LOWER JORDAN RIVER
DIURNAL DISSOLVED OXYGEN ASSESSMENT
(JULY 29 – AUGUST 4, 2017)

Prepared for:

Jordan River Commission

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INTRODUCTION

The lower Jordan River (LJR) study began as a method to evaluate the effects of flow change on dissolved oxygen (DO) in the lower reaches of the river from 2100 South to Burnham Dam. The hypothesis of the study was that an increase in flow would increase DO, potentially indicating a way to mitigate seasonal DO deficits measured at five permanent sensor locations in the LJR. In 2017, the Jordan River Commission secured agreements for the required water rights to begin flow experiments, filed the necessary applications for a temporary change, and set the stage to begin the experiment August 1, 2017. However, due to a lack of water within the system and shared understanding of acquired water rights, the flow experiment was postponed.

Cirrus staff prepared to conduct the experiment. To enhance the spatial resolution, we installed four additional Onset Hobo U-26 DO/temperature sensors along the LJR to complement the five permanent sensor locations. The sensors were installed July 29, 2017, and set at 15-minute intervals to record DO throughout the flow experiment. The sensors remained in the river until August 4, 2017, when the experiment was suspended until water rights issues could be worked out.

A summary analysis of the data collected from July 29–August 4, 2017, is provided below.

RESULTS

DO was measured at nine sites during the monitoring period (Table 1). Concentrations ranged from an instantaneous high of 12.0 mg/L at 2100 South to a low of 3.8 mg/L at 800 South (Figure 1). The daily average ranged from a high of 7.8 mg/L at 2100 South to a low of 4.3 mg/L at Redwood Road over a 5-day period. Concentrations of DO remained stable during the monitoring period at the seven lower sites (Table 2).

Peak DO levels consistently decreased downstream from 2100 South during the monitoring period, exhibiting a pattern consistent with historical observations for the LJR (Table 3). The largest decrease in DO between stations occurred between 2100 South and 1700 South, and the second largest drop occurred between 1700 South and 1300 South. These initial drops could reflect a release of oversaturated DO (> 100 percent) produced by the 2100 South diversion headgate or a loss of primary production within the water column.

Minimum DO remained stable among the nine sites with minimum daily DO values ranging from 5.4 to 3.8 mg/L, showing a constant demand as the river flows north (Table 4). At 2100 South, the average minimum DO (5.1 mg/L) was consistently higher than any other location. Average minimum DO at the remaining eight sites ranged from 4.5 to 3.9 mg/L (Figure 2). Interestingly, the minimum DO between North Temple and Cudahy Lane occurred during the photosensitive period, when primary production by algae should be generating oxygen and increasing DO.

Peak DO in the LJR exhibited a temporal shift as flow moved downstream towards Farmington Bay (Figure 1). At each site, DO peaked later in the afternoon and continued past sunset into the non-photosensitive period or nighttime (Figure 3). Concentrations of DO at 2100 South, 1700 South, 1300 South, and 800 South peaked during what is considered a normal photoperiod (post solar noon). DO peaks at North Temple, 300 North, and Redwood Road during the non-photosensitive period (dark), and DO peaked at sunrise at Cudahy Lane and before solar noon at Burnham Dam (Figure 3).

Examining the temporal shift, we compared the difference in time of the DO peak at 2100 South to each site downstream (delta time). The delta time at each monitoring site established the rate at which the DO peak shifted as water moved downstream.

We utilized flow travel time from the Salt Lake County HEC-RAS model, determined in an earlier flow study report, to compare travel times of a similar flow (approximately 150 cfs) to delta time of the DO peak for the nine sites (Table 5).

Comparing the travel time to the delta time, we saw a very similar rate moving down the river. To illustrate the correlation, we plotted the average delta time for the study period at each site, with the travel time of the HEC-RAS model developed for the Phase 1 TMDL at a flow rate of 150 cfs (Figure 4). This comparison showed a strong relationship between flow travel time and peak DO ($R^2 = 0.98$). The data suggest the timing of peak DO during the study period was driven by the travel time of the water column.

To confirm our observations of the temporal shift in the DO peak, we looked at data collected during the month of August in 2013, 2014, and 2016. We used the same method of calculating delta time at each available site and finding travel times with HEC-RAS and the correct flow during that period.

Based on a limited review of historic data, the DO peak followed a similar pattern to the August 2017 data, where 300 North peaks at night, CudahyLane in the morning and Burnham Dam around solar noon. Peak DO at the Cudahy Lane and Burnham Dam sites occurred later than the observations in 2017. This delay could be the result of some limited primary production altering the peak DO timing.

DISCUSSION

During our attempt to conduct a flow study in August 2017, we deployed four additional sensors to collect DO measurements in the LJR and enhance the spatial resolution of existing data. Approximately one week of continuous data was collected at nine sites downstream from 2100 South. During the monitoring period, the river remained very stable with little daily variation in average DO. The most significant diurnal swings in DO occurred at 2100 South, 1700 South, and 1300 South, with daily peaks above 7.0 mg/L. Moving downstream, the middle three sites (800 South, North Temple, and 300 North) had daily peaks above 6.0 mg/ L. The most downstream LJR sites (Redwood Road, Cudahy Lane, and Burnham Dam) had daily peak DO above 5.0 mg/L.

Minimum DO values were similar across all sites, with an average minimum of approximately 4.0 mg/L. The exception was 2100 South, which averaged approximately 1.0 mg/L higher than the other sites.

The LJR exhibits an odd shift in the diurnal pattern of DO from site to site. A typical DO pattern (influenced by algal photosynthesis and respiration) has a maximum DO sometime past solar noon, which occurs after 1:30 p.m. during July and August for the LJR. Measurements at the upper three LJR sites showed this typical diurnal DO pattern. However, the the three middle LJR sites had peak DO during times when photosynthesis is absent and DO should be at a minimum level. This anomaly was still evident at Cudahy Lane and Burnham Dam, which showed peak DO in the mid-morning when photosynthesis is typically increasing, following a nighttime period dominated by respiration.

Plotting the travel time of 150 cfs with the delta time in DO peak, we saw a similar pattern in timing. This suggests that during stable periods, the diurnal pattern of DO in the LJR is dependent upon DO at 2100 South. This pattern suggests that primary production is not occurring, or occurring in a very limited way, in lower sections of the river during summer months, and that DO is dependent upon oxygen produced at 2100 South or even further upstream.

In conclusion, DO measurements in the LJR remained stable during the monitoring period. Minimum DO across most sites exhibited a similar range with the exception of 2100 South. Peak DO dropped with distance downstream, and we observed a temporal shift in peak DO that correlated with travel time of the river. The temporal shift suggests little primary production is occurring in downstream segments of the LJR below 2100 South.

To build on these findings, we suggest the following steps:

- Based on available historic data, complete a comprehensive review of the temporal shift in DO peak across a wider range of seasons to see if the pattern continues in the spring, fall, and winter.
- Continue to collect seasonal data at nine LJR sites (using the five permanent DWQ sites and the four additional Cirrus sensors) to gain a higher resolution of DO patterns.
- Calculate whole stream metabolism (including gross primary production and ecosystem respiration) at each monitoring site using the River Metabolism Analyzer (RMA.xls version 2.3 or most recent version). The DWQ uses this model for similar analyses.
- Investigate opportunities to increase DO levels at 2100 South to augment low DO conditions downstream.

Table 1. Location of the nine installed sensors for the flow study.	
Sensor Locations	
State Operated	**Cirrus Installed**
2100 South	1700 South
800 South	1300 South
300 North	North Temple
Cudahy Lane	Redwood Road
Burnham Dam	

Table 1. Average daily dissolved oxygen at the nine sensor locations.									
Daily Average Dissolved Oxygen									
	2100 S	**1700 S**	**1300 S**	**800 S**	**North T**	**300 N**	**Redwood**	**Cudahy**	**Burnham**
30-Jul	7.5	6.1	5.5	4.8	4.9	4.9	4.3	4.5	4.6
31-Jul	7.7	6.2	5.4	5.1	5.1	5.1	4.4	4.5	4.5
1-Aug	7.8	6.3	5.6	5.4	5.2	5.3	4.6	4.7	4.6
2-Aug	7.5	6.1	5.4	5.2	5.1	5.2	4.6	4.8	4.8
3-Aug	7.7	6.2	5.5	5.2	5.0	5.1	4.4	4.6	4.7
Average DO	**7.6**	**6.2**	**5.5**	**5.1**	**5.1**	**5.1**	**4.5**	**4.6**	**4.6**

Table 2. Maximum daily dissolved oxygen at each site.									
Daily Maximum Dissolved Oxygen									
	2100 S	**1700 S**	**1300 S**	**800 S**	**North T**	**300 N**	**Redwood**	**Cudahy**	**Burnham**
30-Jul	10.9	8.7	7.5	6.5	5.9	5.9	5.1	5.1	5.1
31-Jul	11.4	8.8	7.3	6.7	6.1	6.1	5.1	5.2	5.2
1-Aug	11.8	9.3	8.1	7.3	6.6	6.6	5.3	5.3	5.4
2-Aug	11.3	8.8	7.5	6.7	6.5	6.6	5.7	5.7	5.6
3-Aug	12.0	9.4	8.0	7.1	6.3	6.1	5.2	5.3	5.4
Average Max DO	**11.5**	**9.0**	**7.7**	**6.9**	**6.3**	**6.2**	**5.3**	**5.3**	**5.3**

Table 3. Minimum daily dissolved oxygen at each site.									
Daily Minimum Dissolved Oxygen									
	2100 S	**1700 S**	**1300 S**	**800 S**	**North T**	**300 N**	**Redwood**	**Cudahy**	**Burnham**
30-Jul	5.2	4.4	4.1	3.8	4.3	4.4	3.8	3.9	4.0
31-Jul	4.8	4.3	4.0	3.9	4.4	4.5	3.9	4.1	3.9
1-Aug	5.4	4.3	4.0	4.0	4.4	4.5	4.0	4.2	4.1
2-Aug	5.0	4.2	4.0	3.9	4.4	4.5	3.9	4.1	4.2
3-Aug	5.0	4.2	4.0	3.9	4.3	4.5	3.9	4.0	4.1
Average Min DO	**5.1**	**4.3**	**4.0**	**3.9**	**4.3**	**4.5**	**3.9**	**4.1**	**4.1**

Table 4. Delta time for peak DO at each site.										
Peak Dissolved Oxygen Travels Times from 2100 South Head Gate										
	FLOW	**2100 S.**	**1700 S.**	**1300 S.**	**800 S.**	**North T**	**300 N.**	**Redwood**	**Cudahy**	**Burnham**
7/29/2017	151	0.0	0.5	1.3	3.0	7.0	7.5	11.5	15.0	20.5
7/30/2017	147	0.0	0.8	1.8	4.3	6.8	7.5	11.0	15.5	21.3
7/31/2017	146	0.0	0.8	1.5	2.8	5.5	6.3	9.8	14.0	20.3
8/1/2017	163	0.0	0.5	1.3	3.0	5.0	5.8	9.5	13.3	19.5
8/2/2017	156	0.0	0.3	1.3	2.5	4.8	5.3	9.0	12.3	19.0
8/3/2017	147	0.0	0.8	1.5	2.8	5.8	6.5	10.3	15.3	20.3
Average	**151.6**	**0.0**	**0.6**	**1.4**	**3.0**	**5.8**	**6.5**	**10.2**	**14.2**	**20.1**
Median	**149.3**	**0.0**	**0.6**	**1.4**	**2.9**	**5.6**	**6.4**	**10.0**	**14.5**	**20.3**
Travel Times	**150**	**0.0**	**0.7**	**1.3**	**2.7**	**4.5**	**4.5**	**8.5**	**13.9**	**18.2**

Table 5. Delta time of DO peak in August 2013, 2014, and 2016.				
	Flow CFS	**300 N.**	**Cudahy**	**Burnham**
7/30/2013	146.4	5.3	18.8	21.5
7/31/2013	134.2	7.0	19.3	23.5
8/1/2013	137.4	7.0	20.0	23.3
8/2/2013	141.7	6.8	18.8	20.3
8/3/2013	138.6	7.5	19.8	22.8
8/13/2014	165.5	4.8	14.0	21.3
8/14/2014	166.7	6.3	15.5	20.5
8/15/2014	162.6	7.3	14.0	20.5
8/16/2014	157.3	6.8	14.8	24.0
8/17/2014	158.0	6.5	15.3	22.0

Table 6 (Cont'd). Delta time of DO peak in August 2013, 2014, and 2016.				
	Flow CFS	**300 N.**	**Cudahy**	**Burnham**
8/1/2016	152.8	6.5	19.3	22.8
8/2/2016	151.7	7.0	16.8	24.0
8/3/2016	150.4	6.2	15.8	23.8
8/4/2016	142.9	7.2	18.0	22.8
8/5/2016	155.8	7.5	15.8	23.8
Average	**150.8**	**6.6**	**17.0**	**22.4**

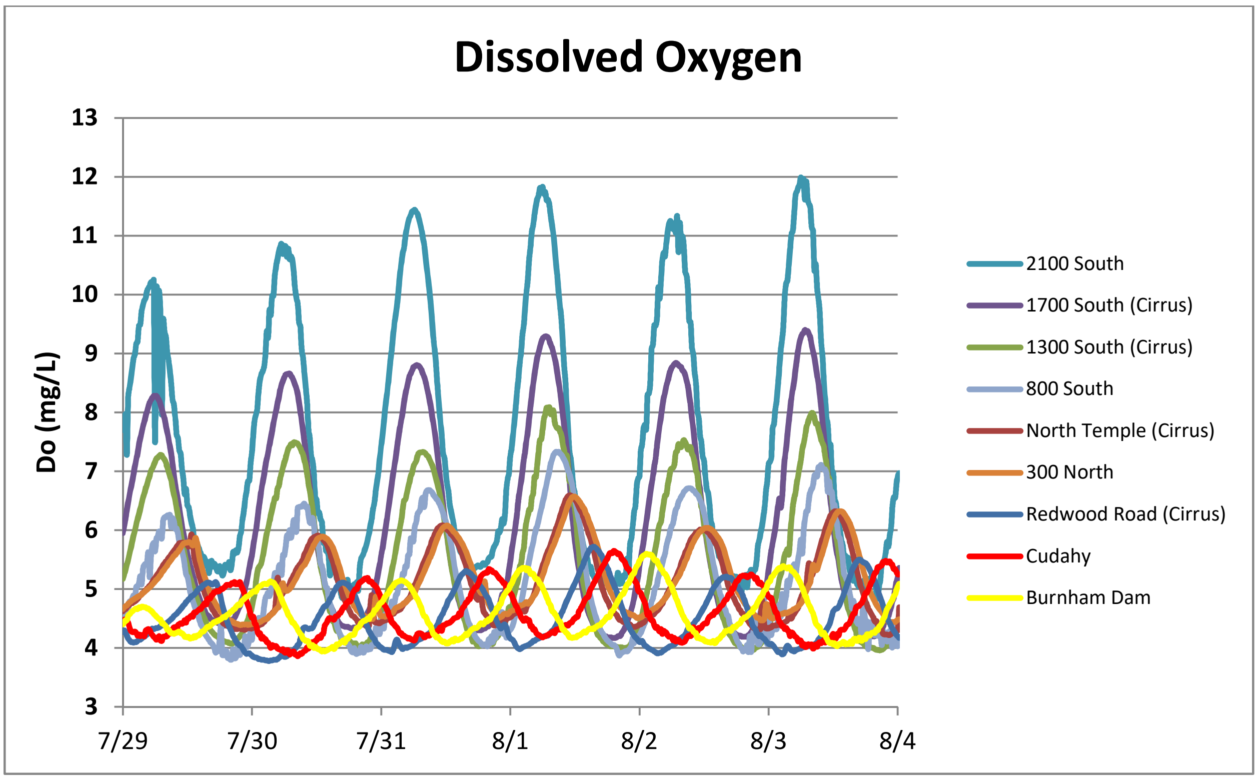

Figure 1. Instantaneous dissolved oxygen from the nine sensors installed along the Lower Jordan River.

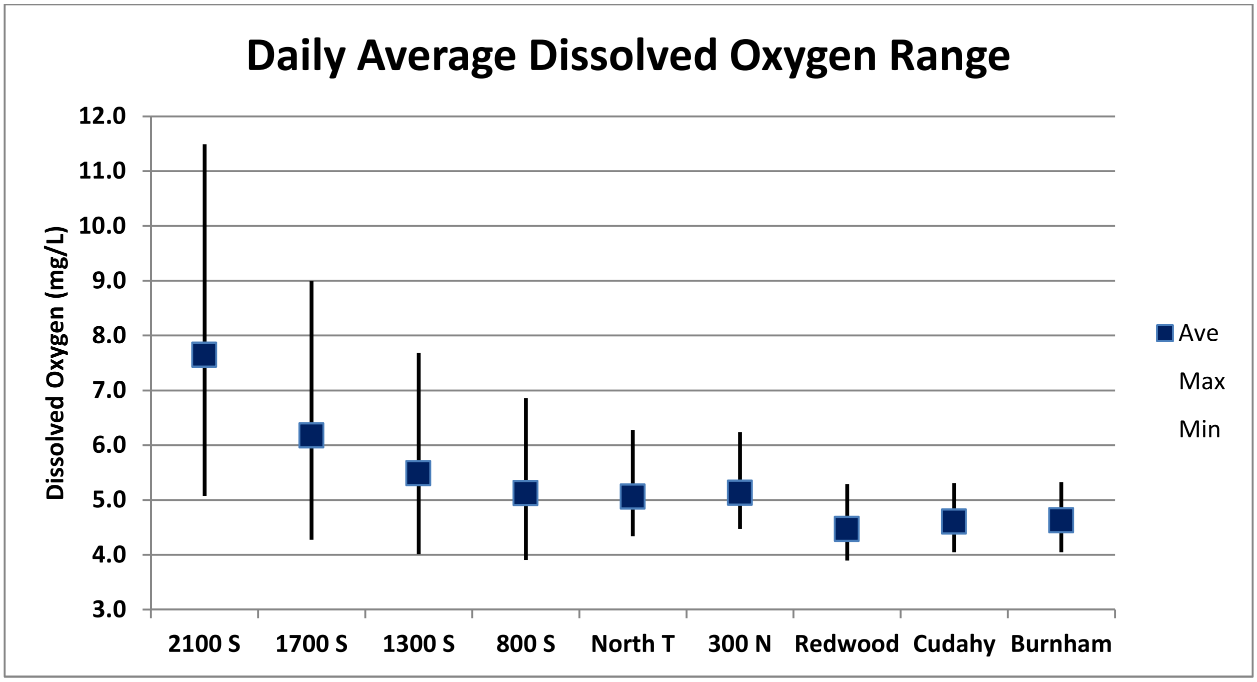

Figure 2. Daily average DO with minimum and maximum bars.

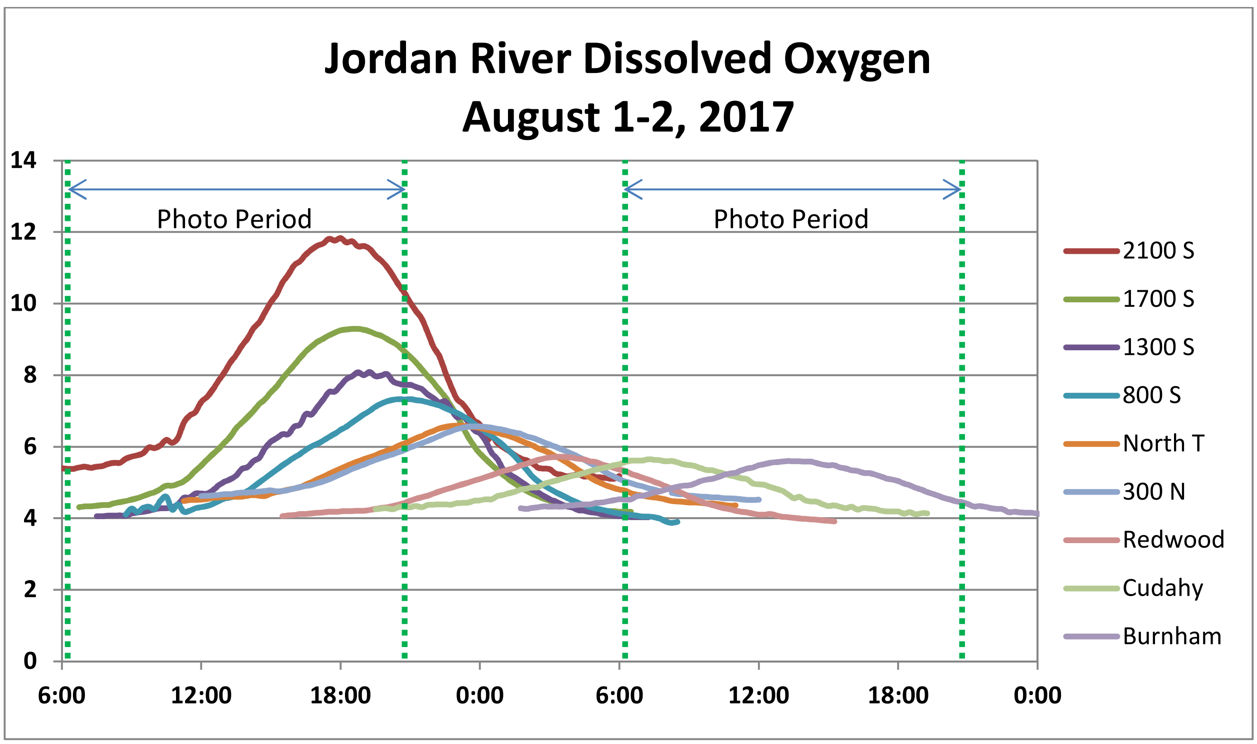

Figure 3. Dissolved oxygen curves for a 24-hour period starting at the DO minimum value illustrating the temporal shift in DO.

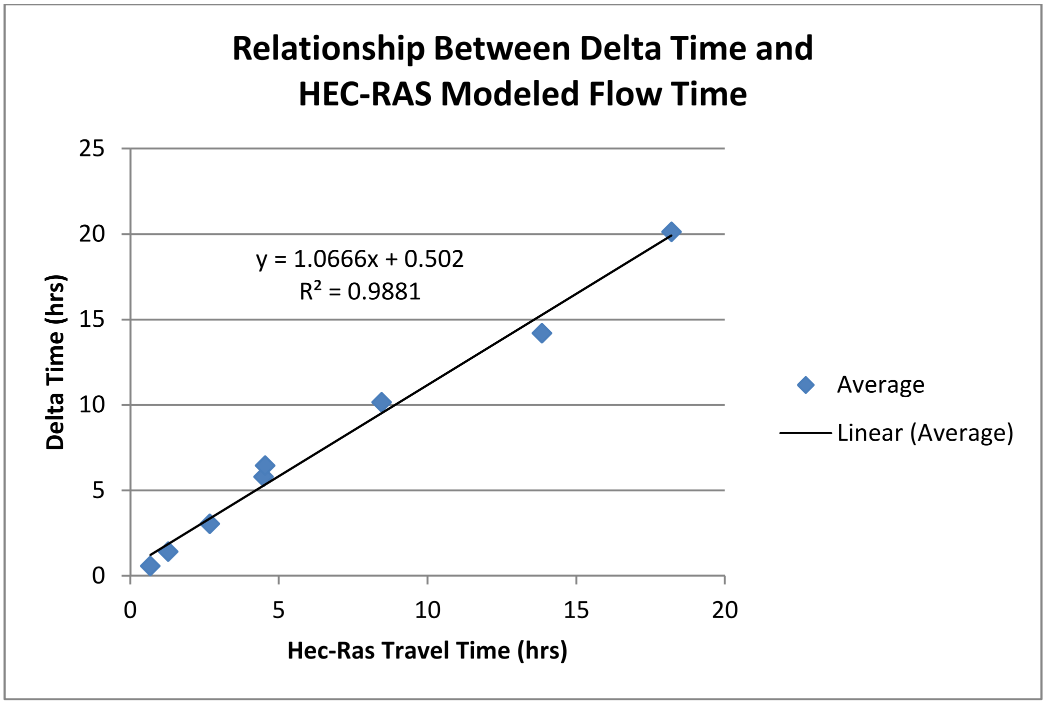

Figure 4. Relationship between Delta time of Peak DO and HEC-RAS modeled time.