WILLARD SPUR SCIENCE PANEL MEETING

This Science Panel meeting was held on October 28, 2015 at the UDEQ building at 195 North 1950 West, Salt Lake City, Utah. The following represents a summary of discussion. It is not intended to represent meeting minutes.

OCTOBER 28, 2015

NAME/AFFILIATION

Jim Hagy*.....U.S. EPA, Office of Research & Development
John Luft*.....Utah Division of Wildlife Resources
Theron Miller*.....Farmington Bay/Jordan River Water Quality Council
Jeff Ostermiller*.....Utah Division of Water Quality
Chris Cline*.....U.S. Fish & Wildlife Service
David Tarboton*.....Utah State University
Suzan Tahir.....Utah Division of Water Quality
Toby Hooker.....Utah Division of Water Quality
Rob Dubuc.....Friends of GSL
Jake Vander Laan.....Utah Division of Water Quality
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Jeff DenBleyker.....CH2M HILL
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INTRODUCTION

Meeting attendees were introduced and Jeff DenBleyker reviewed the meeting's agenda for the day. The objective of the meeting is to review the conditions observed during the 2011-2013 study period and form a consensus on the question: *What are the potential impacts of the Perry Willard Regional Wastewater Treatment Plant (POTW) on Willard Spur?*

Chris Cline asked what the boundaries of the discussion should be. Should the discussion be focused upon only Willard Spur or also look at how the POTW could impact Willard Spur in light of potential changes in climate and in the watershed? It was agreed that while the discussion should not include an assessment or solutions for issues outside of Willard Spur, the discussion should take into account how conditions might change in the future and how impacts from the POTW's discharge might change as a result.

WHAT IS THE CURRENT CONDITION OF WILLARD SPUR?

SUMMARY OF HYDROLOGY & NUTRIENT LOADING, 2011-2013

See the following link for the presentation slides:
http://www.willardspur.utah.gov/panel/docs/2015/10Oct/HydrologyNutrientLoads.pdf

Jeff DenBleyker provided an overview of key observations made as part of the hydrology study. The Bear River, Weber River and East Side basins all contribute surface water inflow to Willard Spur. The Bear River source contributes the greatest inflow volume with spring runoff dominant. Water levels and conditions within Willard Spur depend upon inflows from all sources. There are typically two flow regimes each year; a flowing condition where Willard Spur discharges to Bear River Bay and an impounded condition where there is no discharge to Bear River Bay. Historical imagery and mapping indicates that Willard Spur typically sees both flow regimes each year. A flushing (i.e., flowing) condition during the winter/spring appears to be a critical element in the annual hydrologic cycle for Willard Spur. A water balance indicated that more work needs to be completed to refine estimates of outflow from Willard Spur but, more significantly, to understand the groundwater influence. Inflows to Willard Spur were found to infiltrate into the mudflats during summer months, the pool elevation in Willard Spur appears to be linked to the groundwater elevation, and it appears that fall flows recharged the groundwater table in October 2012 and October 2013 prior to Willard Spur beginning to discharge to Bear River Bay again. An analysis of the POTW's effluent contribution indicates that it does reach the open water but is dependent upon season and surface water and groundwater levels in Willard Spur. The POTW did not contribute effluent to the open waters of Willard Spur during late summer months in 2012 and 2013, eliminating risks of additional nutrient enrichment that may otherwise have occurred.

The Science Panel discussed the importance of the flowing regime, i.e., annual flushing flows. Potential risks from nutrient enrichment appear to currently be diminished by these annual flushing events; thus these flushing flows are a critical element in the physical and biological conditions of Willard Spur. The potential for year-to-year accumulation of nutrients and organic matter would be greater in the absence of these annual flushing events. Additionally, the absence of annual flushing events could cause Willard Spur to become increasingly more saline with coincident changes to SAV and other organisms in the food web. Willard Spur could also become a playa with concurrent loss/change in habitat. Nutrients from all sources could become a significant problem with the absence of these annual flushing events. As long as Willard Spur's annual hydrologic cycle includes the flowing regime and Great Salt Lake water levels are low enough, Willard Spur can maintain a freshwater ecosystem and appears to have a "self-cleansing mechanism". One reason *Phragmites* might not be as significant of a problem in Willard Spur as it could be is that nutrients are flushed from the system and aren't accumulating in the sediments. The Science Panel discussed the importance of groundwater and the link to the watershed both upstream and downstream of Willard Spur. It is a connected system, thus we cannot look at Willard Spur as an isolated system. Even the contribution of water from the POTW's effluent, while very small, should be considered as a resource, however as future discharges increase with anticipated population growth, we should revisit the potential risks from nutrients with the benefit of its water.

Jeff DenBleyker provided an overview of key observations from the external nutrient loads contributed by surface waters. Looking at "end-of-pipe" nutrient loads, the Bear River basin provides the vast majority of the nutrient load followed by the Weber River basin. The POTW would contribute less than 5% of the annual nutrient load. In reality, the relative contribution of nutrients is even smaller because the estimates assumed that the flows reach the open water and end-of-pipe concentrations are assumed to pass the 1.5+ mile to the open water without any assimilation, (i.e., reduction)—both of which are conservative assumptions that are unlikely to occur. The Science Panel discussed the idea that if there is a significant anthropogenic nutrient load from other sources, perhaps money used to pay for chemical treatment of P from the POTW could make a more significant impact if used to reduce other sources. This will be something discussed again at a future meeting.

The Science Panel agreed that the POTW's "end-of-pipe" load could be significant but also acknowledged that much of the POTW's load did not reach the open water of Willard Spur. This was especially true during low water conditions when the relative contribution of the plant in comparison to the assimilative capacity of the Spur is smallest. The nutrient loading report includes estimates of how the POTW's effective load contribution to the open water likely decreased due to infiltration and evapotranspiration but it does not account for the reduction in nutrient concentrations that occurs as the water travels through open channels, fringe wetlands, and the mudflats on its way to the open water. Lack of data precluded this from being included in the analysis. Thus, based on several lines of evidence, the "end-of-pipe" load estimates are higher than what is actually contributed during low water levels in the impounded condition. The Science Panel discussed the reduction of nutrients that the old outfall ditch, the pasture, and even the tailrace channel provide and agreed that this is an element that likely substantially reduces the risk of the POTW creating a problem. Historical mapping indicates that the tailrace channel is a constructed channel, thus the channel will likely not be included within the boundary of Willard Spur. The POTW may be able to take credit for the channel's reduction of the effective nutrient contribution (when it is the receiving water and conveyance canal) to Willard Spur, however a plan should be in place for monitoring the actual load to see if this nutrient-reducing function is maintained moving forward.

Summary of the Food Web, 2011-2013

See the following link for the presentation slides: http://www.willardspur.utah.gov/panel/docs/2015/10Oct/FoodWeb.pdf

Jeff DenBleyker provided a draft executive summary of the various reports completed by Principal Investigators as part of this project. Jeff will ask the PIs to review prior to finalizing. Jeff also provided an overview of key observations from these studies.

Willard Spur supports a very diverse bird population whose use of Willard Spur is linked closely to the habitat and available use – all seemingly driven by water levels. Willard Spur can support a warm water fishery, as sufficient water allows, dominated by fish tolerant of more extreme conditions and closely linked to waterbodies upstream. Macroinvertebrate and zooplankton communities are similar in composition and response to other GSL wetlands. Their abundance and composition likely mimics Pond 5C, the primary water source, in the Federal Bear River Migratory Bird Refuge and varies seasonally dependent upon water levels and flow regime. Emergent vegetation communities too, are closely linked to freshwater inflows, water levels and salinity. The observed increase in *Phragmites* cover is of concern. Willard Spur is a highly dynamic, complex and resilient ecosystem representative of other GSL wetland systems. Willard Spur is closely integrated with the ecosystem surrounding it. Water inflows and water levels are important drivers of the changes observed throughout and among years. Nutrient enrichment can create an adverse response within and among all assemblages but no direct impact was observed during the study. The observed seasonal succession of the macroinvertebrate community, particularly the loss of phytophilous taxa, is likely due to several factors, but primarily can be attributed to the senescence and loss of SAV in early to late July as flushing flows are cut off. The Science Panel discussed how the resiliency of Willard Spur is a critical characteristic of the ecosystem and one that must be preserved. They discussed whether the observed early senescence of submerged aquatic vegetation (SAV) has an impact on bird use. They agreed that early loss of SAV in general is not good for waterfowl but does not appear to be impacting them, (e.g., summer use of the impoundment by shorebirds, fall migrations depend upon bulrush seeds that are likely washed into the system). They agreed that early senescence, if caused by nutrients, is not good. The experiments conducted by Hoven et al. demonstrated that several indices of SAV condition were negatively affected by the nutrient treatments. However, there are many stressors beyond nutrients that are likely contributing to the observed senescence, (e.g., higher water temperatures, higher salinity, high pH, nutrient reductions from upstream wetlands during periods where N or P is particularly limiting, etc.). Particularly in dry years, many of these factors reached potentially stressful conditions as SAV started to senesce, but it is impossible to determine the extent to which excess nutrients during the same period of time would exacerbate, or even be protective against, the effects of other these other stressors.

The Science Panel discussed whether the high spring nutrient contributions to Willard Spur drive excessive primary production, causing the pH to rise and, combined with biofilm growth, create a carbon limited condition for the SAV. Does this stress the SAV? They also discussed the possibility of whether the nutrient stores in sediments are limited and thus causing SAV to rely more upon waterborne nutrients. When the surface water nutrient load declines, perhaps that also stresses the SAV. We do not have enough information to conclude what is causing the early senescence but the Science Panel did agree that nutrient balance may play a role, among many other factors.

SUMMARY OF OPEN WATER CHARACTERISTICS, 2011-2013

See the following link for the presentation slides:
http://www.willardspur.utah.gov/panel/docs/2015/10Oct/OpenWater.pdf

Toby Hooker provided an overview of key observations from his draft report 2011-2013 Ambient Conditions from Baseline Monitoring of Willard Spur. Toby described the methodology used to summarize the significant quantity of data collected as part of the project and identify important characteristics and responses in the ecosystem. Much of Toby's discussion focused upon data collected at four sites distributed along the length of Willard Spur (from west to east- WS-8, WS-6, WS-3, and OUTFALL-CNFL) that served as sentinel sites. In general, water temperature and salinity increased as water depths decreased. Water column pH increased along with SAV cover; chlorophyll-a increased later in the season but was not a primary driver of metabolism. Total Nitrogen (TN) and Total Phosphorus (TP) in the water column typically increased later in the summer but dropped as flows resumed in the fall; most of the TN was dissolved, generally organic N and most of the TP was dissolved P. The senescence of SAV may have provided an internal source of nitrogen during the impounded condition during the summers of 2012 and 2013 that then subsequently flushed out in the fall. There may also be some external sources of N to the impounded condition during the late summer, but not from the POTW during 2012 and 2013. The year 2011 had much lower TN in the water column likely as a result of the flowing condition and maintenance of healthy SAV throughout the summer. There is an apparent signature of elevated Total Inorganic Nitrogen (TIN) concentrations near inflowing water (near HCWMA and the east side), but these higher concentrations were very localized as elevated concentrations were not observed in concurrently collected samples from nearby sites in the open water of the Spur.

There is a low N:P ratio during the early season, followed by elevated N:P ratios during the late summer, and subsequent decline in N:P as fall progressed. N may be accumulating in the sediments or more likely, lost through denitrification, and P may be recycling. During periods of active SAV growth, nutrients (especially P) in the sediment may be pumped to above ground SAV tissue. Later, after SAV senescence begins, the nutrients may be released to the water column. The flowing hydrologic regime appears to decrease the N:P ratio again, perhaps through dilution or changes in wetland biota. It was observed that sediment needs to be anoxic for P bound to iron to be released at the sediment/water interface. If the P is not iron bound then perhaps P release from sediment is regulated by pH and carbonate minerals and would be more recalcitrant than iron bound P.

Toby reviewed a benchmarking analysis looking for potential water quality violations using primarily warm water aquatic life use criteria. There were a few ammonia (NH_3) exceedances on the east side when the Spur was cut off, SAV senescence ensued and water was shallow and warm. If temperatures rise, this may be important to watch. 56 out of 209 samples for pH exceeded the pH aquatic life criterion of 9, but these high concentrations are expected where rates of primary production are high. No exceedances were observed for dissolved oxygen. However, DO was also sampled during daylight, when values would be expected to be high. Dissolved metals do not appear to be a risk however some boron results exceeded criteria for agricultural use (that are not applicable to Willard Spur).

SAV abundance appeared to have peaked a little earlier in 2012 and 2013 than in 2011 but as mentioned above, also was observed to senesce in these years as opposed to 2011. Toby reviewed the effects of the impounded regime. Water depths are lower and water temperatures and TDS are higher for impounded conditions. Surprisingly not much difference is apparent in pH between flowing and impounded conditions. Not much difference in DO and chlorophyll-a between conditions. TN, TP, Total Organic N, and N:P ratios were all higher for the impounded condition. Peak SAV abundance occurred after the impounded condition began but then rapidly declined. Abundance of macroinvertebrates increased and composition of communities shifted from a phytophilous-dominated community to benthic-dominated community as SAV senescence rapidly ensued at the onset of impoundment. SAV condition appeared more sensitive in flowing condition to TN in water than TP, however, SAV bio-volume was opposite. SAV was declining in the impounded condition as TN increased.

Summary of Nutrient Cycling in Willard Spur, 2011-2013

See the following link for the presentation slides:
http://www.willardspur.utah.gov/panel/docs/2015/10Oct/NutrientUptake.pdf

Jeff Ostermiller provided an overview of methodology and results from UDWQ's uptake experiments to understand the SAV's role in nutrient uptake and cycling in Willard Spur. While there are significant changes occurring in Willard Spur throughout the year, how is the uptake capacity changing?

In nutrient addition experiments using mesocosms, N and P uptake were generally three times faster in mesocosms with SAV vs. no-SAV during the clear water phase in May-early July. Irrespective of SAV presence, nitrate uptake was 3-4 times faster than for phosphate during this same phase. This supports the idea that the SAV are also getting P from their roots which is generally considered to be the primary source of P for SAV. Epiphytes growing on the SAV could be getting their P from the water or SAV leaves, while SAV could be getting their P from multiple sources: water, epiphytes, and sediment.

During the green water phase (late summer), nutrient concentrations in the water column increased yet were relatively low compared to other wetlands. Nitrate was lower at night in the no-SAV treatment than with SAV. Phosphate was lower with SAV during the day than without SAV, suggesting SAV photosynthesis in this system includes P uptake from the water column. Such may be the case in systems with low sediment P concentrations. Uptake rates were generally faster later in the year perhaps due to higher rates by phytoplankton vs SAV and/or an increase in numbers of heterotrophic microbes after senescence began. Nitrate uptake rates were significantly faster at night without SAV. For these later (green water phase) experiments the mesocosms without SAV were placed in areas where SAV had already senesced, so it is possible that these higher nitrate uptake rates result from an increase in denitrification rates as the carbon from the SAV becomes increasingly labile to denitrifiers. There were very high background nitrate concentrations in the tailrace relative to the experimental nutrient spikes, consequently reducing the effectiveness of the experiment conducted there. Uptake rates for N and P were observed to be slower in the tailrace than in the open water, possibly due to the lack of SAV in the tailrace or, if this was during the discharge of the POTW to the tail race, this would provide a "fresh" and continuous supply of nitrate to the tailrace resulting in less nutrient demand.

The Science Panel discussed the importance of SAV. SAV appears to play an important role in uptake during the May-July timeframe (clear water phase). As the SAV senesce they release nutrients, including more labile carbon sources, to the water column and heterotrophic communities become more important – but green water is appearing simultaneously – so there is at least competition for the newly-available nutrients. This increase in microbial abundance is important to nutrient cycling in the Spur in a couple of ways. First, nutrients are directly incorporated into algal and bacterial biomass. Second, some of these microbes facilitate denitrification. The combination of these biological nutrient removal processes likely explains the faster uptake rates that were observed in the later, green water phase experiments relative to those conducted in the clear water phase. Also, the fact that we observed the fastest uptake rates in the nighttime, no-SAV treatments in the green water phase is consistent with the increased importance of denitrification during SAV senescence. Finally, the fact that nutrients, both N and P, seem to become more limiting later in the season, despite the increase in water column nutrient (especially P) concentrations is consistent with an increase in biological uptake. This coupled with the fact that uptake rates were equally high at night suggests that the increase in biological demand has both autotrophic and heterotrophic origins.

A key concern is that we do not want to see Willard Spur shift from an SAV dominated system to an algae dominated system. If this occurred, we would likely see a drop in the ability of the Spur to process nutrients. This is evidenced by the relatively slower uptake rates observed in the no-SAV treatments during the clear water phase, and the much slower uptake rates observed in the tailrace relative to the open waters of the Spur during the green water phase.

We also saw an increase in the relative abundance (biomass) of epiphytes and sediment periphyton later in the season. Phytoplankton did not appear to differ between SAV and no-SAV treatments. Also we saw C:N and C:P in SAV tissue increase during the green water phase; perhaps the SAV are sequestering nutrients back to their tubers as they senesce? Tubers are likely what contribute to the resilience of SAV and quick growth in the spring.

Nutrient ratios in photosynthetic organic matter can also be used to determine whether N or P were most limiting to primary production. Nutrients (N and P) appear to be more limiting later in the season rather than earlier, particularly for those autotrophs that reside higher within the water column (i.e., SAV, epiphytes and seston). In contrast, sediment algae appear to be both N and P limited throughout the entire growing season, which may reflect competition, initially with SAV as they transport and store nutrients in their tissue earlier in the season and then later with water column algae (phytoplankton) and microbes. The Science Panel agreed that Willard Spur is very biologically active and can process a lot of nutrients.

Jeff Ostermiller described an analysis he performed that scaled uptake rates to the entire ecosystem, on a daily basis, over the three years of the Spur investigations. The key question that this modeling exercise attempted to address was whether there were periods of time where daily loads exceeded the uptake capacity of the Spur. Several conservative assumptions were used to make these calculations because we wanted to know if the POTW might threaten the Spur in a future, worst case scenario. Perhaps most importantly, loads from the POTW were calculated from end of pipe concentrations (i.e., assumes no loss of nutrients in the tailrace), at design capacity flows, and assuming no nutrient treatment; although this has been demonstrated not to be the case.. Therefore, these future scaling estimates reflect a higher nutrient load from the POTW to the Spur than would ever be expected to occur.

The most important conclusion from these daily comparisons of uptake and load is that for the vast majority of the growing season the uptake capacity of N and P vastly exceeded external loads. The large difference between the loads and capacity imply that nutrient inputs are unlikely to cause harm and may even be beneficial to the Spur for most of the year. However, under these worst case scenarios, future nutrients (especially N) loads could exceed uptake late in the season during dry years due to the smaller size of the Spur. These models also show that once assimilative capacity was exceeded N hypothetically could accumulate to the point where concentrations exceeded thresholds of potential concern (identified in the U of U study). Notably however, by the time this was to happen, any POTW discharge would likely not have reached the open waters of the Spur. This isolation, coupled with the worst possible case, conservative assumptions that went into the calculations suggests a low risk from the POTW to the Spur, even at full capacity and without nutrient treatment. On the other hand, this analysis also highlights a diminished uptake capacity late in the season suggesting that this may be the period where nutrients are most likely to accumulate should alterations to the existing hydrologic or ecological conditions of the Spur change in the future.

The Science Panel agreed that the capacity of an ecosystem to take up and process nutrients does not necessarily mean that additional nutrients would not cause harm to SAV and associated biota. The University of Utah (Hoven et al. 2015) enrichment experiments did not result in measurable increases in water column concentrations, yet SAV conditions was negatively affected in the high nutrient treatment. This observation suggests that protective concentrations of nutrients fall somewhere between current conditions and saturation concentrations. However, it is extremely difficult to identify specific water column nutrient concentrations that are protective. If we could identify such a concentration, we could establish numeric criteria, but again the data from these investigations are insufficient to make such recommendations. Moreover, the high uptake rates and low water column nutrient concentrations observed over much of the years suggests that water column nutrient criteria would not be very meaningful for this ecosystem. Instead, alternative measures of condition (i.e., SAV condition indices) or nutrient enrichment (i.e., increases in sediment or plant tissue nutrient concentrations) may be more ecologically meaningful indicators of nutrient enrichment that could be incorporated into a long-term monitoring program.

Overall, all of the investigations suggest that the potential risks of the POTW discharge to aquatic life within the Spur are quite small. Even worst case future increases in nutrient inputs would not be measurable for most of the year (biological uptake >> nutrient loads), which means that barring major changes in other external factors (i.e., major hydrologic alterations) current conditions of the Spur are likely to be maintained in the future for most of the year. The only condition where future increases in nutrients appear to pose any threat to the Spur is late in the growing season (July-September) during years where the Spur becomes isolated from Bear River Bay. Even within this sensitive period, impacts from the POTW are unlikely because there is assimilation in the tailrace before the discharge reaches the Spur and a relatively short period where the discharge reaches the open waters of the Spur. Nevertheless, given the ecological importance of the Spur and its relatively unique low nutrient characteristics it may be prudent to explore BMPs that could be implemented to further protect the ecosystem. For instance, ongoing monitoring should be conducted so that unforeseen impacts can be quickly detected. It also might be possible to decrease the risk of the discharge even further by diverting as much of the discharge as possible to irrigate private lands upstream from the tailrace, especially during periods where the Spurs biota are already stressed by hydrologically-driven stressors. Such BMPs may go beyond what is absolutely required to ensure the long-term protection of the Spur, but provided that they can be implemented economically, they could provide an additional margin of safety in the protection of the Spur's aquatic life uses.

Does Willard Spur currently support its beneficial uses?

Presentation slides summarize current beneficial uses are found at:
http://www.willardspur.utah.gov/panel/docs/2015/10Oct/BeneficialUses.pdf

The Science Panel agreed that Willard Spur is supporting its beneficial uses. Willard Spur undergoes a transformation in response to flow regimes. As the conditions and community compositions change, so do the beneficial uses within Willard Spur, (e.g., senescence of SAV and resulting transformation of the system during impoundment, bird community response to changes in habitat and food sources during flowing vs. impounded regimes, warm water fishery changes as water dries up, etc.). The ecosystem Willard Spur supports is resilient as illustrated by its observed ability to recover from and adapt to both very wet and very dry conditions. Much of this resilience appears to be due to the flushing flows the winter and spring seasons seem to have historically provided.

Nutrient enrichment presents a potential risk to the Spur. Sustained diversion of water currently discharging to the Spur may present an even larger risk and could result in significant ecosystem changes. For example, a perennial impounded state (i.e., lack of annual flushing flows and associated groundwater recharge) could lead to accumulation of salts and nutrients, leading to significant vegetation changes.

Does the POTW's effluent discharge degrade the Willard Spur ecosystem?

Observations discussed by the Science Panel:

1. Nutrient concentrations in the water and sediment of Willard Spur are low, particularly during periods of active SAV growth.
2. Many designated aquatic life uses of Willard Spur depend on seasonal production of SAV. Absence of SAV, or transition to a phytoplankton-dominated state in early summer rather than late summer, if caused by nutrient pollution, should be considered a harmful change. Decreased temporal overlap of migratory bird use and supportive habitat condition could increase the impact on migratory bird use.
3. Willard Spur is nutrient limited. Generally it is co-limited by N & P. Although later in the season P limitation becomes increasingly important in drier years.
4. The nutrients from the POTW discharge are likely to be lost before entering the open waters of Willard Spur, thus end-of-pipe nutrient concentrations are higher than concentrations that would actually be delivered to the Willard Spur ecosystem. Some of these nutrients may never make it to the Spur at all, provided that they are lost to the

atmosphere (e.g., denitrification), to groundwater or are incorporated into plant material that is harvested (e.g., field irrigation). The remainder of nutrients that are taken up before the discharge enters the open water of the Spur may ultimately make it to the Spur, but any delays of these nutrient inputs further minimizes any risk of nutrient accumulation.

5. Nutrient uptake capacity is high in the Spur, which means that nutrients from the POTW discharge that make it to the open waters of the Spur are unlikely to increase water column nutrient concentrations under current hydrologic conditions. Instead, nutrients from the discharge would be incorporated and fully processed in the open waters of the Spur. The question is whether the incorporation of these nutrients has the potential to harm uses in the Spur.
6. Systemic SAV senescence appears to initiate after Willard Spur enters the impounded regime. This appears to be a natural condition that occurs in most years unless precipitation within the watershed is atypically high (e.g., 2011).
7. Although the experimental data are limited, the experimental results reported by Hoven et al. indicate that nutrient amendments adversely affected SAV. Moderate to high amendments resulted in depressed growth early in the growing season and accelerated senescence later in the summer. SAV condition metrics were decreased with high nutrient treatments. Neither nutrient treatment resulted in a measurable increase in water column nutrients, which suggests that the observed deleterious effects to SAV may occur below uptake saturation (uptake ≤ nutrient load). However, the fact that these responses were not observed in the low nutrient treatments suggests that some assimilative capacity, with respect to the potential for any future nutrient increases to harm SAV, remains.
8. A plausible mechanism for nutrient enrichment to degrade SAV within the Spur was described by Hoven et al. based on observations in the Spur and evidence from literature sources. The hypothesized pathways are: increased nutrient loading -> increased primary production (SAV, epiphytes, phytoplankton) -> increased pH and decreased DIC availability -> reduced growth due to DIC limitation -> increased overgrowth on SAV leaves by biofilms, diatoms and sediments (BDS) -> initiation of senescence of SAV -> release of nutrients -> shift of WS to green phase. But it should be kept in mind that the shift to the green phase occurred naturally in experimental controls that did not have any nutrient amendments. The relative roles of nutrients and other naturally occurring stressors could be more fully described and quantified by further research.
9. Other stressors may also contribute to SAV senescence and cumulative impact of these stressors remains unclear:
    - Increasing salinity of water
    - Increasing water temperatures
    - Reduction of inflow and resulting reduction in nutrient load may limit the SAV's supply of nutrients
    - Bioavailable P in the sediment runs out, SAV stops growing and begins to senesce
10. Willard Spur's nutrient uptake capacity diminishes as the water level drops. While uptake rates may be greater after water levels drop during the green phase of the impounded regime, the reduced surface area and volume of available water reduce the ecosystem's overall uptake capacity. Any nutrients that make it to the Spur during this period could potentially accumulate within the Spur, although this is unlikely unless the yearly hydrologic connectivity to Great Salt Lake is shortened or eliminated in the future.
11. As SAV decomposes, nutrients are released back into the water column. Decomposing organic matter facilitates an increase in heterotrophs although there is clearly an increase in algal biomass as well.
12. We observed a BOD pulse early in the water year, perhaps from contributions from desiccated/decomposed material from the prior year.
13. There are two options for managing POTW effluent to further reduce any risks posed to the Willard Spur ecosystem: 1) discharging to a location where water evaporates and/or infiltrates to minimize or eliminate contributions during the critical impounded condition, and 2) removing P from effluent during the critical impounded condition, although, again, it is extremely unlikely for the effluent to reach the open water and yet still contain an enriched nutrient load during this condition.

Summary of Conclusions

The Science Panel agreed that Willard Spur has a demonstrated sensitivity to increased nutrients as observed in experiments completed as part of this project, (e.g., nutrient limitation, increasing biofilm on stressed SAV, etc. (Hoven et al 2014a, Hoven et al 2014b, Ostermiller 2015)). The data also show that there are numerous stressors that influence the ecosystem and make decoupling the relative roles of nutrients and other stressors extremely challenging (Hoven et al 2014a, Hoven et al 2014b, Gray 2012, Gray 2013, Gray 2015a, Gray 2015b, Hooker 2015, CH2M 2015). Given the demonstrated sensitivity to nutrients and that mechanisms for an adverse effect from nutrients are possible, the Science Panel agrees that it is reasonable to assume that added nutrients, whether from point sources or non-point sources, still have the potential to have an impact on the ecosystem. The goal is to find the most effective mechanism to manage these nutrient sources, especially during critical periods, with the available resources, to prevent an adverse impact from occurring.

Impacts from and specific to the POTW were not observed during the course of this study, however there is a potential that the POTW may have had localized impacts near the discharge location, (e.g., elevated nitrates in the isolated tailrace channel during the mesocosm experiments, and BOD). The POTW's effluent 1) mixed with the open water during the flowing condition and 2) only briefly reached the open water at the beginning of the impounded condition. Most importantly, the effluent did not reach the open water during what the Science Panel considers to be the most critical impounded period of July – October of 2012 and 2013. The Science Panel agreed that alternatives that reduce or eliminate the load during this period would significantly reduce the risk of the POTW having an impact on Willard Spur.

The Science Panel discussed various mechanisms for potential impacts from the POTW:

1. The Science Panel discussed the potential impacts from nutrients if the Plant's discharge evaporates or infiltrates into the soil as it was observed to do during summer months. The Science Panel agreed that nutrients from the POTW's discharge that evaporates and/or infiltrates, does not pose a risk. Phosphorus may be left at the sediment surface and has the potential to accumulate there. However, under current conditions we did not see phosphorus accumulating within the sediments of Willard Spur. This indicates that P is flushed out when flushing flows return in the fall. Some nitrates inputs likely are denitrified and released to the atmosphere. Nitrate may also go into the groundwater but this would likely be an exceptionally slow process as the Spur sediments are dominated by clay material (very low in porosity). The potential for the POTW to contribute a nutrient load to Willard Spur decreases as the effluent infiltrates, denitrifies, is assimilated or adsorbed to sediments. Monitoring of these removal processes would document that nutrient removal continues to exist in the future. This would be particularly important in the future as the volume of the POTW's discharge is expected to increase which could increase the potential for connectivity. However, it was noted that this small discharge (approximately 1.2 cfs) is already at half the design flow. Therefore, only a slight increase to about 3 cfs is not expected for another 10-20 years from now.

   The Science Panel agreed that the probability of the POTW's contributing nutrient load to the open water is even more remote when the effluent was discharged to the old outfall ditch, the pasture, and the tailrace channel, albeit from slightly different mechanisms. Discharge to the pasture has the lowest risk of causing nutrient accumulation because the vast majority of the nutrients have been demonstrated to be taken up by the sediments or plants and the pasture is periodically mowed – further removing nutrients from the system. If the discharge goes directly to the tailrace, uptake in the channel would reduce the load that reaches the open waters of the Spur during high water conditions but yet this flow totally disappears during low flow/ summer "cutoff" conditions. Applying the daily uptake rates observed in the tailrace suggest that uptake in the tailrace would remove most N and at minimum of 10-20% of the P. During late summer in dry years, when uptake capacity is lowest, the open water is rapidly isolated from the tailrace- preventing effluent water from reaching the open water. Hence, nutrient reductions would occur via biological uptake and infiltration as the water flows through fringe wetlands and across the mudflats and would be completely prevented from reaching the open water within a few weeks of the water being cut off from the Refuge supply. There is, however, the potential for nutrients to accumulate in these areas. If the tailrace is used as the discharge point, these areas should be monitored to determine if nutrients are accumulating.

2. The Science Panel agreed that the POTW's discharge does not appear to be a concern during the flowing condition. The POTW's effluent appears to be mixed, dispersed, and diluted by a factor of up to several thousand and an increase in nutrients from the POTW are non-detectable in the water column, presumably because they are

biologically assimilated or exported to GSL. Added nutrients when SAV are thriving could actually help maintain the SAV if other stressors and factors did not combine to trigger SAV senescence. It is important to note, however that added nutrients after the SAV senesce may have a greater potential to create problems. But keep in mind that senescence only occurred after the flushing flows were cut off from the primary source which was overflow water from Pond 5C in the Refuge. Inflow water from HCWMA or the POTW failed to reach to open water of the Spur shortly after the discharge from Pond 5C was discontinued. Subsequent SAV senescence is coincident with several stressors that all develop once the Spur becomes isolated from Great Salt Lake. Thus, if Willard Spur remains within the flowing regime, as it did in 2011, then the risk is unperceptively small throughout the year. In dry years, elevated risk from increased nutrients from the POTW would be relatively higher as the size of the Spur diminishes. However, under current conditions the risk to the Spur quickly becomes minimized further when the effluent water is isolated from the open water of the Spur under low pool conditions. That said, nutrients added to the experimental plots designed by Hoven et al. (2015; part of this study), were related to diminished SAV condition and slightly earlier senescence, so potential risk from those nutrients that do enter the Spur cannot be entirely eliminated.

3. The Science Panel agreed that there is a potential for the POTW's effluent to impact the open water if nutrients were able to reach the open water during the critical impounded condition and end of pipe concentrations were maintained for this entire distance, again—conditions not observed during these investigations. There are not adequate data to precisely define the mechanisms, responses, or metrics to measure an adverse response, but given the unique low nutrient conditions that appear to be an important characteristic of the Spur, the Science Panel agrees that there is the potential for adverse effects should nutrients ever accumulate in the water column.

4. Under current conditions the panel thinks that the risk of the discharge harming the Spur is low to nonexistent. However, if possible, management of nutrient loads during the growing season may be prudent. There are several ways in which nutrient loads from the POTW could be minimized. Any of these practices that are implemented would constitute an additional margin of safety, protecting the Spur, to the extent practical, from unanticipated future events. The panel also recommends that the impacts of the Spur be reevaluated if appreciable changes in timing or extent of its hydrologic connectivity to Great Salt Lake changes in the future.