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Tanju Kiriscioglu
University of Nevada Las Vegas

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The Fate and Transport of Nitrogen (N) and the Effect of Emergent Plants on Natural Treatment of N-species at Las Vegas Wash, Nevada

by

Tanju Kiriscioglu

A thesis prospectus submitted in partial fulfillment of the requirements for the Bachelor of Science Degree
Department of Environmental Studies
Greenspun College of Urban Affairs

Content Advisor
Krystyna A. Stave, Ph.D., Associate Professor, Environmental Studies

Class Advisor
Timothy J. Farnham, Ph.D., Assistant Professor, Environmental Studies
ENV499 A&B

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1. Introduction

The purpose of this study is to analyze the effect of emergent plant communities at Las Vegas Wash (the System) using a system dynamics modeling approach. Understanding the dynamics of nitrogen (N --major polluting nutrient in the Wash) that enters the System is important because it occasionally causes algal blooms, choking Lake Mead through excessive eutrophication. Emergent plant communities are an integral part of wetland ecosystems and they play a crucial role in natural treatment of nutrients. This study is intended to test this hypothesis.

The study makes use of Wash data from reliable sources (Las Vegas Valley Water District, Las Vegas Wash Coordination Committee, USGS, Clark County Sanitation District, and literature review) to examine spatial and temporal changes of different nitrogen species; to describe causal relationships between major environmental variables and feedback mechanisms that make up the System; to ascertain major inflows and outflows (rates at which a variable enters or exits a stock), stocks (the accumulation of a variable within the system), sources, and sinks; and to simulate the System’s behavior over time by changing the values of the environmental variables that make up the model. The model will help us identify policy levers in the System including the effect of emergent plant communities.

The study is important because there is an ongoing restoration of the wetlands at the Las Vegas Wash and it is critical to understand how the nutrients accumulate and
flow through the System. Efficient management of the wetland plant communities is crucial for the improvement of the biological treatment that takes place there. The dynamics of nutrient accumulation at these plant communities need to be understood better to evaluate means for managing the removal of nitrogen from the System most effectively: The model is intended to simulate results of harvesting emergent plants before they become detritus through litter fall.

1.1 The Problem

Las Vegas Valley’s population has increased from a few thousand people to over 1.6 million in slightly over a century (CCA, 2003), putting considerable amount of strain on local ecosystems. Recent studies have documented how degraded water quality at Las Vegas Wash and Las Vegas Bay area at Lake Mead have adversely affected fish and wildlife habitat associated with these areas (Bureau of Reclamation, 2001).

Prior to the development of the Las Vegas Valley, flow at Las Vegas Wash was perennial, but early in the 20th century, extensive groundwater withdrawal diminished flow in the Wash, causing the Wash to become ephemeral during precipitation and surface runoff events (Kilroy et al, 1997). After the construction of the first wastewater treatment plant in 1931, the Wash flow started to increase and during the 50’s it became steady again. With increased population in the Valley came increased demand for water, and increased return flow effluents (point source pollution) and urban runoff (non-point source pollution) that have made their way through Las Vegas Wash into Lake Mead (Figure 1, page 3). These changes have mostly impacted local aquatic ecosystems: the once ephemeral Wash has first turned into a thriving riparian wetland during the ‘60’s
and '70's (Morris, 1983) and then into an eroded channel in '80's (Las Vegas Wash Coordination Committee (LVWCC), 2006), seriously decreasing the rates of natural removal of nutrients --nitrogen (N) and phosphorus (P) in particular-- as described by the Clark County Department of Comprehensive Planning (1978).

According to United States Geological Survey's (USGS) National Water Quality Assessment (NAWQA) that was done between the years of 1992-96, the annual total nitrogen (TN) load at Las Vegas Wash downstream increased from 750 tons in 1974 to 2,400 tons in 1988. The median ammonium ($\text{NH}_4^+$) concentration in Las Vegas Wash was nearly 300 times the NAWQA national median and all samples exceeded the USEPA aquatic-life criterion for un-ionized ammonia --$\text{NH}_3$ (USGS, 1996). Since that time, Southern Nevada Water Authority (SNWA), the Valley's water purveyor, and the Valley's three major dischargers (City of Henderson, City of Las Vegas, and Clark County Water Reclamation District) have spent millions of dollars to improve the Wash's
water quality by conducting numerous studies, upgrading wastewater treatment facilities, improving treatment methods, promoting water conservation and water recycling, and education and public outreach. Nitrogen loading at Lake Mead continued at high rates, in spite of the fact the wastewater treatment has improved drastically (Nevada Division of Environmental Protection (NDEP), 2003). During recent years, Las Vegas Wash flow rates went up from 215 million m³ in 2000 to 245 million m³ in 2005 and the total nitrogen (TN) loads went up from 3.094 tons to 3,423 tons per year even though TN concentrations went down from 14.39 mg/L (ppm --part per million) to 13.97 mg/L as seen in Figure 2, page 5. Figure 1 illustrates (NO₃⁻)-N as the major contributor to the overall N-load at Lake Mead and it is currently on the decline; the TKN (Total Kjeldahl Nitrogen) is on the rise, and (NH₄⁺)-N seems to be steady. Even though downstream (NO₃⁻)-N concentration is decreasing, it still is above an acceptable level and at the rate the Valley’s population is increasing, it is not clear whether the trend will stay this way or bend upwards as better wastewater treatment will become increasingly difficult and costly under current circumstances.

The Las Vegas Wash and surrounding wetlands are already subjected to high evapotranspiration rates characteristic of desert climates, and it doesn’t help that the riparian zone soils are further exposed to heavy loads of nitrates (NO₃⁻). The overabundance of salty soil has facilitated the spread of saltcedar, or tamarisk, (*Tamarix ramosissima*) an exotic, invasive tree introduced in 1930’s to the Southwest from southern Eurasia to control soil erosion at river banks (Horton 1977; Baum 1978). Now a dominant riparian shrubby tree in the Colorado River Basin below 2,000 m elevations,
Tamarix spreads rapidly throughout the area, including Las Vegas Wash, severely choking local ecosystems (Graf 1978). Southwestern willow flycatcher (*Empidonax traillii extimus*) is a riparian species, nesting on mostly native riparian thickets and native wetland trees and shrubs. With the dominance of exotic tamarisk communities and the decline of native plant communities around Las Vegas Wash (in 1975, Wash salt cedar cover was approximately 300 acres and native vegetation was 1246.6 acres. In 1998, salt cedar cover went up to 1,021 acres and the native vegetation cover dropped to 304 acres (Las Vegas Wash Coordination Committee, 2006)), this small passerine bird was placed on the federal Endangered Species list in 1995.

Figure 2. N-species concentrations at Las Vegas Wash downstream between 2000-2005.
The most visible repercussion of the increased return flows is erosion that contributes greatly to problems associated with salinity in the Colorado River ecosystems, and affects plant communities and neighboring habitats in the wetlands. (Wolff, Buck, et al, 2001). In an effort to protect the razorback sucker (*Xyrauchen texanus*) from extinction due to degradation of water quality at Lake Mead, the U.S. Fish & Wildlife Service listed this species as endangered in 1991 and designated Lower Colorado Basin as critical habitat in 1994 (Tuttle and Orsak, 2002).

The national standard for nitrogen in drinking water is 10 milligrams/L (ppm) (USGS) and since the water intake for the municipal water takes place right where the Wash joins Lake Mead with high concentrations of nitrogen, it is crucial that we manage this problem before it gets worse. Local wastewater treatment plants (Clark County, Las Vegas, and Henderson) do remove a great portion of the polluting nutrients from the Valley’s wastewater stream, but further natural treatment at the wetlands is necessary since a more comprehensive treatment at the Valley’s wastewater treatment plants is costly and time-consuming, and storm water and urban run-off due to non-point sources do not get treated before reaching Lake Mead. In July 2001 Las Vegas’ wastewater treatment agencies were authorized to increase the maximum discharge permitted to the Wash from 176 million gallons a day (mgd) --about 197,000 acre-feet a year -- to about 244 mgd, or over 273,000 acre-feet per year. However, Nevada also has adopted Total Maximum Daily Loads (TMDL’s) --a provision under the federal Clean Water Act that requires states to set standards for pollutants that impair waterways: Phosphorus and ammonia were identified as primary pollutants and they were each assigned total
maximum daily loads of 433 lbs/day (196.4 kg/day) and 970 lbs/day (440 kg/day) respectively (Nevada Division of Environmental Protection (NDEP), 2003).

2. The Approach

Sterman describes system dynamics as a problem evaluation approach based on the premise that the structure of the system, that is, the way essential, interrelated system components are connected, generates its behavior (Sterman, 2000). If the dynamic behavior of the system arises within the system, finding effective and feasible policy solutions requires the understanding of the structure of the system (Stave, 2003). System dynamics is a well-suited discipline to understand and analyze the nature of the problem whose behavior is governed by internal feedback relationships that have a long-term time horizon (Vennix, 1996). I have used system dynamics analysis as a tool for examining the effect of emergent vegetation on nitrogen in the Las Vegas Wash.

2.1 The Study Area

The study focuses on the environmental model of fate and transport of nitrogen at Las Vegas Wash. The Las Vegas Wash is an 18 km long natural drainage channel (Figure 3 & Figure 4) that provides the only surface and sub-surface water drainage into Lake Mead for the entire 2,193 square miles of Las Vegas Valley (United States Department of Interior, 2006). It is located in Clark County, Nevada, and in southeastern portion of the Las Vegas Valley between the City of Las Vegas and Lake Mead. The Wash is primarily a mesic to hydric biotic environment. The hydrophytic wetland vegetation is dominated by Typha latifolia & Typha domingensis (cattail), Phragmites australis (reeds), and Scirpus validus (softstem bulrush) communities; extensive growths of phreatophyte
Tamarix ramosissima and Tamarix chinensis communities border the wetlands and the riparian buffer zones (U. S. Bureau of Reclamation, 1982).

This study addresses the 14 km long stretch of the Wash that starts approximately at the City of Las Vegas wastewater treatment plant and ends at Northshore Road, right past Lake Las Vegas. Southern Nevada Water Authority has been monitoring water quality at designated sites along the Las Vegas Wash (Figure 5, page 10). Data collected at these sites were used to observe the behavior over time graphs (BOTG) for nitrogen.

Figure 3. Satellite Image of Las Vegas Valley. Source: United States Geological Survey (USGS)
2.2 Questions of Interest

With this study I hope to answer the following questions:

- How do the different N-species enter and exit the Las Vegas Wash? Where do they accumulate?

- What compartment(s) of the nitrogen biogeochemical cycle plays a crucial role for the storage, transformation, and transport of N within the System?

- What plant communities are crucial for N removal from the System?

- Is litter fall and detritus generation a major contributing factor for nitrogen pollution?

Figure 4. An Overview of the Las Vegas Valley Watershed, Sub-watershed Boundaries, and the Proximity to Lake Mead and the Drinking Water Intake Point. The sub-watersheds are: C1 (C1 Channel), PIT (Pittman Wash), DUC (Duck Creek), FLA (Flamingo/Tropicana Wash), LOW (Lower Las Vegas Wash), CEN (Central Basin), GOW (Gowan Basin), RAN (Range Wash), and NOR (North Basin)

- Do major rain/flood events play a role in increased N levels at the Wash?
- What are the policy levers to reduce nitrogen levels in the Wash and what are the relative effectiveness of each?

2.3 Hypothesis

My hypothesis is this: A great deal of the nitrogen gets removed from the System and gets accumulated in the biomass of the emergent plant communities. If my study can support that wetland plant communities (emergent plants in particular) do indeed play a major role in the biological treatment of nitrogen, recommendations will be made to authorities on how to better implement the ongoing wetlands construction plan since a
thorough treatment is necessary to minimize the impact at local ecosystems and ecosystems down the Colorado River.

3. Methods:

The system dynamics problem solving process can be summarized in five steps:

1. Define the problem: This is the step to represent the problem as a trend over time.

2. Conceptualize of the system: This is the step where the system is described, a dynamic hypothesis is established, causal loop diagram (CLD) and stock and flow diagram (S&F) are constructed and validated.

3. Build confidence in the model.

4. Use the model for policy analysis.

5. Apply the results to the real system.

Figure 6. Diagram of nitrogen fate and transport in a wetland. Source: William F. DeBusk, University of Florida. http://edis.ifas.ufl.edu/SS303
Since I'm examining the fate and transport of nitrogen at Las Vegas Wash, the best place to start examining the nitrogen concentrations is where the System's outflow is located (sampling site LW0.8; Figure 5, page 10). This will give me an understanding of how much of the nitrogen is exiting the System and how it behaves over time. In order to do that, the concentrations of different species of nitrogen at LW0.8 were plotted on a five-year horizon (2000-2005) and this established the reference mode (a.k.a behavior over time graph (BOTG), Figure 1) for which the model was based on. (For this I have used data that was collected, tested, and compiled by Dr. Zou Xiaoping, Hydrologist II for Southern Nevada Water Authority (SNWA).)

3.1 Dynamic Hypothesis

Building the dynamic hypothesis is the most crucial step in modeling; if the hypothesis is wrong, the model will not represent the system under study. This is the step to build a hypothesis that one thinks is the reason why the system is behaving the way it does. The behavior of a system is a function of its structure; in other words structure is what generates the behavior. It is very important to get familiarized with the system in order to build a viable dynamic hypothesis (Ford, 1999). Nitrogen fate and transport involves biogeochemical cycling. In order to build a causal loop diagram, all the variables that make up the system and their causal relationships need to be identified. In order to identify the variables of the system, I had to understand the biogeochemical cycling of nitrogen in a wetland ecosystem that is illustrated in Figure 6, page 11.

Nitrogen species that enter wetlands from surrounding ecosystems undergo complicated processes. They are either stored in pure or transformed form (only to be released out of the system in a short time or to be buried for a very long time) or they
directly get transported out of system (Vymazal, 1995; National Academy of Sciences, 1978; Mitsch and Gosselink, 1986). Las Vegas Wash is an anthropogenic (urban) wetland where most of the nitrogen that enters the System ends up exiting in a few hours due to the fast flow of the water.

Different N-species (organic-N, NH$_4^+$-N, NO$_3^-$-N and NO$_2^-$-N (very negligible)) that enter the Wash has the potential to:

1. Get deposited onto the Wash bed (by *sedimentation* of both organic and inorganic particulate nitrogen, and by *litter fall* that results in detritus);

2. Get decomposed (*decomposition, ammonification, organic N mineralization*):
   - organic matter $\rightarrow$ gets broken down into smaller molecules including NH$_4^+$ (ammonium) $\rightarrow$ NH$_4^+$ becomes food for microorganisms $\rightarrow$ NH$_4^+$ eventually leaches into soil or diffuses into water;

3. Diffuse from the water column into the soil and vice versa (*diffusion*):

   - NO$_3^-$ (nitrate ion) in water $\leftrightarrow$ NO$_3^-$ in soil,
   - NH$_4^+$ in soil $\rightarrow$ NH$_4^+$ in water;

4. Get nitrified (*nitrification*): NH$_4^+$ $\rightarrow$ microbial conversion by *Nitrosomonas* and *Nitrobacter* spp. $\rightarrow$ NO$_3^-$;

5. Get released into the air (*denitrification*): NO$_3^-$ $\rightarrow$ microbial conversion by *Pseudomonas* spp. $\rightarrow$ N$_2$ ($\uparrow$nitrogen gas), N$_2$O ($\uparrow$nitrous oxide);

6. Get released into the air as NH$_3$-ammonia (*ammonia volatilization*);

7. Get taken up (this applies to NH$_4^+$ and NO$_3^-$) by the emergent plants (*plant uptake*);
8. Get retained in the soil through the process of cation exchange where the NH\textsubscript{4}\textsuperscript{+} is weakly bound to soil by electrostatic attraction (adsorption);

9. Get buried into the soil for long term storage (peat accretion).


There is also nitrogen fixation that takes place at the wetlands (or anywhere else) which is the conversion of nitrogen in its gaseous state to ammonia and nitrate: In high energy fixation, atmospheric nitrogen and oxygen combine to form nitrates (due to lightning and cosmic radiation) which are then deposited on Earth through precipitation; in biological fixation, symbiotic bacteria Rhizobium on the roots of legumes, free-living bacteria (such as Azobacter and Clostridium) in soil, and blue-green algae (cyanobacteria such as Nostoc and Calothrix) both in soil and water can fix nitrogen to yield ammonia (Vymazal, 1995; Vymazal, 1999).

Since the biogeochemical cycling for any nutrient is a very complicated process, there was no way for me to foretell which one of the aforementioned processes dominates the Las Vegas Wash fate and transport of nitrogen.

My dynamic hypothesis is this: The driving force behind nitrogen pollution at Las Vegas Wash is the increasing human population which in turn increases the treated wastewater getting discharged into Las Vegas Wash. The natural biogeochemical cycling at the Wash is probably already disrupted due to human activity and the majority of the nitrogen --both in reclaimed water (treated wastewater) and urban runoff--doesn’t get much exposure to any of the aforementioned processes, including assimilation: water
Figure 7. The simplified Causal Loop Diagram (CLD) of Fate & Transport of Nitrogen at Las Vegas Wash. A “+” sign on the tip of an arrow connecting two variables indicates a direct relationship and a “−” sign an inverse relationship between the variables. For example, as the Las Vegas Valley population increases, so does the generated Wastewater; the “+” sign designates the direct relationship. The signs at the center of certain loops indicate there is a negative (balancing) feedback, in which a change in one variable feeds back to balance the initial change.

retention (the amount of time water spends in the body of surface water) time is too short (in the order of 2-3 hours for the entire Wash (Desert Research Institute, 2006)) and most of the nutrients bypass the Wash, getting discharged into Lake Mead and impacting the ecosystems there. The major feedback loop in the system is the efficiency of wastewater treatment that keeps increasing (with increasing cost of wastewater treatment) every time
pollution discharge into Lake Mead increases. The other important yet smaller feedback loop is the decomposition of organic nitrogen in biomass that gets converted to inorganic nitrogen. The simplified causal loop diagram (CLD) (Figure 7, page 15) summarizes my dynamic hypothesis.

3.2 Main Assumptions in the Model

The following assumptions were made for the model:

1. Las Vegas population has been increasing exponentially since 1900 and it will do continue so for a while and then level off once the quality of life reaches undesirable levels.

2. Per capita non-residential water consumption is: 36 m$^3$/(person*year), per capita residential water consumption is: 105.85 m$^3$ / (person*year), and per capita human waste generation: 0.73 m$^3$ / (person*year) and they remain constant throughout the model.

3. The cost and treatment efforts at Las Vegas Valley wastewater treatment plants have to increase as the Valley’s waste load into Lake Mead increases.

4. The Las Vegas Wash was a perennial stream in 1900’s; it did not have a steady flow until the inception of Clark County Water Reclamation Facility (formerly Clark County Sanitation Plant) in 1931. The baseflow entering the Wash is considered to be a constant flow and it is in the order of 10-13 m$^3$/year.

5. The Upper Wash is the stretch between the City of Las Vegas wastewater treatment plant and Pabco Road. During this stretch the Wash is considered to be a losing stream.
6. The Lower Wash is the stretch between Pabco Road and Northshore Road. During this stretch the Wash is considered to be a gaining stream.

7. The water volume at the Upper Wash and the Lower Wash are estimated to be 26,937 m$^3$ and 68,218 m$^3$ respectively.

8. The surface of the Wash water at the Upper Wash and Lower Wash are estimated to be 44,895 m$^2$ and 124,457 m$^2$ respectively. The Las Vegas Wash is assumed to have a V-shaped profile (as opposed to a U-shaped profile) and the streambed surface area at the Upper Wash and the Lower Wash are estimated to be 56,119 m$^2$ and 155,572 m$^2$ respectively.

9. The length of the Upper Wash and the Lower Wash are estimated to be 4,064 m and 6,848 m respectively.

10. The Las Vegas Wash drainage basin is estimated as 5.69 E+09 m$^2$.

11. The soil nitrogen content at the Wash is assumed to be 35% NO3-, 35% NH4+, and 30% organic N, which makes the Wash soil a mineral soil.

12. At the Wash, the following values were used:

   \[
   \begin{align*}
   \text{NH}_4^+ \text{ diffusion rate} &= 0.005 \text{ g/(m}^2\text{*year)}, \\
   \text{ammonification rate} &= 0.01752 \text{ kg/(m}^2\text{*year)}, \\
   \text{nitrification rate} &= 0.05 \text{ kg/(m}^2\text{*year)}, \\
   \text{denitrification rate} &= 0.35 \text{ kg/(m}^2\text{*year)}, \\
   \text{assimilation rate} &= 0.005 \text{ kg/(m}^2\text{*year)}, \\
   \text{atmospheric nitrogen deposition rate} &= 0.016 \text{ kg/(m}^2\text{*year)},
   \end{align*}
   \]
sedimentation rate = \( \frac{1}{2} \) of TKN discharge,

NH\(_4\)+ to NH\(_3\) conversion rate is estimated to be 3-5%.

The values for some environmental variables are still under review.

### 3.3 Building the Model

During the modeling process, I used VENSIM® PLE (Ventana Systems Inc., 2004), a simulation software. The time horizon for the model is 200 years, from 1900 to 2100. For the model I have used data that I have gathered through literature review, as well as Dr. Xiaoping’s data that consisted of flow rates of water at predetermined sites (shown in Figure 3) and concentrations of nitrogen species NH\(_4\)+ (ammonium), NO\(_3\)- (nitrate), NO\(_2\)- (nitrite), NO\(_3\)+ NO\(_2\), and TKN (Total Kjeldahl Nitrogen) among other variables measured at these sites. (The combination of the organic nitrogen (TKN + NH\(_3\)), NH\(_4\)+, NO\(_3\)-, and NO\(_3\)- -- make up the total nitrogen (TN) in the wastewater. TKN is the organically bound nitrogen in wastewater that is usually much higher on influent (untreated waste) samples then effluent samples. In most domestic wastewater facilities the biological activity breaks down the organic matter, consuming the nitrogen as energy in the process. Even though the three wastewater treatment facilities in Las Vegas Valley do properly treat nitrogen in the Valley’s wastewater stream, a certain percentage is still released into the Wash. The monitoring of which is critical for environmental health.)

If no data was available for any of the model variables, I estimated them until my model generated an output that resembled the reference mode.

Once all the variables in the model were established, their causal relationships were identified and the causal loop diagram was constructed, the completion of which
facilitated the design of stock and flow diagram (S&F) (Figure 8). (Stock and flow diagrams have an advantage over the causal loop diagrams since they include stocks (where matter accumulates) and flows (the rate at which the matter enters or exits a stock). It also helps us identify the functional relationship between the variables. On the other hand, the strength of a causal loop is its ability to reveal feedback mechanisms clearer than the stock and flow diagrams. That’s why both of these structures need to be

Figure 8. Las Vegas Wash Nitrogen Fate & Transport model structure (simplified Stock and Flow Diagram).
Once the reference modes were duplicated (i.e., confidence was built), it was time to identify the policy levers. Policy levers are those variables the change in which (usually a reduction in their values) has the capacity to improve conditions. After the effectiveness of the policy levers were tested, they were recommended to the authorities.

4. Results

The main driving force behind fate and transport of nitrogen at Las Vegas Wash is the anthropogenic nitrogen that is discharged into the Wash. The amount of loads for each N-species increases with increasing human population. When the loads get too high, stringent environmental laws and regulations kick in to force the Valley’s wastewater treatment facilities for more effective treatment practices. Figures 9 through 12 (pages 20-21) are the results of the Las Vegas Valley water balance and N-species loads from the Lower Wash into Lake Mead; they are what I have expected.

![Graph of lower wash outflow into lake mead](image)

*"outflow below Lake Las Vegas (at Northshore Road)" : base run — m^3/m^2/Year

Figure 9. Lower Wash outflow into Lake Mead (at Northshore Rd.)
Figure 10. NH4+ loads into Lake Mead (at Northshore Rd.)

Figure 11. TKN loads into Lake Mead (at Northshore).

Figure 12. NO3- loads into Lake Mead (at Northshore).
The data in figures 13 and 14 is based on the LVVWD 2000-2005 data that's shown in the Appendix. The model's output is very similar to this data.

<table>
<thead>
<tr>
<th>Year</th>
<th>O-Flow (m$^3$/yr)</th>
<th>F-Flux (tons/yr)</th>
<th>C-Concentr. (g/m$^3$)</th>
</tr>
</thead>
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<td>2956</td>
<td>13.56</td>
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<td>220 E+6</td>
<td>3216</td>
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<td>221 E+6</td>
<td>2877</td>
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<tr>
<td>2003</td>
<td>239 E+6</td>
<td>3501</td>
<td>14.67</td>
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<td>237 E+6</td>
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<td>14.66</td>
</tr>
<tr>
<td>2005</td>
<td>240 E+6</td>
<td>3096</td>
<td>12.90</td>
</tr>
</tbody>
</table>

Figure 13. NO3- loads into Lake Mead (at Northshore Road)

<table>
<thead>
<tr>
<th>Year</th>
<th>O-Flow (m$^3$/yr)</th>
<th>F-Flux (tons/yr)</th>
<th>C-Concentr. (g/m$^3$)</th>
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<td>18.52</td>
<td>0.0842</td>
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<td>32.69</td>
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<td>239 E+6</td>
<td>34.91</td>
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<td>34.74</td>
<td>0.09</td>
</tr>
<tr>
<td>2005</td>
<td>240 E+6</td>
<td>30.96</td>
<td>0.1542</td>
</tr>
</tbody>
</table>

Figure 14. NH4+ loads into Lake Mead (at Northshore Road)

Figures 15 and 16 summarize the amount of nitrogen (NH4+ and NO3-) that accumulates in wetland (native and invasive) vegetation. Due to the fact that Valley's population is expected to increase (probably not at the same rate as between the years of 1975-2000) until the second half of the century; the amount of nitrogen in the Wash water, the amount of vegetation cover, and the amount of nutrient assimilation is also expected to increase.
Figure 15. NH4+ based organic-N in Upper Wash wetland (native & invasive) species biomass
Figure 16. NO3- based organic-N in Upper Wash wetland (native & invasive) species biomass.
Figure 17. The effects of population decrease and better wastewater treatment on N-species loads into Lake Mead at Northshore.
Figure 18. The effects of harvesting on Wash emergent and submerged plants.

Figures 17 and 18 (page 25 and 26) summarize the effects of policy changes on the nitrogen loads into Lake Mead.
5. Discussion & Recommendations

The model has simulated the fate and transport of nitrogen at Las Vegas Wash rather well. Since each model is nothing but an abstraction of reality, there are some areas in the model that require improvement once the nature of the nitrogen dynamics of the System is understood better.

The Las Vegas Wash is not a true wetland; it is an anthropogenic riparian zone which is exposed to large amounts of nutrients, predominantly nitrogen. (During the last decade, the phosphorus (P) loads decreased significantly, so did the NH4+ loads, but the NO3- loads remained to be a problem in spite of the fact its concentration is stabilized. Since NO3- is a by-product of wastewater treatment, and since more efficient and effective wastewater treatment is very costly, NO3- loads will remain within the guidelines of “Total Maximum Daily Load” allocation for the Valley. One way to reduce the load would be to slow down growth in the Las Vegas Valley Metropolitan Statistical Area; reduced human population will reduce wastewater generation, which in turn will reduce NO3- load into the Wash.

An important observation is the nitrate concentration going up as the Wash water travels downstream. This appears to be important for two reasons: 1. The non-point source of N pollution due to urban run-off needs to be further investigated; 2. We have to find out how much of the nitrogen does actually get removed from the System by emergent plants. (One of the purposes of this model is to ascertain the role and importance of emergent (and submerged) plant communities in the natural treatment of effluents.) Wetlands in general are supposed to capture most of the nutrients as they are considered to be kidneys of neighboring ecosystems. Once would be tempted to conclude
that reduced human population would also have a drastic impact on the reduction of
nutrient loads into the Wash, but this remains to be a discussion topic. Since recent
studies --According to Piechota & Reginato Las Vegas Valley's calibrated non-point
source TN concentration for different land use types in 2000 were: Commercial: 7.5
mg/L; Highways/Roads: 8.1 mg/L; Industrial: 2.3 mg/L; Park, Golf Courses: 1.5 mg/L;
Public Land: 2.1 mg/L; Residential: 6.4 mg/L; Undeveloped: 7.4 mg/L, with a non-point
source TN-load into Las Vegas Wash that's estimated to be 67.73 tons (Piechota &
Reginato, 2002). This amount divided by 1,378,130 (Las Vegas Valley's population in
2000) equals to 0.049 kg N/(Year*people). Out of this amount, 0.0245 kg
N/(Year*people) belongs to NO3- (50% of TN), 0.0049 kg N/(Year*people) belongs to
NH4+ (10% of TN), and the rest belongs to TKN (0.0196 kg N/Year*people) (Piechota
& Reginato)).-- claim that the non-point source N-pollution is not as significant as
originally thought, I suspect that there is considerable amount of salt loading due to
groundwater infiltration taking place at Mid-Wash and Lower Wash that contributes to
the overall NO3- load into Lake Mead. (According to Schmidt and Hess, salt loads into
the Wash via groundwater were 384 tons/day in 1975; 380 tons/day in 1976; 371 tons/day
in 1977; and 207 tons/day in 1978 (Schmidt & Hess, 1980) (in comparison, current NO3-
loads into the Lower Wash are in the order of 3,000 tons/yr); in those years this was a
major environmental problem and its main cause was the settling ponds for industrial
effluents in Henderson (from the industrial complex) where pollutants leached into the
ground and then were transported to the Wash by means of groundwater migration
(Morris, 1983).)

Page 28 of 37
Morris contends that Las Vegas Wash nutrient uptake by emergent plants is rather significant (1983). At the time of his research the Wash water had a velocity of 1-2 m/s and the retention time was about 18 hours. The Wash water velocity in 2006 is as high as 6-8 m/s and the retention time is in the order of 2-3 hours (LVWWDD); in other words, it takes water to travel from the beginning of Upper Wash (Vegas Valley Road) to the end of Lower Wash (past Northshore Road) in about 2-3 hours. The emergent plants do not really get a chance to assimilate enough nutrients if the water speed is that high. My estimate is that under the current conditions, about 2-3 times less nutrient removal is taking place compared to 1980’s when the emergent plant cover was larger and when the Wash water velocity was much less. My model justifies that only to an extent with a slow decline in nutrient assimilation during the late 90’s and early 00’s. Approaching 2010, once the Wash will widen due to increased flow, the water speed will slow down and the nutrient uptake will increase again (Figures 15, 16).

Efficiency of removal of nutrients (nitrogen and phosphorus) from surface waters is a function of the loads entering the system and the degree of contact of waters with the wetlands (Burns and Taylor, 1979). Increasing velocities and volumes of flow decrease retention time that is important for enhanced recovery of these nutrients.

Several studies have been conducted in the past to investigate the nutrient removal by emergent and floating plants. The experimental wastewater treatment facilities in Zuidersee, Netherlands --wastewater ditches of rushes in reeds-- provided an excellent environment for the removal of nutrients where the removal rate was a function of time: the longer the retention time, the better the purification (Schmidt). Similarly, studies by Wolverton, Barlow, and McDonald (1976) demonstrated that water hyacinths can absorb
and metabolize various nutrients (including nitrogen and phosphorus) better with increased retention times. A study done at Spring Creek in Calumet County, Wisconsin, has shown nutrient uptake by vegetation to be over 10 g/m²/year (Spangler, Sloey, and Fetter, 1976). Vymazal claims that emergent plant uptake rates vary greatly both temporarily and spatially (1995). Average *Phragmites australis* nitrogen uptake rates are 22.2 - 82.2 g/(m²*m*Year) and average *Typha latifolia* rates are as high 262 g/(m²*m*Year) depending on the physical location of the wetland and the conditions where the wetland is located. This model assumes that Las Vegas Wash emergent plant nitrogen uptake rates are in the order of 60 g/(m²*m*Year) since Las Vegas Wash has ideal conditions (except the water retention time) for nutrient uptake and the growing season is rather long. According to Vymazal, NH4+ and NO3- uptake rates are inversely proportional. If the water ammonium concentration is high, emergent plant ammonium uptake rate will be high and nitrate uptake will be low and vice versa. Las Vegas Wash ammonium concentration rate is not very high compared to nitrate concentration, so this model assumes that NH4+: NO3- uptake ratio is 1:4. This comes up to 45 g NO3- uptake/(m²*m*Year) and 15 g NH4+ uptake/(m²*m*Year).

Joost de Jong claims that overall purification of wastewater increases drastically when the residence time (retention time) is in the order of days; in a bulrush pond in Netherlands, close to 100% purification was accomplished when the residence time was slightly over 2 weeks (Schmidt, 1980).

In order to attain the optimum purification of surface waters in a marsh environment by natural means, selected species to do the job must have a capacity to accumulate these nutrients, must have a rapid growth rate, and should produce a large
standing crop (Schmidt). Once the vegetation has amassed enough nutrients, it must be removed from the system before it decays and deposits the amassed nutrients back into the system; proper planning and execution of the harvest is essential. There are several emergent and floating plants that will meet these criteria: *Eichlorina crassipes*, *Alternanthera philorerooides*, *Justicia Americana* (water willow), *Typha latifolia* (cattail), *Scirpus validus* (softstem bulrush), *Phragmites australis* (reeds), *Schoenoplectus lacustris*, *Iris versicolor* (blue flag), and *S. fluviatilis* (Schmidt). Emergent plant communities at Las Vegas Wash have the potential to assimilate more nutrients if the stream velocity is further reduced by more weirs; the construction of more ponds and the improvement of the existing ones are necessary to prolong the retention time.

The model has identified three policy levers that are recommended for policy change:

1. Slowing down the growth in the Valley.
2. Harvesting of emergent plants if feasible.

The Las Vegas Valley’s population has been growing out of control during the last three decades and nobody really knows when it will slow down. The decrease in the Valley’s quality of life will probably the major determining factor to bring the growth to a halt. As long as the reclaimed water (>150 mgd) does not get treated better, the N-load into Lake Mead will increase until 2050, further degrading the environmental conditions at Lake Mead and the Colorado River downstream.

Harvesting of the plants sounds like a good alternative to decrease the nitrogen load into the Wash, but feasibility studies must be done first.
And better treatment of wastewater is the last policy lever that is probably the most likely to occur that will decrease the nitrogen loads into the Wash. Currently, it costs about $US 1,100.-/million gallons to treat wastewater and any attempt to increase the level of wastewater treatment will increase the overall cost drastically.

6. Conclusion

We need do develop a better understanding on the biogeochemical cycles that take place in Las Vegas Wash wetland ecosystem, and the desert wetlands in particular, so that we can better manage the excessive nitrogen stocks in our surface waters.

Increasing human populations in Southwestern United States, especially along the Colorado River corridor, will continue to negatively impact and influence how riparian areas along this corridor are utilized and managed by means of sustainable use and conservation of natural resources, including surface & ground waters. Effective stewardship of these riparian ecosystems must improve to prevent degradation due to human impact. Therefore I strongly recommend further study of the fate and transport of major nutrients at the Wash by means of system dynamics modeling.

Special Thanks

- Dr. Farnham, Class Advisor
- Dr. Stave, Content Advisor
- Dr. Zou Xiaoping, Hydrologist II for Southern Nevada Water Authority
- Class of 2006, Environmental Studies, UNLV
Table 1. SNWA’s data for N-species at different sampling sites for the year 2005.

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Las Vegas Wash Coordination Committee (LVWCC), 2006. Working to stabilize and enhance the valuable environmental resources of the Las Vegas Wash. http://www.lvwash.org


