- Determine the appropriate design basis for the pump station and pipeline system sizing, including the optimal flow rate, outlet location(s), and recommended operations.

Note that the draft technical memorandum (TM) dated September 2, 2015, outlined an approach to quantify the volumes of water available for diversion from Devil's Gate Reservoir using a design storm. This revised TM outlines the approach and presents the model constraints using actual Devil's Gate inflow data to develop an average availability for diversion.

2 Data Sources

Several datasets are obtained and used to develop the WCM; these include data from the Los Angeles County Department of Public Works (LACDPW), the City of Pasadena, and publicly available datasets. **Table 2-1** summarizes the datasets and corresponding sources used in the WCM.

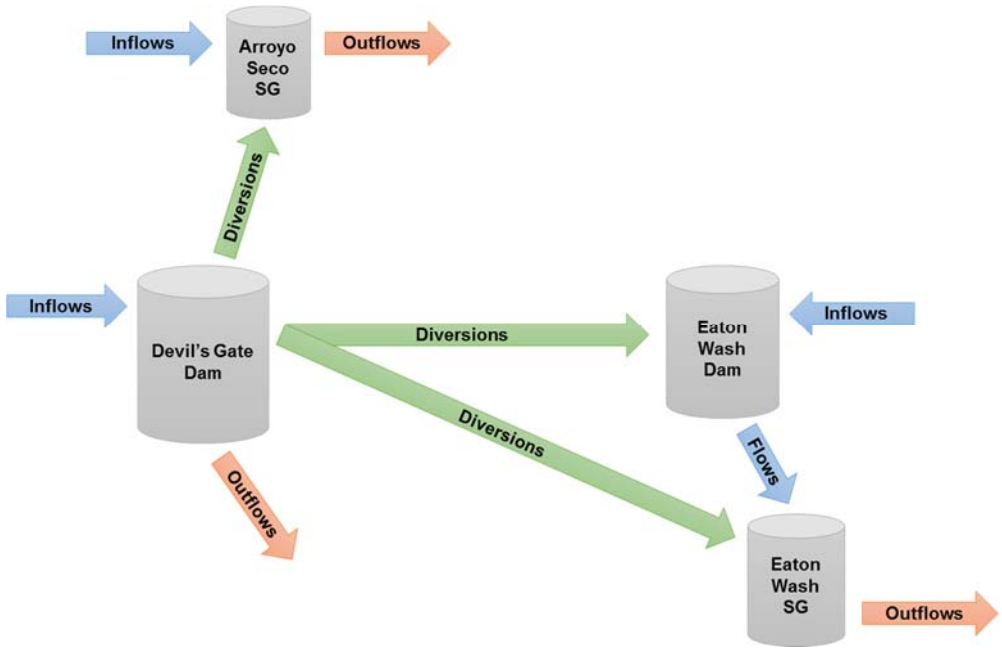
Table 2-1
Data Sources and Descriptions

Dataset	Type	Description	Source
Devil's Gate Dam Hourly Inflow	Tabular	Hourly inflow data for Devils Gate Dam, Apr 1999 to Sep 2014	Los Angeles County Department of Public Works
Devil's Gate Dam Operation Plan	Word	Devil's Gate Dam operating guidelines for operators during rising and falling reservoir conditions	Los Angeles County Department of Public Works
Eaton Wash Dam Hourly Inflow	Tabular	Hourly inflow data for Eaton Wash Dam, Oct 1999 to Sep 2014	Los Angeles County Department of Public Works
Eaton Wash Dam Operation Plan	Word	Eaton Wash Dam operating guidelines for operators during rising and falling reservoir conditions	Los Angeles County Department of Public Works
Arroyo Seco Spreading Grounds Weekly Inflow	Spreadsheet	Weekly inflow data for Arroyo Seco Spreading Grounds, Oct 1996 to Apr 2015	Los Angeles County Department of Public Works
Devil's Gate Cut Plan	Spreadsheet	Survey data with surface area and volume at different contour levels of Devils Gate Reservoir	Los Angeles County Department of Public Works
Weather Underground Historical Temperature	Tabular	Historical temperature records for Bob Hope Airport (KBUR)	The Weather Channel, http://www.wunderground.com/history/airport/KBUR/2014/1/1/CustomHistory.html?

3 Methods

The WCM is a spreadsheet storage model that accounts for the daily inputs to and outputs from each storage feature in the model. Inputs include natural flows or releases upstream and outputs include downstream releases and overflow, evaporation, and infiltration. **Figure 3-1** illustrates the connectivity in the model between the different storage features: Devil's Gate Dam, Eaton Wash Dam, Eaton Wash Spreading Grounds, and Arroyo Seco Spreading Grounds.

Figure 3-1
Simplified Model Connectivity Schematic



3.1 STORAGE

Each storage in the model has an associated capacity, beyond which the storage is not able to assimilate more inflow (excess will exit through spillway/overflow). Other additional characteristics of each storage is useful in the WCM. **Table 3-1** summarizes storage characteristics for each storage modeled in the WCM.

Table 3-1
Storage Capacities

Storage	Storage Capacity (acre-feet)	Intake Capacity		Spillway Elevation (ft amsl)
		(cfs)	(acre-feet per day)	
Devil's Gate Reservoir	2,255.74(1)	N/A	N/A	1,040.5(1)
Eaton Wash Reservoir	652.3(1)	N/A	N/A	887.5
Eaton Wash Spreading Grounds	575(1)	125(1)	247.9	N/A
Arroyo Seco Spreading Grounds (Basins 5 through 13)	33.39(2)	25	49.6	N/A

(1) From LACDPW
(2) From City of Pasadena

3.2 INFLOWS

The datasets summarized in **Table 2-1** were used to generate daily inflow volumes accruing in Devil's Gate Reservoir, Eaton Wash Reservoir, Eaton Wash Spreading Grounds, and Arroyo Seco Spreading Grounds. Hourly flows were aggregated on a daily basis, while weekly flows were averaged across their daily time steps, e.g., a 7 acre-foot volume over 7 days was converted to a 1 acre-foot volume per day for that time period.

3.3 OUTFLOWS

Outflows include infiltration, conservation (diversion from Devil's Gate Reservoir), and releases from each storage based on operation plans. These are described in the following subsection.

Based on comments from LACDPW, evaporation was assumed to be negligible and is not considered in this study. Further, the infiltration rate at Devil's Gate Reservoir and Eaton Wash Reservoir is assumed to be zero.

3.3.1 Infiltration

Infiltration rates at each storage are determined from a maximum infiltration rate and vary based on daily storage using an exponential model. **Table 3-2** summarizes the maximum infiltration rates by storage.

Table 3-2
Maximum Infiltration Rates

Storage	Maximum Infiltration Rate	
	(cubic feet per second)	(acre-feet per day)
Devil's Gate Reservoir(1)	0	0
Eaton Wash Reservoir(2)	5.0	9.9
Eaton Wash Spreading Grounds	14.0	25.8
Arroyo Seco Spreading Grounds	13.9	27.6

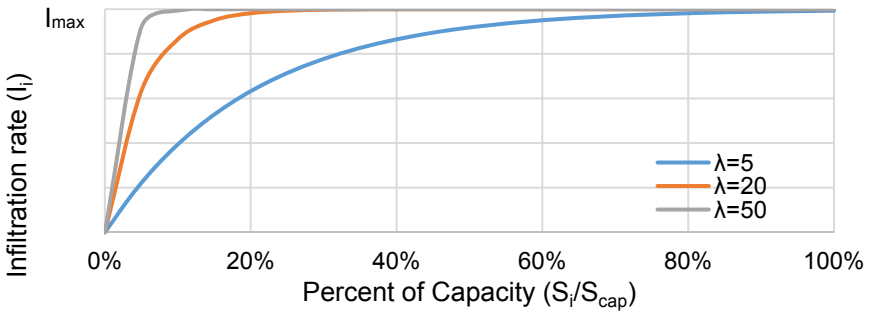
(1) Infiltration rate set to zero per LACDPW
(2) Infiltration rate determined by minimizing the root-mean-square error between calculated percolation at Eaton Wash Spreading Grounds and historical inflow data

Infiltration rate in each storage is modeled as a function of water level. An exponential infiltration rate function is calculated as:

$$I_i = I_{max}\left[1 - \exp\left(-\lambda \frac{S_i}{S_{cap}}\right)\right]$$

where I_i is the infiltration rate at day i, I_{max} is the maximum infiltration rate at the storage, λ is a parameter used to adjust the shape of the exponential function (set to 20 in the WCM), S_i is the volume in storage at day i, and S_{cap} is the storage capacity. **Figure 3-2** illustrates the infiltrate rate model used and the effect of the parameter λ on the infiltration rate.

Figure 3-2
Exponential Infiltration Rate Model



3.3.2 Operation Plan Releases

The operation plans for Devil's Gate Dam and Eaton Wash Dam are used in the WCM to simulate releases when reservoir levels are at prescribed elevations. The operating procedures are implemented in the WCM as described in the tables below.

Table 3-3
Devil's Gate Dam Operation Plan Procedures

Condition	Elevation (ft amsl)	Required Release
Rising Reservoir	< 1,010	Sluice gate rating curve flow at 100% open
	1,010 – 1,025	Pond water
	1,025 – 1,030	100 cfs
	1,030 – 1,035	300 cfs
	1,035 – 1,040.5	800 cfs
	1,040.5 (Spillway)	Greater of 800 cfs and inflow
Falling Reservoir	1,040.5 – 1,035	800 cfs
	1,035 – Pump Intake Level	Pond water
	< Pump Intake Level	Sluice gate rating curve flow at 100% open

Table 3-4
Eaton Dam Operation Plan Procedures

Condition	Elevation (ft amsl)	Required Release
Rising Reservoir	< 880	Pond water (no outflow)
	880 – 887.5	100 percent of inflow
Falling Reservoir	887.5 – 880	500 cfs
	880 – 870	100 percent of inflow at minimum plus conservation capacity at Eaton Wash Spreading Grounds
	< 870	Conservation capacity at Eaton Wash Spreading Grounds

3.3.3 Conservation

Diversion of flow from Devil's Gate Reservoir for conservation is modeled by setting a pumping rate and pump intake elevation to evaluate the average volume of water conserved. Diversions can be made if the water level in Devil's Gate Reservoir is at least the pump intake level and conservation volumes are calculated daily as the minimum of:

- pumping rate;
- available capacity at each storage being diverted to; and
- volume of water available in Devil's Gate Reservoir.

Results of the WCM show daily and annual diverted volumes for a selected alternative to evaluate different pumping rates and pump intake levels to identify a preferred alternative.

4 References

City of Pasadena Water and Power Department, (2011). Water Integrated Resources Plan. Accessed from http://cityofpasadena.net/waterandpower/waterirp/