Prepared for: City of Davis
Project Title: Water Distribution System Water Quality Hydraulic Modeling
Project No: 142447

Technical Memorandum No. 1
Subject: Water Quality Hydraulic Modeling
Date: April 5, 2012
To: Dianna Jensen, Principal Civil Engineer
From: Melanie Holton, Project Manager

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Reviewed by: Paul Selsky, PE (C43544)
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Limitations:
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1. Introduction

This technical memorandum (TM) presents the assumptions, evaluation, results, and operational recommendations for operating the City of Davis water distribution system groundwater wells to meet wastewater discharge water quality requirements for selenium and boron while maximizing the water quality for hardness and total dissolved solids (TDS). The objective is to operate the water system to maintain acceptable discharge concentrations for selenium and boron while meeting peak demands and level of service standards as presented in the City’s Water Distribution System Optimization Plan (WDSOP) (BC, 2011).

1.1 Scope of Work

Brown and Caldwell (BC) updated the City’s hydraulic model to include additional groundwater water quality data for selenium, boron, hardness and TDS. Demands were updated maintaining the demand allocation that is currently in the model from the WDSOP. The East Area tank and Well 34 are included and operational in the model. The updated hydraulic model is provide on a CD with this TM.

Well operational alternatives were analyzed using the extended period simulation hydraulic model to determine the optimal scenario that would enable the City to meet discharge water quality requirements for selenium of 4.4 parts per billion (ppb) or micro grams per liter (µg/l) while meeting operational standards and minimizing boron, hardness and TDS. The following modeling scenarios were performed:

1. Run Baseline. 2016 Groundwater Only – Ran the model with wells operating based on current operational controls to provide a baseline comparison of water quality and system pressure results prior to modifying operations for meeting selenium water quality requirements. This run was developed as part of the City’s WDSOP and used as a baseline operating scenario for this analysis since the projected 2016 demands are similar to the average 2008 to 2010 (current) demands used for the other model runs in this analysis.

2. Run 1. City Proposed Operations – Ran the model with the wells operating based on the City’s spreadsheet received on 12/9/11 with current demands. See Attachment A for the 12/9/11 spreadsheet. The East Area Tank does not recover under this scenario.

3. Run 2. Modified Operations, 100% Demand – Ran the model based on the City proposed operations, but with the number of wells that are running modified to allow the East Area Tank to recover while still meeting level of service criteria for pressure and minimizing concentrations of boron and hardness. 100% of current demands are used for this model scenario.

4. Run 3. Modified Operations, 90% Demand – Ran the model based on the City proposed operations, but with the number of wells that are running modified to allow the East Area Tank to recover while still meeting level of service criteria for pressure and minimizing concentrations of boron and hardness. 90% of current demands are used for this model scenario.

5. Run 4. Modified Operations, 80% Demand – Ran the model based on the City proposed operations, but with the number of wells that are running modified to allow the East Area Tank to recover while still meeting level of service criteria for pressure and minimizing concentrations of boron and hardness. 80% of current demands are used for this model scenario.
2. Analysis Criteria and Results

This section presents the analysis criteria and results.

2.1.1 Analysis Criteria

The system demands used for this analysis are based on the average of the maximum day demands (MDD) occurring from 2008 to 2010. Table 1 provides a summary of these demands. The average day demand, population, and resulting per capita demands for 2008 through 2010 are also shown. The average per capita water use in the model for this analysis is 171 gallons per capita per day (gpcd). This is higher than the City’s 2020 goal of 167 gpcd.

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Day Demand¹, mgd</th>
<th>Maximum Day Demand¹, gpm</th>
<th>Population²</th>
<th>Per Capita Water Use, gpcd</th>
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<td>67,460</td>
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<td>2009</td>
<td>11.5</td>
<td>14,959</td>
<td>67,933</td>
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<td>2010</td>
<td>10.7</td>
<td>13,934</td>
<td>68,289</td>
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<tr>
<td>Average</td>
<td>11.6</td>
<td>15,176</td>
<td>67,894</td>
<td>171</td>
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</tbody>
</table>

¹. Source: Dianna Jensen, City of Davis. Spreadsheet dated 12/09/11.

Table 1. Analysis Demands

Level of service criteria from the WDSOP for system pressures are as follows:
- Desired during MDD, without fire flow: 40 psi
- Allowable during peak hour demand without fire flow: 35 psi

Water quality criteria include the following:
- Not exceeding the 4.4 µg/l daily system-wide selenium levels. Daily system-wide selenium levels are calculated by summing the product of flow and selenium level of each source and dividing the sum by the sum of the flows from each source for a 24-hour period.
- Minimizing daily system-wide boron levels. Daily system-wide boron levels are calculated by summing the product of flow and boron level of each source and dividing the sum by the sum of the flows from each source for a 24-hour period.
- Minimizing hardness and TDS average levels at each node. Average hardness and TDS levels for a 24-hour period are illustrated for each model run. The system-wide hardness and TDS levels are also calculated by summing the product of flow and TDS or hardness level of each source and dividing the sum by the sum of the flows from each source for a 24-hour period. The system-wide goals for hardness and TDS from the WDSOP are 110 mg/l and 300 mg/l, respectively.

2.1.2 Analysis Results

The analysis results are presented in Table 2 below and on Figures 1 through 15 which are located at the end of this TM. Below is a summary of the key analysis results for each run.

1. Run Baseline. 2016 Groundwater Only - level of service criteria are met, however selenium exceeds the target 4.4 µg/l daily levels.
a. Daily selenium is 6.6 µg/l and daily boron is approximately 840 µg/l.

b. Peak hour pressures are between 46 and 50 psi on the west side of the system and over 50 psi elsewhere (see Figure 1).

c. Average hardness ranges from 70 to 700 mg/l (see Figure 2). Daily hardness is approximately 250 mg/l.

d. Average TDS ranges from 200 to 1,000 mg/l (see Figure 3). Daily TDS is approximately 450 mg/l.

2. Run 1. City Proposed Operations – Selenium target levels are met, however the East Area Tank water levels do not recover under MDD (see Chart 1).

a. Daily selenium is 2.9 µg/l and daily boron is approximately 820 µg/l.

b. Peak hour pressures are generally 46 to 50 psi, and over 50 psi on the east side of the system (see Figure 4).

c. Average hardness ranges from 70 to 700 mg/l, predominantly under 350 mg/l (see Figure 5). Daily hardness is approximately 170 mg/l.

d. Average TDS ranges from 200 to 1,000 mg/l, predominantly under 550 mg/l (see Figure 6). Daily TDS is approximately 370 mg/l.

3. Run 2. Modified Operations, 100% Demand – Selenium target levels are met and minimum service requirements are also met. The East Area Tank water levels are able to recover under MDD (See Chart 1).

a. Daily selenium is 3.8 µg/l and daily boron is approximately 820 µg/l.

b. Peak hour pressures are generally over 50 psi (see Figure 7).

c. Average hardness is generally under 525 mg/l, with levels as high as 700 mg/l on the east side of the system (see Figure 8). Daily hardness is approximately 190 mg/l.

d. Average TDS levels are generally less than 550 mg/l, with levels as high as 1,000 mg/l on the east side of the system (see Figure 9). Daily TDS is approximately 400 mg/l.

4. Run 3. Modified Operations, 90% Demand – Selenium target levels are met and improved when demand is reduced and minimum service requirements are also met.

a. Daily selenium is 2.7 µg/l and daily boron is approximately 800 µg/l.

b. Peak hour pressures are generally over 50 psi (see Figure 10).

c. Average hardness is generally under 175 mg/l (see Figure 11). Daily Hardness is approximately 150 mg/l.

d. Average TDS is generally under 400 mg/l (see Figure 12). Daily TDS is approximately 350 mg/l.

5. Run 4. Modified Operations, 80% Demand – Selenium target levels are met and further improved when demand is reduced another 10%, and minimum service requirements are also met. Boron levels increase slightly. This is due to higher boron concentrations in the deep wells which were used as the primary source of supply due to the lower levels of selenium, hardness, and TDS.

a. Daily selenium is 2.6 µg/l and daily boron is approximately 820 µg/l.

b. Peak hour pressures are greater than 50 psi (see Figure 13).

c. Average hardness is generally under 175 mg/l (see Figure 14). Daily Hardness is approximately 140 mg/l.

d. Average TDS is generally under 400 mg/l (see Figure 15). Daily TDS is approximately 340 mg/l.
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<th>Well</th>
<th>Selenium µg/l</th>
<th>Boron µg/l</th>
<th>Hardness mg/l</th>
<th>TDS mg/l</th>
<th>Pumping Capacity gpm</th>
<th>Run Baseline. 2016 Groundwater Only</th>
<th>Run 1. City proposed operation (based on spreadsheet), 100% Demand</th>
<th>Run 2. Modified Operations, 100% Demand</th>
<th>Run 3. Modified Operations, 90% Demand</th>
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3. Observations and Recommendations

The following provides a summary of the observations from this analysis as well as recommendations for operating the groundwater-only system in order to meet level of service and selenium requirements of 4.4 µg/l.

Observations
- While selenium levels improve (decrease) as demands are reduced, boron levels slightly increase. This is because the deep wells are used as the primary supply and boron levels are lower in some of the intermediate wells than in the deep wells. As demands are decreased, flow from intermediate wells is decreased to reduce levels of selenium, hardness, and TDS, while flow from deep wells is maintained.
- Average hardness and TDS levels do not meet the City objectives of 110 mg/l and 300 mg/l, respectively, while meeting the demands in this analysis with groundwater well supply only. Average hardness and TDS levels are improved as demand decreases and supply from the intermediate wells is decreased.

Recommendations
Table 3 provides a list of wells that are recommended for operation under each demand scenario in order to meet the maximum selenium requirements while maintaining adequate system pressures.
<table>
<thead>
<tr>
<th>System Demand</th>
<th>Primary Supply Wells (20 to 24 hours per day)</th>
<th>Peak Supply Wells (14 to 19 hours per day)</th>
<th>Peak Supply Wells (3 to 11 hours per day)</th>
</tr>
</thead>
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<td>100% current MDD demand (15,176 gpm)</td>
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<td>80% current MDD demand (12,141)</td>
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<td>20, 25, 26, 28</td>
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Run Baseline. 2016 Groundwater Only
MDD Average Hardness
Project: 142447
Date: 3-19-12
Title: Davis, California
Run Baseline. 2016 Groundwater Only
MDD Average TDS
Run 1. City Proposed Operation
Peak Hour Pressure
Davis, California
Water Distribution System Water Quality Hydraulic Model
Run 2. Modified Operation 100% Demand
Peak Hour Pressure
Run 2. Modified Operation 100% Demand
MDD Average Hardness
Map showing the water distribution system in Davis, California, with various areas and facilities labeled. The map includes symbols for Active Deep Well, Active Intermediate Well, Inactive Well, UC Davis Intertie, Water Distribution Pipe, TDS (mg/L) levels, and city and county boundaries. The TDS levels are categorized as 0 - 250, 251 - 400, 401 - 550, 551 - 700, 701 - 850, 851 - 1000.

Legend:
- Active Deep Well
- Active Intermediate Well
- Inactive Well
- UC Davis Intertie
- Water Distribution Pipe
- TDS (mg/L)
  - 0 - 250
  - 251 - 400
  - 401 - 550
  - 551 - 700
  - 701 - 850
  - 851 - 1000
- City Boundary
- County Boundary

Project:
- 142447

Site:
- Davis, California

Title:
- Water Distribution System Water Quality Hydraulic Model
- Run 2. Modified Operation 100% Demand
- MDD Average TDS

Date:
- 3-19-12
Project: 142447
Date: 3-19-12
Title: Davis, California
Water Distribution System Water Quality Hydraulic Model
Run 3. Modified Operation, 90% Demand
Peak Hour Pressure

Legend:
- Active Well
- Active Intermediate Well
- Inactive Well
- UC Davis Intertie
- Water Distribution Pipe
- Ave Pressure (psi)
- City Boundary
- County Boundary

- 0 - 30
- 31 - 35
- 36 - 40
- 41 - 45
- 46 - 50
- > 50
Davis, California
Water Distribution System Water Quality Hydraulic Model
Run 3. Modified Operation, 90% Demand
MDD Average Hardness

Legend
- Active Well
- Active Intermediate Well
- Inactive Well
- UC Davis Intertie
- Water Distribution Pipe

Hardness (mg/L)
- 0 - 175
- 176 - 350
- 351 - 525

City Boundary
County Boundary
Davis, California

Water Distribution System Water Quality Hydraulic Model

Run 3. Modified Operation, 90% Demand

MDD Average TDS
Peak Hour Pressure

Davis, California
Water Distribution System Water Quality Hydraulic Model
Run 4. Modified Operation, 80% Demand
Davis, California
Water Distribution System Water Quality Hydraulic Model

Run 4. Modified Operation, 80% Demand
MDD Average Hardness

Legend
- Active Well
- Active Intermediate Well
- Inactive Well
- UC Davis Intertie
- City Boundary
- County Boundary

Hardness (mg/L)
- 0 - 175
- 176 - 350
- 351 - 450

Davis Cemetery
Sutter Davis Hospital
University Mall
University Airport
Yolo County
Solano County

Legend
- Active Well
- Active Intermediate Well
- Inactive Well
- UC Davis Intertie
- City Boundary
- County Boundary

Hardness (mg/L)
- 0 - 175
- 176 - 350
- 351 - 450

Davis Cemetery
Sutter Davis Hospital
University Mall
University Airport
Yolo County
Solano County

Davis, California
Water Distribution System Water Quality Hydraulic Model

Run 4. Modified Operation, 80% Demand
MDD Average Hardness

Legend
- Active Well
- Active Intermediate Well
- Inactive Well
- UC Davis Intertie
- City Boundary
- County Boundary

Hardness (mg/L)
- 0 - 175
- 176 - 350
- 351 - 450

Davis Cemetery
Sutter Davis Hospital
University Mall
University Airport
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Solano County

Davis, California
Water Distribution System Water Quality Hydraulic Model

Run 4. Modified Operation, 80% Demand
MDD Average Hardness

Legend
- Active Well
- Active Intermediate Well
- Inactive Well
- UC Davis Intertie
- City Boundary
- County Boundary

Hardness (mg/L)
- 0 - 175
- 176 - 350
- 351 - 450

Davis Cemetery
Sutter Davis Hospital
University Mall
University Airport
Yolo County
Solano County
Davis, California

Water Distribution System Water Quality Hydraulic Model

Run 4. Modified Operation, 80% Demand
MDD Average TDS
References

Attachment A: City’s 12/9/11 Spreadsheet
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<th>Pumping Rate gpm</th>
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<th>Volume at 24 hours a day gallons</th>
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Anticipated conc of Selenium (µg/l) 2.83

Tanks (gpm) 10,200
Capacity for Peak Hour (gpm) 29,428