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## MEMORANDUM

DATE: June 5, 2002

TO: Sean White, Sonoma County Water Agency

Cc: Amy Hutzel, California Coastal Conservancy (CCC)  
Susanne von Rosenberg, GAIA Consulting  
Craig Conner, US Army Corps of Engineers (USACOE)  
Larry Wyckoff, California Dept. of Fish and Game (CDFG)

FROM: Don Danmeier  
Chris Campbell

RE: **SCWA Simulation Results With Variable Dilution**  
PWA Ref. #: 1571-03

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### INTRODUCTION

Preliminary modeling of various salinity reduction alternatives of the Napa Salt Ponds has been carried out by Philip Williams & Associates (PWA) as part of its Napa-Sonoma Marsh Restoration (NSMR) Feasibility Study (Phase 2 Stage1). PWA was contracted by the Sonoma County Water Agency (SCWA) to perform three additional simulations that would focus on the application of recycled water.

This memorandum summarizes the model setup and presents results from these additional model runs. Configuration of the simulations were developed in conjunction with SCWA and members of the NSMR Project Team and is similar to salinity reduction alternatives investigated in the Feasibility Study. Details of the model scheme, input data, and its limitations as well as a discussion of other results can be found in the Phase 2 Stage 1 Report (PWA, 2002b).

## CONFIGURATION OF THE SIMULATIONS

The general configuration of the salinity reduction alternative under consideration is shown in Figure 1. Under this alternative, flows from Ponds 7, 7A and 8 are combined with recycled water at a mixing chamber before discharging into the Napa Slough. Constant flow rates of 5,000 and 15,000 ac-ft/yr of recycled water will be assumed in these simulations. It has been assumed that this recycled water is available at a uniform rate year-round, and variable deliverable rates will likely change the results.

While flow through Ponds 7A and 8 is tidally driven, a control structure has been added so that the discharge from Pond 7 into the mixing chamber meets a specified dilution ratio. Therefore, the model includes the following hydraulic structures:

- Two 30-inch diameter circular culverts with flap gates (intake only) from Mud Slough into Pond 8.
- One 48-inch diameter circular culvert with flap gate (outlet only) from Pond 8 to canal north of Pond 8.
- Two 48-inch diameter circular culverts with flap gates (intake only) from Napa Slough to Ponds 7 and 7A (one culvert per pond).
- One 48-inch diameter circular culvert with flap gate (outlet only) from Pond 7A into the mixing chamber.
- Discharge from Pond 7 into mixing chamber is adjusted in order to meet a pre-determined dilution ratio of bittern. Flow is restricted to be outlet only.

## DISCHARGE FROM BITTERN POND

The presence of bittern in Pond 7 requires that discharge from this pond be metered in order to satisfy water quality criteria. Based on discussions with members of the Project Team, a target fixed dilution of 1:100 was initially applied at the discharge location from Pond 7 into the mixing chamber because of toxicity concerns.

Simulations were also carried out with a variable dilution rate in order to increase the flow of water through Pond 7. This approach was developed in conjunction with the SCWA and the Project Team and includes the following steps:

1. Determine a new discharge from Pond 7 that is based on the amount of bittern in Pond 7.
  - a. From result files of the fixed 1:100 dilution simulation and no recycled water, extract the discharge from Pond 7 ( $Q_{P7}$ ), Pond 7A ( $Q_{P7A}$ ), and Pond 8 ( $Q_{P8}$ ) at outlets.
  - b. Compute the time series of fraction bittern ( $FB$ ) based on mass balance from the fixed 1:100 dilution and no recycled water simulation. Assume that Pond 7 is initially completely bittern ( $FB = 1$  at time = 0).

- c. Adjust  $Q_{P7}$  based on fraction bittern using the following relation

$$Q_{P7-NEW} = \frac{Q_{P7}}{FB}$$

- d. Confirm that  $Q_{P7-NEW}$  is reasonable (as  $FB$  approaches 0,  $Q_{P7-NEW}$  will become too large. So make sure  $Q_{P7-NEW} \leq Q_{P7A}$ ).
2. Set the discharge at the outlets as  $Q_{P7-NEW}$ ,  $Q_{P7A}$ , and  $Q_{P8}$  using control structures in numerical model. This allows for a variable dilution ratio based on the mass of bittern remaining in Pond 7.
3. Increase the discharge from Pond 7 when 15,000 ac-ft/yr ( $Q_{15}$ ) of recycled water is used. In order to maintain the same dilution as before, discharge from Pond 7 in the 15k simulation should be

$$Q_{P7-NEW2} = Q_{P7-NEW} \times \left[ \frac{Q_{P7-NEW} + Q_{P7A} + Q_{P8} + Q_{15}}{Q_{P7-NEW} + Q_{P7A} + Q_{P8}} \right]$$

4. Set the discharge at the outlets as  $Q_{P7-NEW2}$ ,  $Q_{P7A}$ , and  $Q_{P8}$  using control structures in numerical model. This allows for simulation of 15 ac-ft/yr of *additional* throughput and a variable dilution ratio based on the mass of bittern remaining in Pond 7.
5. Increase the discharge from Pond 7 when 5,000 ac-ft/yr ( $Q_5$ ) of recycled water is used. In order to maintain the same dilution as before, discharge from Pond 7 in the 5k simulation should be

$$Q_{P7-NEW3} = Q_{P7-NEW} \times \left[ \frac{Q_{P7-NEW} + Q_{P7A} + Q_{P8} + Q_5}{Q_{P7-NEW} + Q_{P7A} + Q_{P8}} \right]$$

6. Set the discharge at the outlets as  $Q_{P7-NEW3}$ ,  $Q_{P7A}$ , and  $Q_{P8}$  using control structures in numerical model. This allows for simulation of 5 ac-ft/yr of *additional* throughput and a variable dilution ratio based on the mass of bittern remaining in Pond 7.

## INITIAL CONDITIONS AND BOUNDARY DATA

Initial conditions and boundary data used for the SCWA simulations were identical to those applied in the preliminary salinity reduction analysis. A complete description of this data can be found in the Napa-Sonoma Marsh Restoration Feasibility Study Phase 2 Stage 1 (PWA, 2002b). A brief description of the data is given below.

### Initial Salinity and Water Surface Elevations

Measurements taken by Tom Huffman of the CDFG in February 1998 will be used as initial conditions in Ponds 7, 7A, and 8. Table 1 lists these water surface elevations and pond salinities. Note that water levels in all the ponds are approximately 2 m NAVD88.

**Table 1. Salt Pond Initial Conditions from February 1998**

<b>Pond</b>	<b>WSE (m, NAVD88)</b>	<b>Salinity (ppt)</b>
7	2.06	135
7A	2.12	46
8	1.97	86

### Precipitation and Evaporation Data

Mean monthly rainfall and evaporation rates were established from data collected by Cargill for the period of January 1955 to May 1999. Daily averages were then interpolated between monthly values and applied to the model.

### Sonoma Creek and Napa River Flows

Synthetic hydrographs were generated that represent the mean hourly flows in the Napa River based on gauged data obtained from the USGS. Flows in Sonoma Creek were estimated based on methods derived in Phase 1 of the Feasibility Study (PWA, 2002a).

### Tidal Boundary Data

Predicted tides will be applied as boundary data at the mouths of the Napa River and Sonoma Creek.

### Salinity Boundary Data

Representative time series of salinity based on the 1-D predictive model developed by Dr. Noah Knowles of the Climate Research Division at Scripps Institute of Oceanography were applied at the mouths of Napa River and Sonoma Creek.

### Simulation Time Periods

The simulations will be run for as long as is necessary up to a maximum of six years real time.

## RESULTS AND DISCUSSION

### POND SALINITY

Simulated time series of pond salinity with fixed dilution, as previously presented on January 30th, 2002, are shown in Figures 2 through 4. Note that the 5k and 10k ac-ft/yr simulations were only carried out for the first two years, and results for the 0k and 15k ac-ft/yr runs are carried out for all six years. Results from the variable dilution simulations are shown in Figures 5 through 7, which present time series for runs that include 5k and 15k ac-ft/yr of recycled water. Due to the bittern discharge criteria, salinity reduction in Pond 7 occurs over a much longer time period than Ponds 7A and 8.

It is interesting to note that there is a more rapid drop in salinity during the early years of the simulation and much slower rate of desalination in the later years. Presumably, this is due to the fact that the relatively low throughput of Pond 7 is not substantially larger than the amount of make-up water required to offset evaporation.

In order to estimate the time for Pond 7 to reach a target salinity between 20 – 25 ppt, the peak yearly salinities from the six years of simulated results were extrapolated. Results are shown in Figures 8 and 9, respectively, for the linear and exponential extrapolations. The linear regression in Figure 8, while providing a good fit to the data, should be considered an optimistic desalination time when extrapolated to the expected salinity. The exponential decay regression ( $y=y_0+ae^{-bx}$  where  $y_0=20$ ) in Figure 9, which also provides an equally good fit to the data, should be considered a more realistic desalination time. The 15k simulation desalinates the quickest, as should be expected with a greater recycled water discharge, with a time approximating 40 years. However, results from the 5k simulation show maximum yearly salinity of about 50 ppt at the end of four decades. In order to estimate the effects of a 0k simulation with variable dilution, an extrapolation was carried out on the peak yearly salinities. This assumes that the mass of salt extracted from Pond 7 is proportional to the amount of recycled water added to the system. An exponential fit to the extrapolated 0k values suggests that the peak salinity in Pond 7 is about 85 ppt after four decades, well above the 50 ppt predicted under the 5k simulation.

A mass balance was performed in order to estimate the fraction of bittern in Pond 7 during the salinity reduction alternative. The initial salt content is assumed to be complete bittern and is flushed with slough water over the 6-year simulation. Results plotted in Figure 10 indicate that the 5k variable dilution desalination approach equally effective as the 15k fixed dilution configuration. Figure 11 shows the fraction of bittern fitted with an exponential decay regression ( $y=ae^{-bx}$ ); the exponential decay regression was selected based on the preference for Figure 9 over Figure 8 and the likelihood that minute quantities of bittern salt will remain in the pond during the desalination process. In Figure 11, the 15k ac-ft/yr variable dilution simulation shows the most rapid depletion of bittern salt from the pond, as expected, since greater rates of recycled water accommodate greater rates of discharge from the pond.

## EFFECTS ON RECEIVING WATER

The overall effect of the project on the Napa Slough is shown in Figure 12, which plots the sectionally averaged salinity in the receiving water. Results from the simulations indicate that the ambient salinity in Napa Slough near the discharge location is typically about 3 – 4 ppt, although discharge during the first month of the project under the 15k variable dilution case is close to the maximum allowable increase of +5 ppt defined by the Project Team.

It should be noted that no attempt has been made to model the near-field mixing processes in Napa Slough near the point of discharge and that water quality criteria has yet to be defined by the Regional Water Quality Control Board. The geometry and dilution of the effluent plume needs to be analyzed at later stages in the Feasibility Study, as regulatory criteria will be imposed at the edge of the initial mixing zone.

## SUMMARY

The additional simulation of salinity reduction in the Upper Ponds allowed for the effect of 5,000 ac-ft/yr and 15,000 ac-ft/yr of recycled water to be examined. Further, results from the application of a variable dilution ratio based on mass of bittern were compared to results from a fixed 1:100 dilution simulation. Examination of the model runs lead to the following conclusions and findings:

- Desalination in Pond 7 is much slower than other ponds due to the bittern discharge criteria. Dissolution of precipitated salts is expected to be significant due to the high target salinity levels of the Upper Ponds when the site was operated as a salt evaporation facility.
- Results from this study should be interpreted with care due to the limitation of the numerical model and the fact that water quality discharge criteria have yet to be finalized. Discharge restrictions imposed at the edge of the near-field mixing zone may lead to longer desalination times.
- Results from this study suggest that Pond 7 maximum yearly salinity is reduced to about 20 ppt in approximately four decades if the variable dilution is used in conjunction with 15,000 ac-ft/yr of recycled water. Extrapolation of 5,000 ac-ft/yr simulations suggest that Pond 7 maximum yearly salinity is about 50 ppt at the end of four decades. Assuming that discharge from Pond 7 is proportional to the throughput of the system, a variable dilution approach without the use of recycled water would lead to a maximum Pond 7 salinity of about 85 ppt at the end of 4 decades.
- Numerical simulations indicate that Ponds 7A and 8 are flushed relatively quickly, but seasonal trends in salinity persist due to limited tidal exchange and net evaporation during the summer.

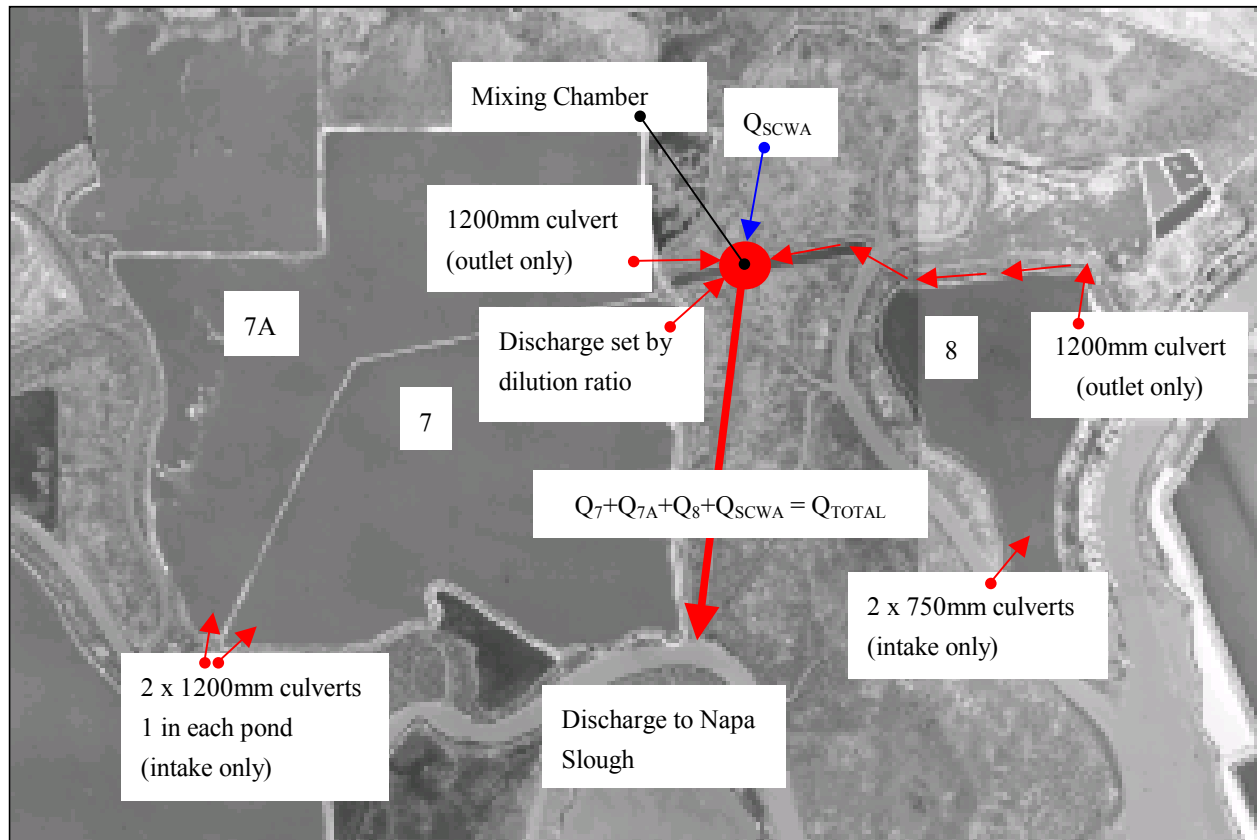
Engineered breaches along these two ponds could be introduced after desalination in order to increase the amount of flushing on a tidal cycle.

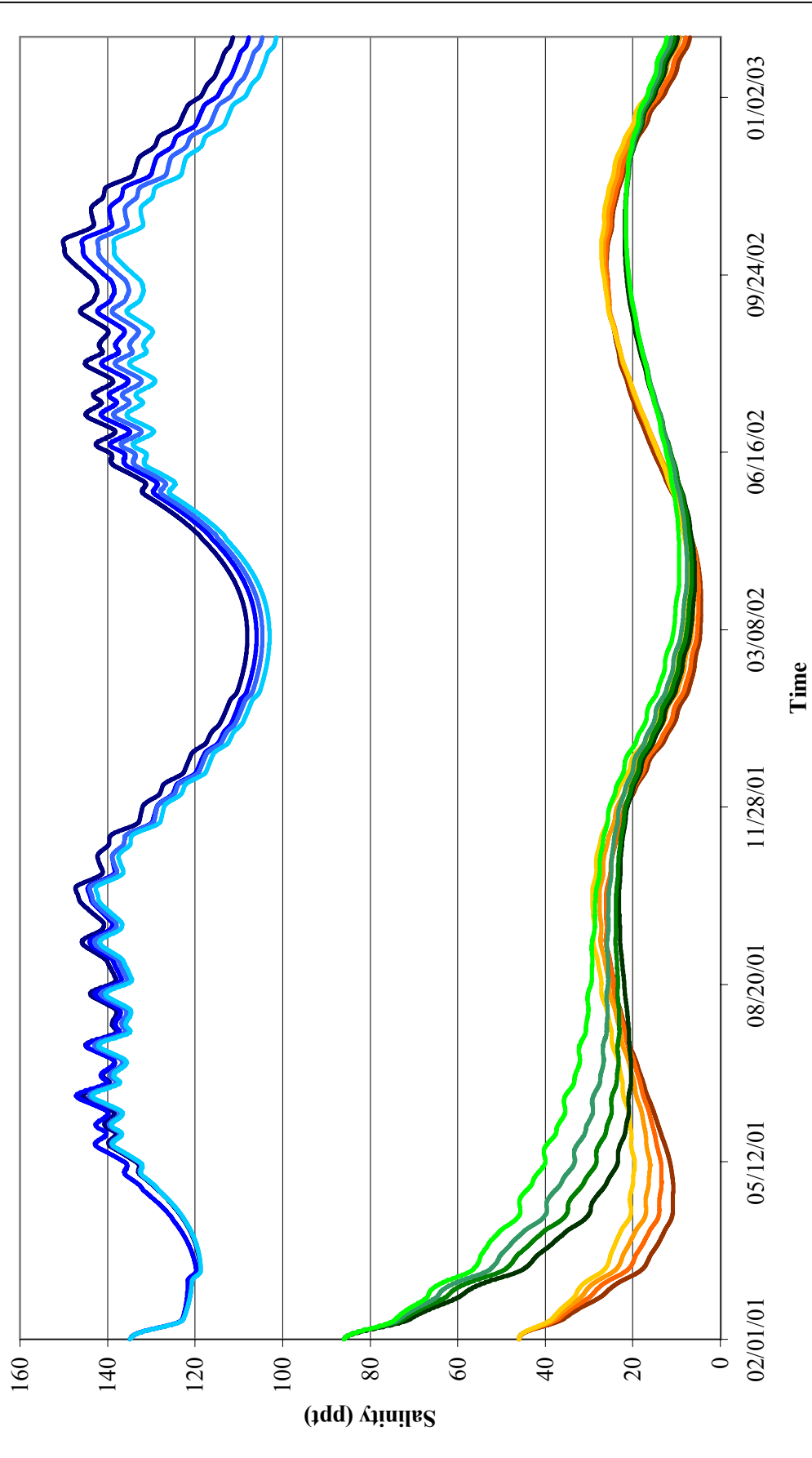
## **References**

Philip Williams & Associates, Ltd. (PWA) 2002a. Napa-Sonoma Marsh Restoration Feasibility Study, Phase 1. Project No. 1174-8. Prepared for the US Army Corps of Engineers, San Francisco District.

Philip Williams & Associates, Ltd. (PWA) 2002b. Napa-Sonoma Marsh Restoration Feasibility Study, Phase 2 Stage 1. Project No. 1545/1546. Prepared for the California Coastal Conservancy.

**Figure 1. Model Set Up for Ponds 7, 7A, and 8**






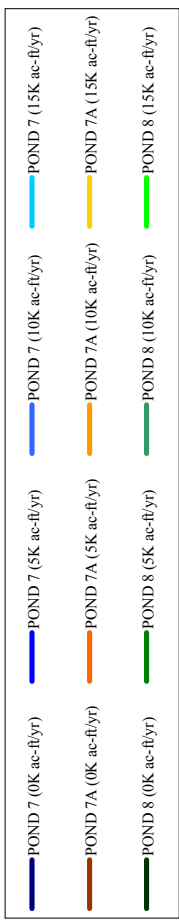
*figure 2*

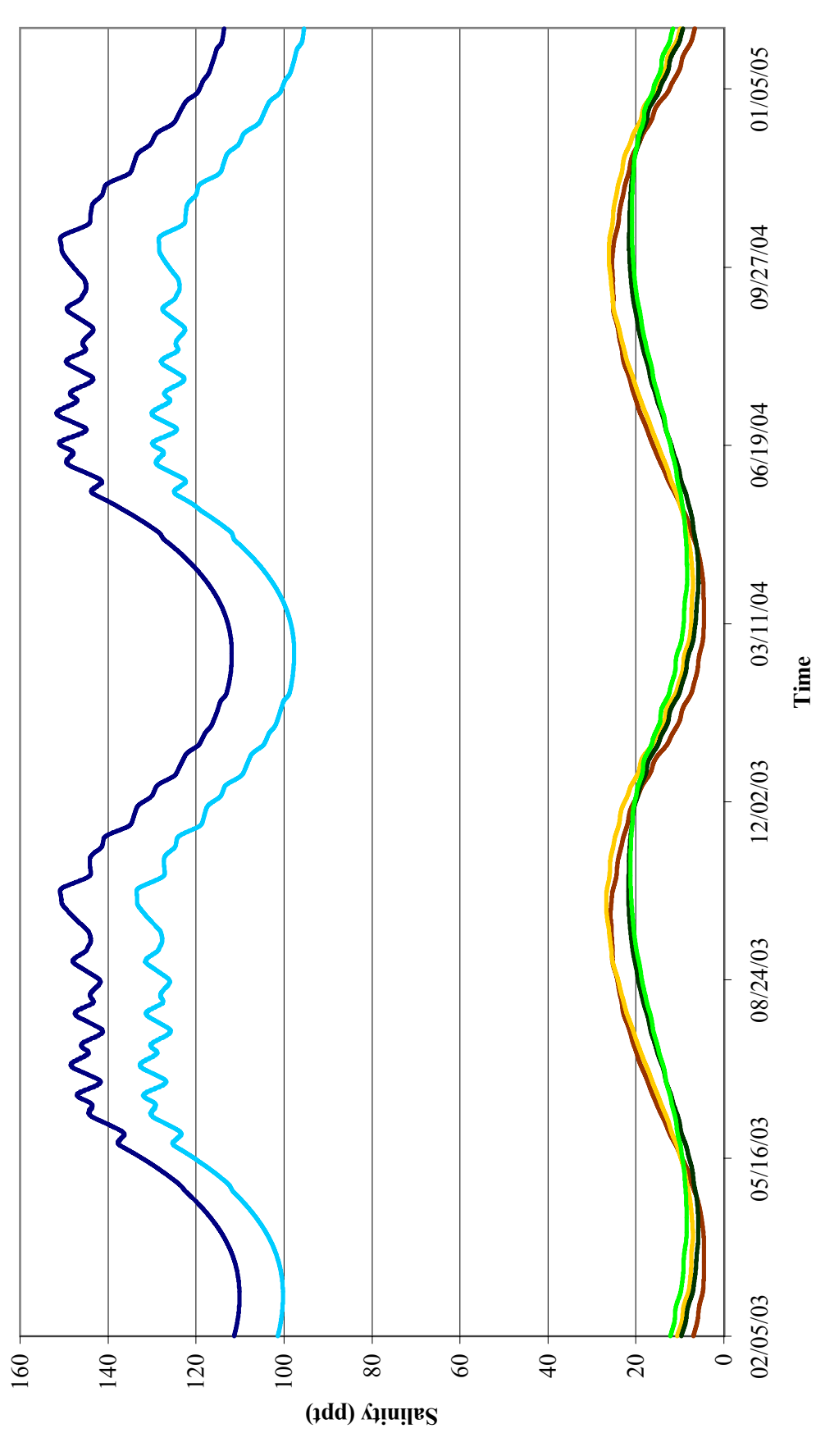
*NSMR P2S1 SCWA Technical Memo*


**Pond Salinity (Years 1 & 2) - Fixed Dilution**

PWA Ref. # 1571-03

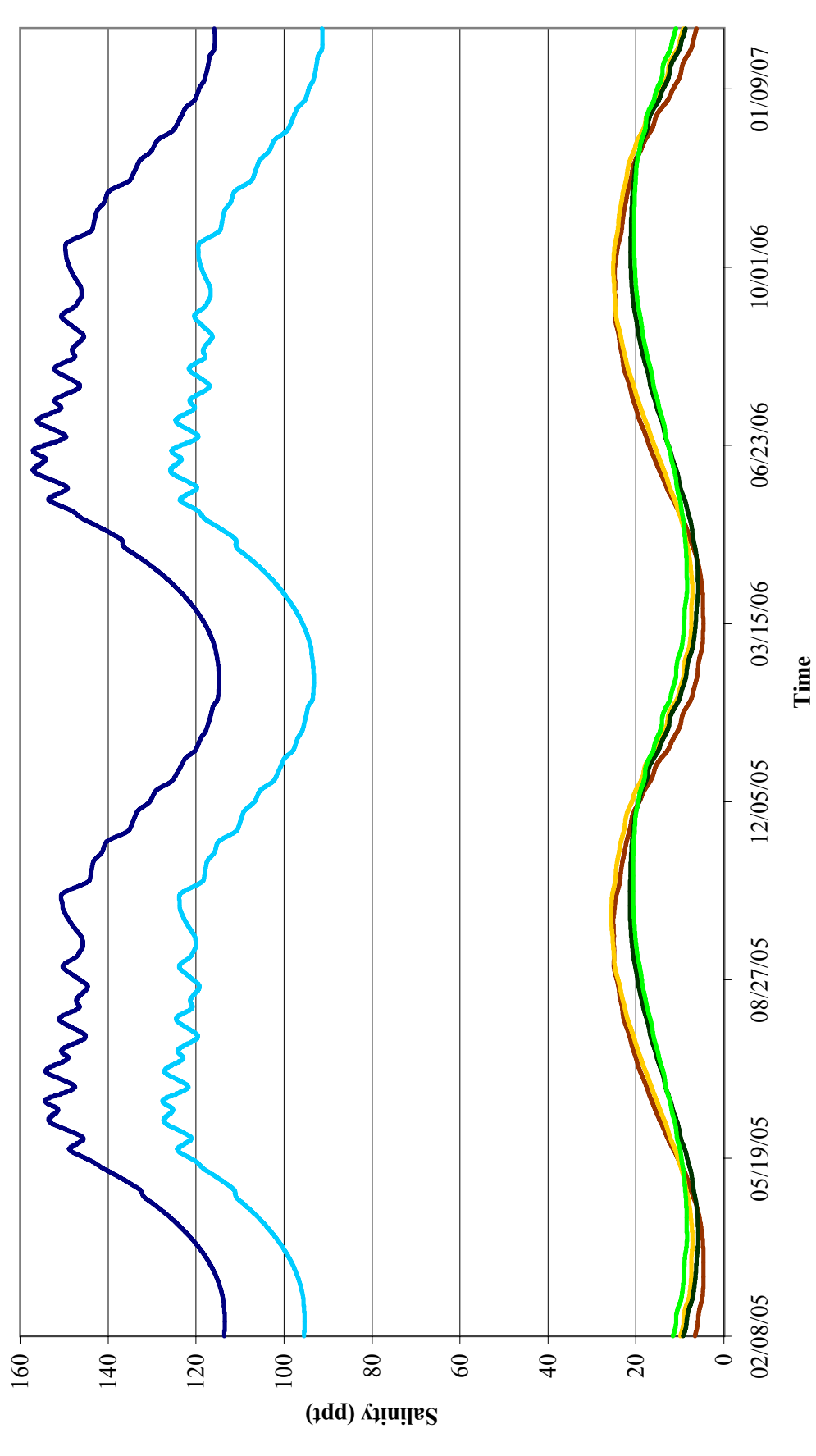
 PWA






*figure 3*  
 NSMR P2S1 SCWA Technical Memo  
**Pond Salinity (Years 3 & 4) - Fixed Dilution**  
 PWA Ref. # 1571-03  


- POND 7 (0K ac-ft/yr)
- POND 7A (15K ac-ft/yr)
- POND 8 (15K ac-ft/yr)



*figure 4*  
 NSMR P2S1 SCWA Technical Memo  
**Pond Salinity (Years 5 & 6) - Fixed Dilution**  
 PWA Ref. # 1571-03  


- POND 7 (0K ac-ft/yr)
- POND 7A (0K ac-ft/yr)
- POND 8 (0K ac-ft/yr)
- POND 7 (15K ac-ft/yr)
- POND 7A (15K ac-ft/yr)
- POND 8 (15K ac-ft/yr)

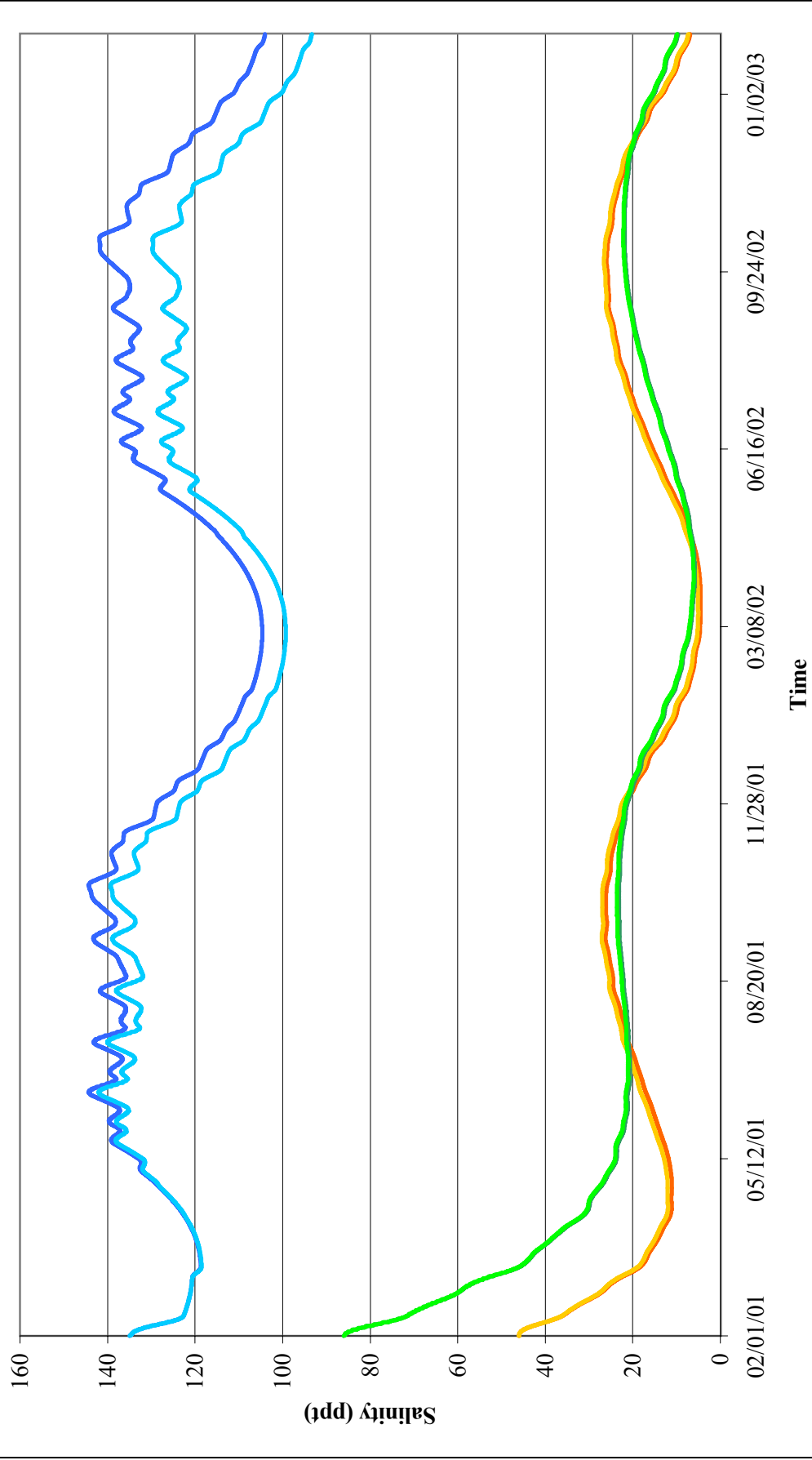
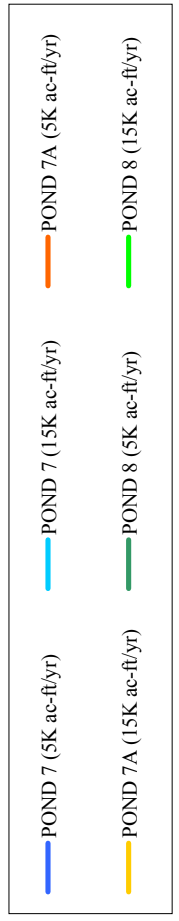


figure 5

NSMR P2S1 SCWA Technical Memo

**Pond Salinity (Years 1 & 2) - Variable Dilution**

PWA Ref. # 1571-03



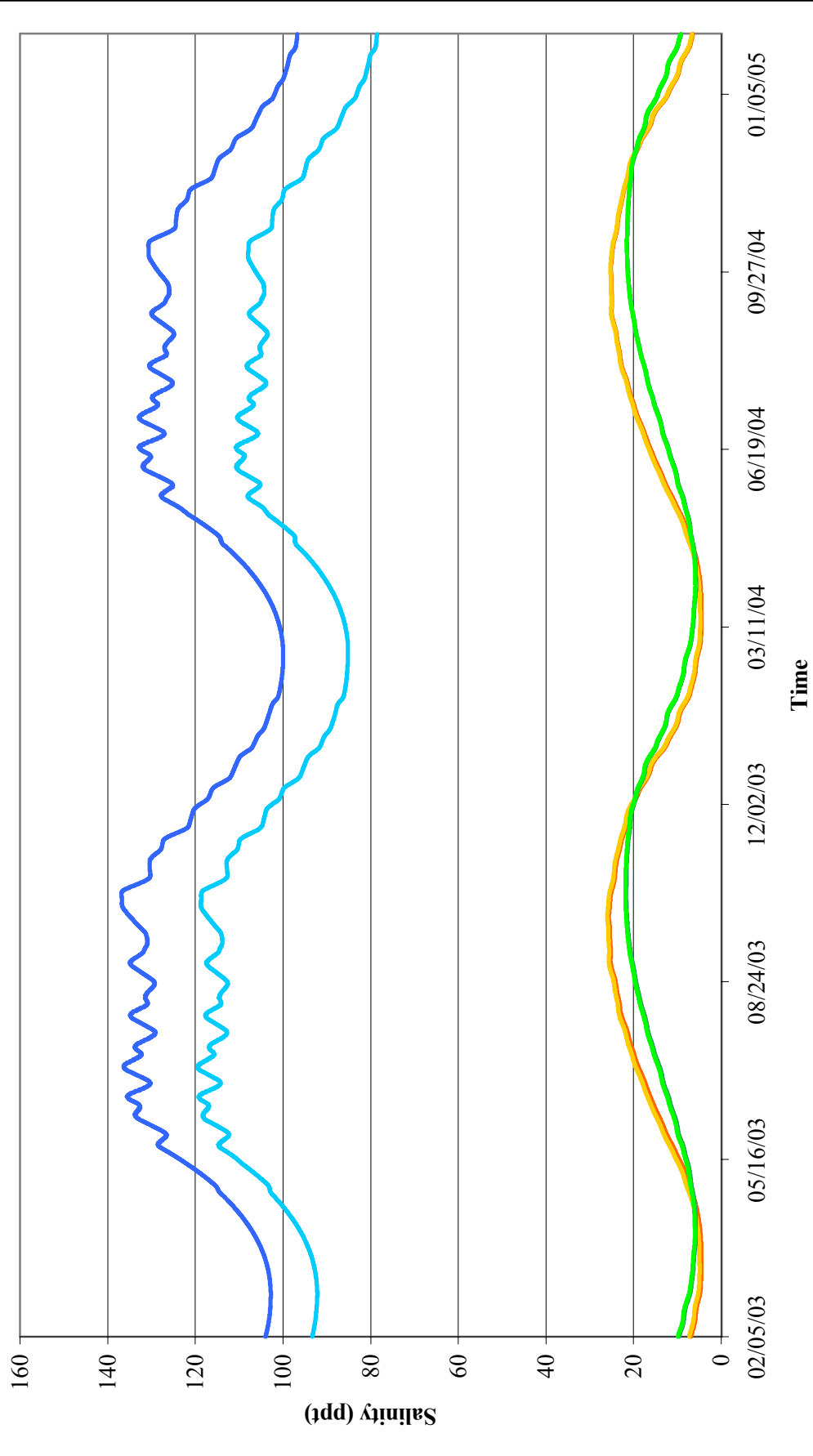
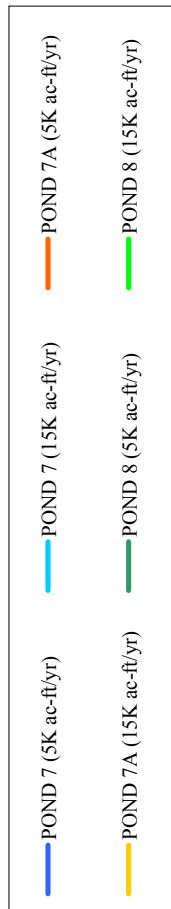
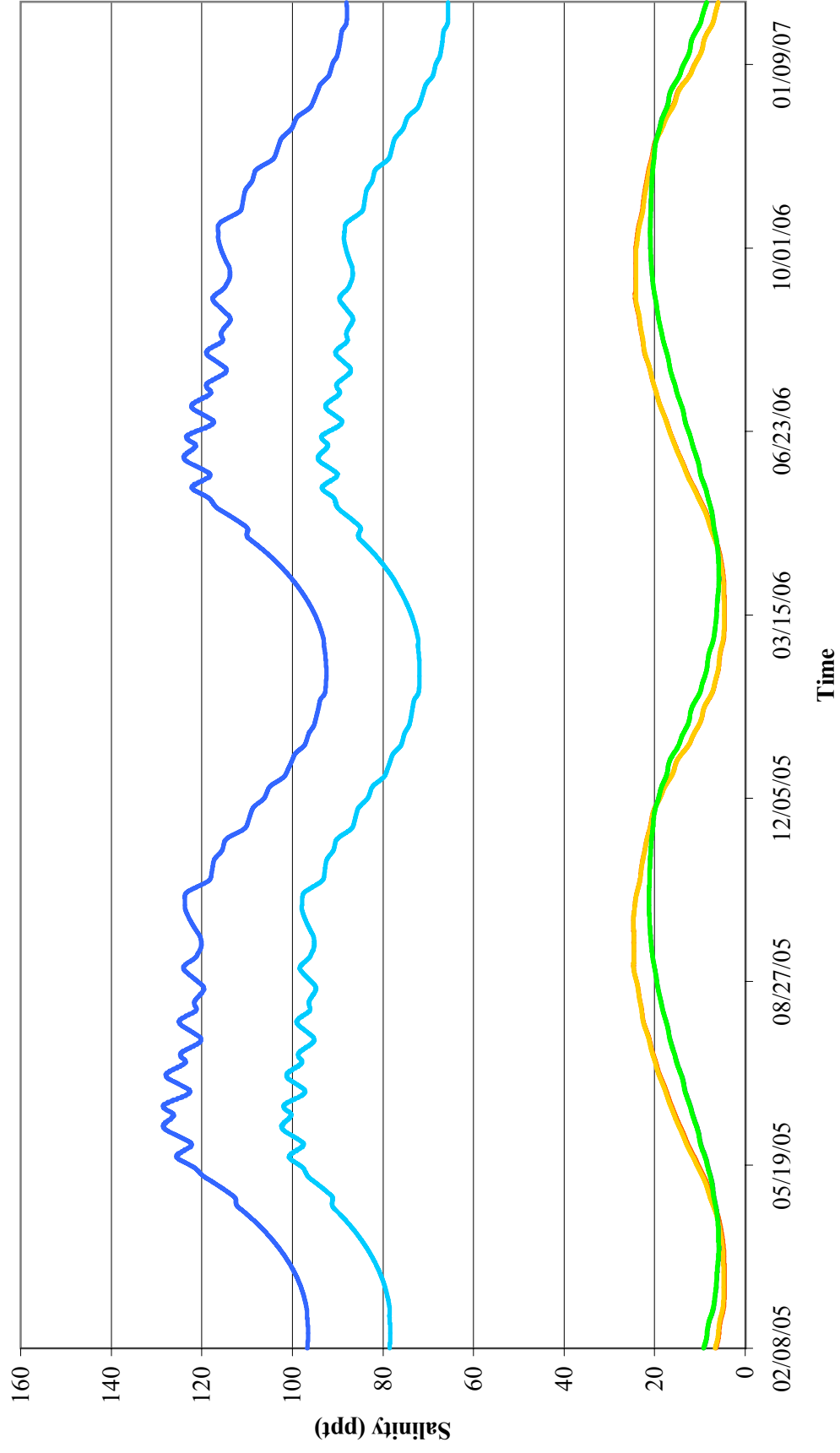


figure 6

NSMR P2S1 SCWA Technical Memo  
**Pond Salinity (Years 3 & 4) - Variable Dilution**

PWA Ref. # 1571-03

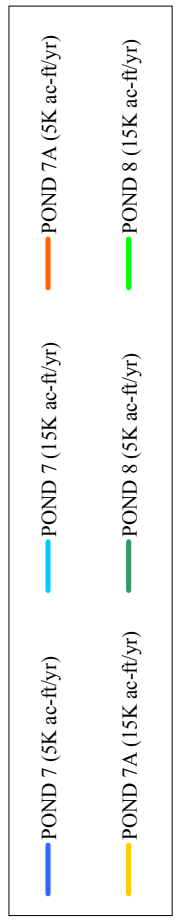


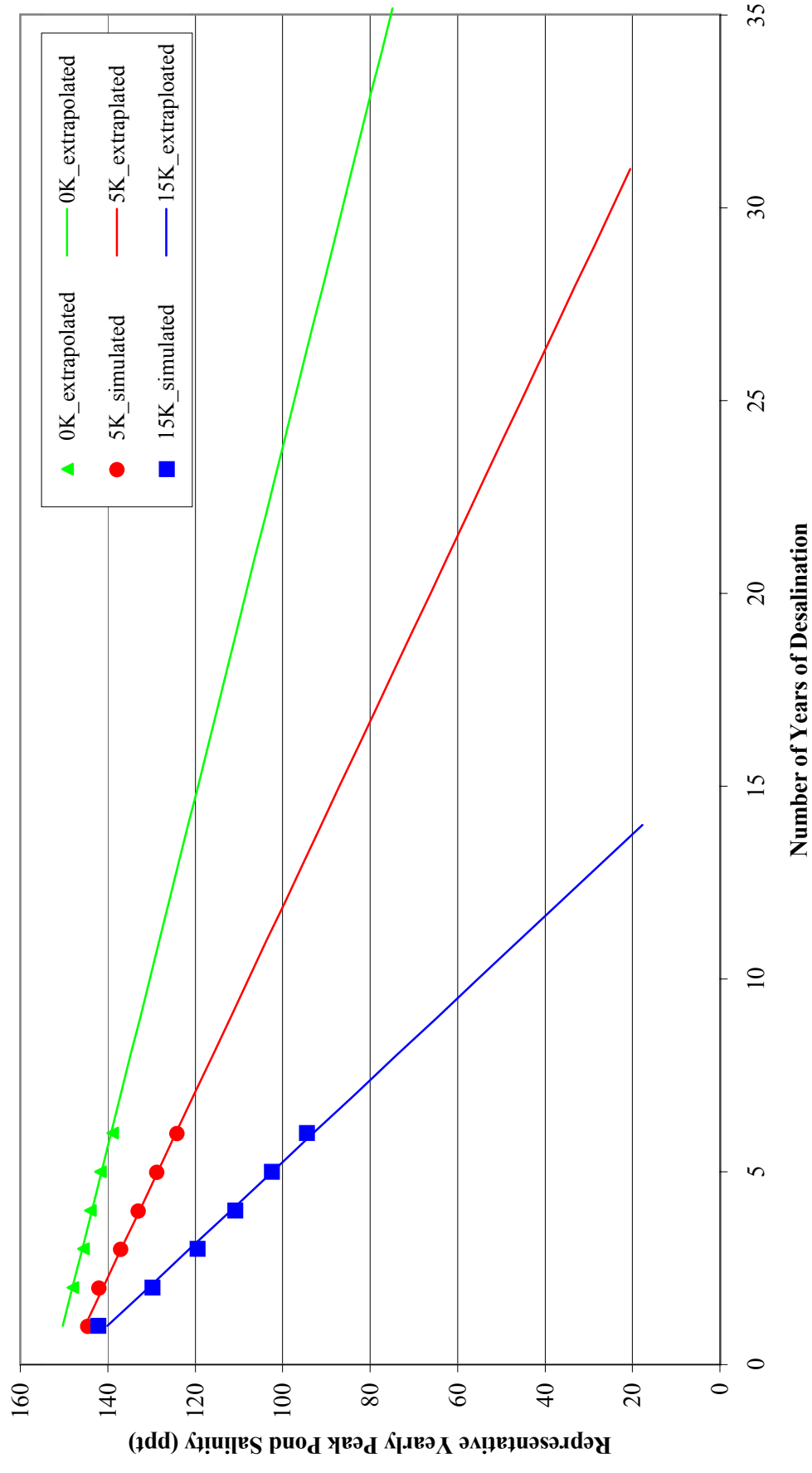


*figure 7*

**NSMR P2S1 SCWA Technical Memo**  
**Pond Salinity (Years 5 & 6) - Variable Dilution**

PWA Ref. # 1571-03





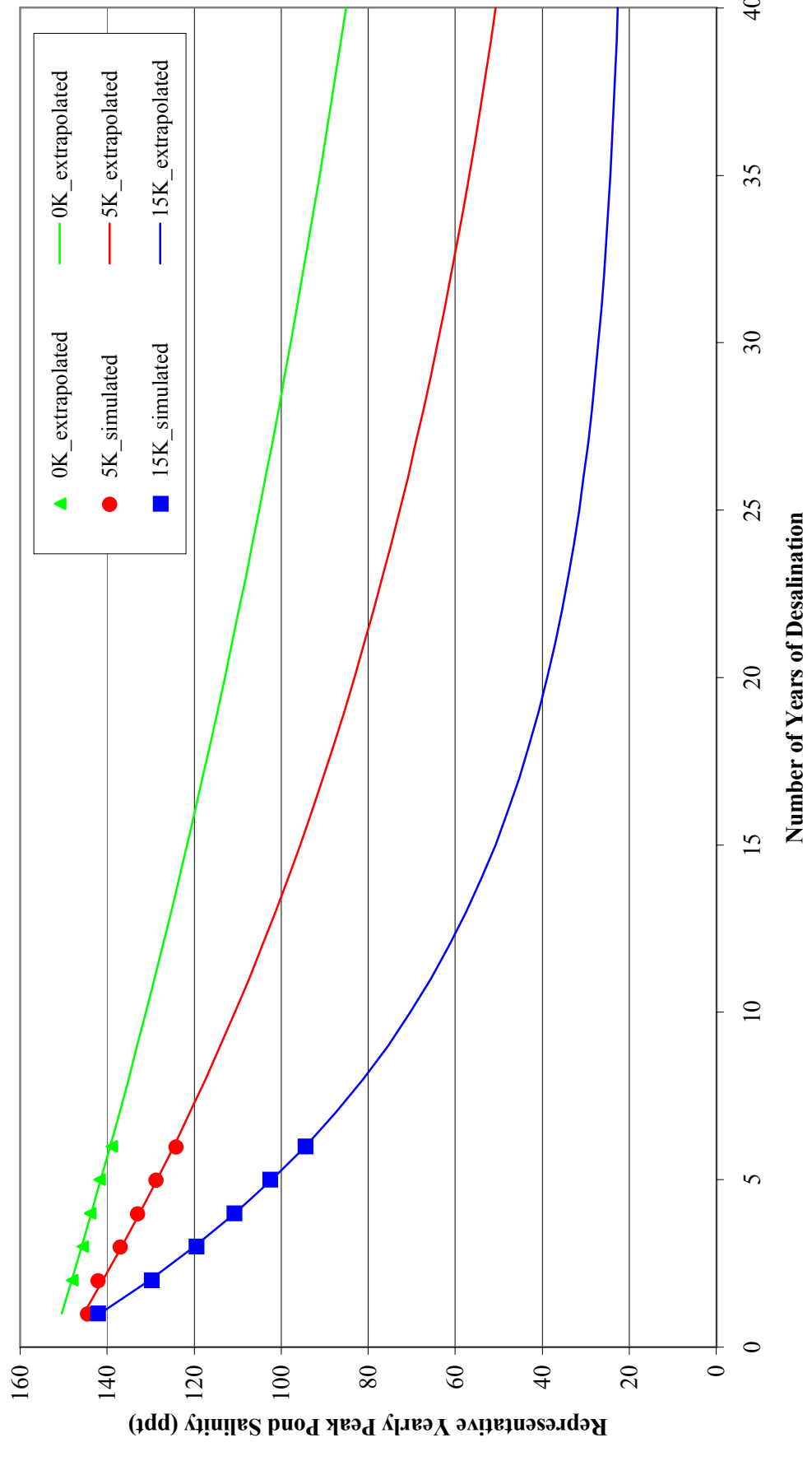
Notes: Symbols show simulated yearly maximum using variable dilution. Lines show the extrapolated values using linear regression.

figure 8

NSMR P2S1 SCWA Technical Memo  
**Peak Pond Salinity - Linear Decay**

PWA Ref. # 1571-03





Notes: Symbols show simulated yearly maximum using variable dilution.  
 Lines show the extrapolated values using exponential decay.

*figure 9*

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NSMR P2SI SCWA Technical Memo  
**Peak Pond Salinity - Exponential Decay**

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PWA Ref. # 1571-03

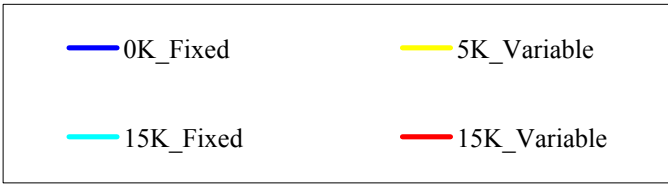
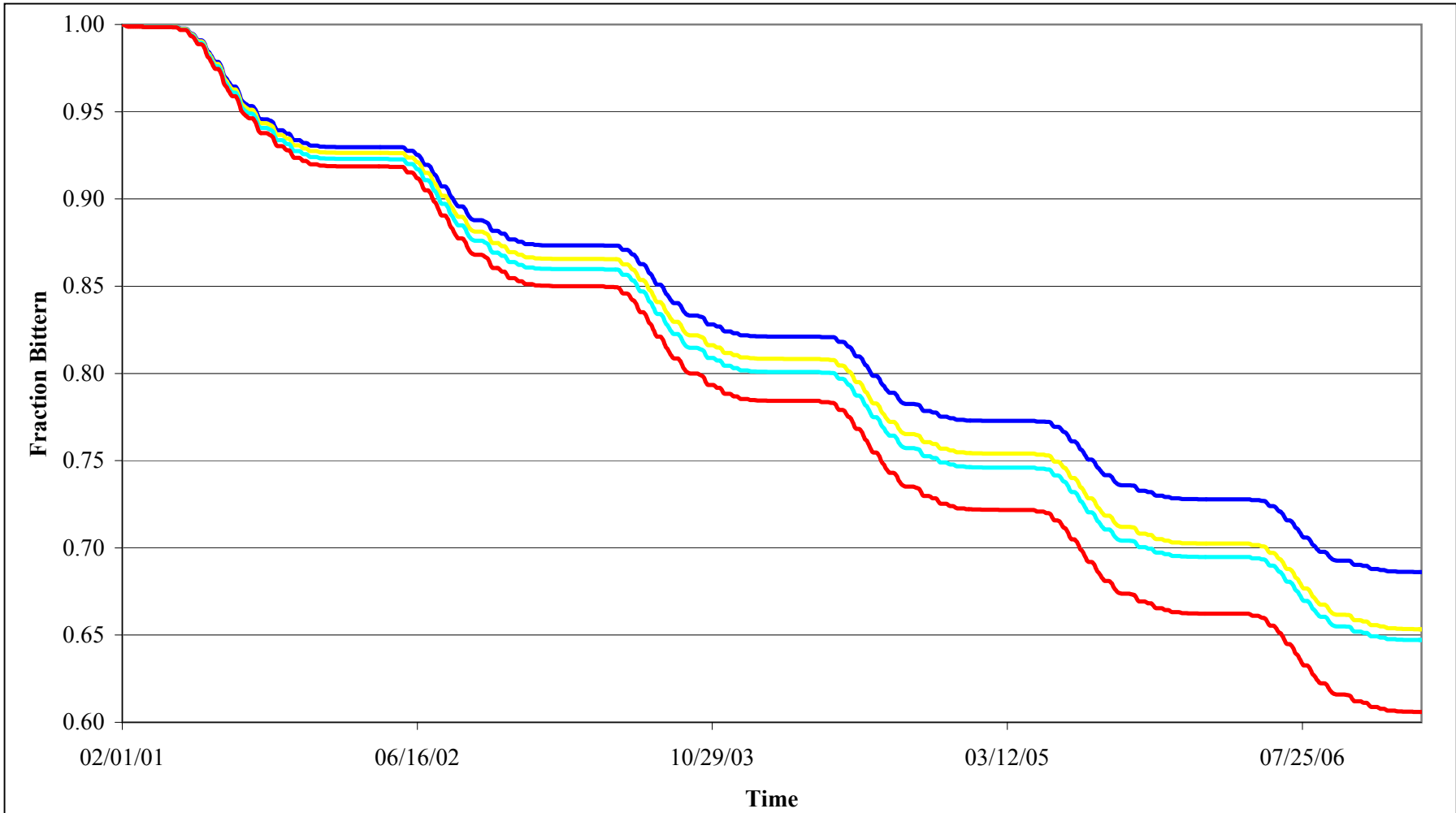


figure 10

NSMR P2S1 SCWA Technical Memo  
**Fraction Bittern Salt in Pond 7**

PWA Ref #1571-03



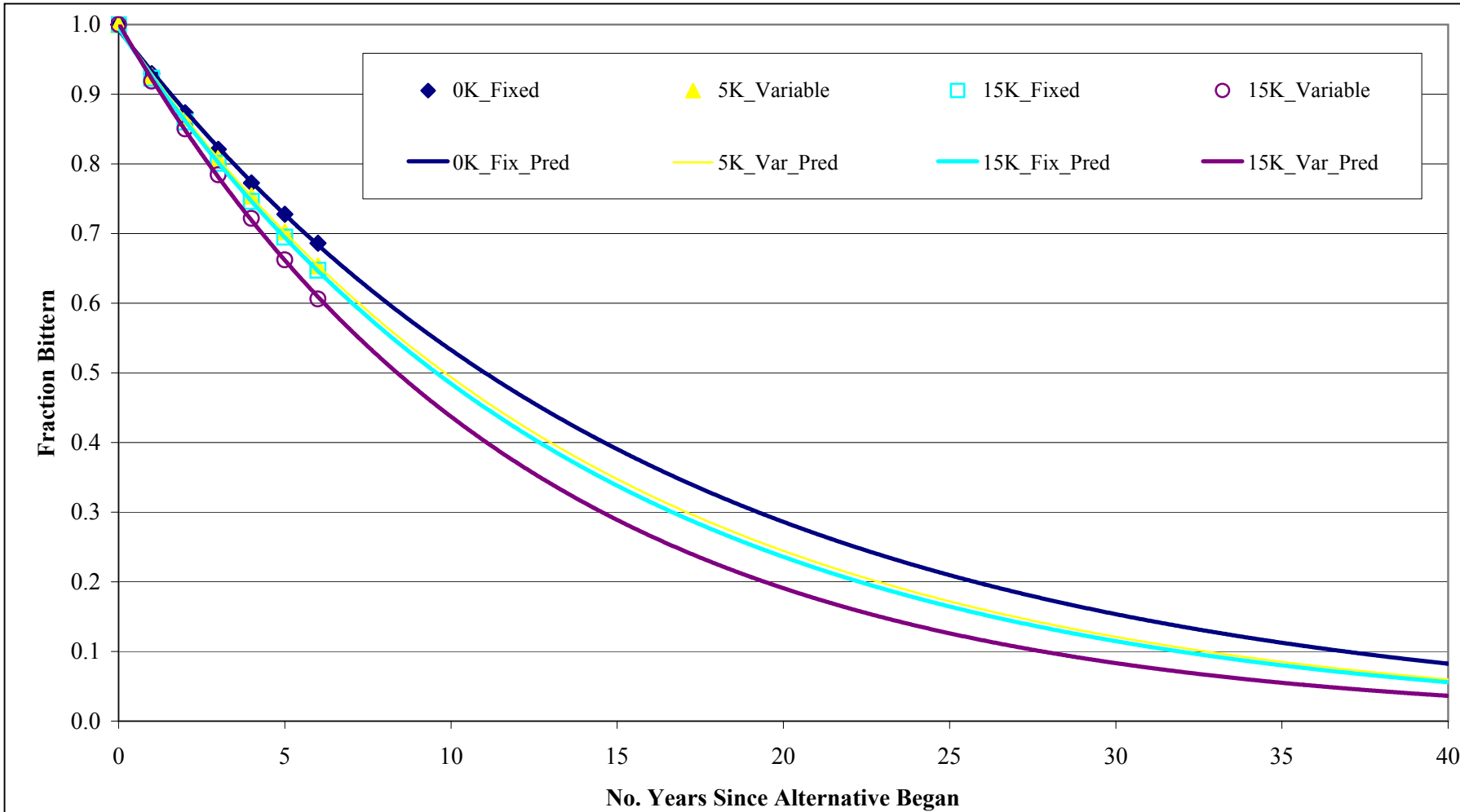


figure 11

NSMR P2S1 SCWA Technical Memo  
**Fraction Bittern Salt in Pond 7**

PWA Ref #1571-03



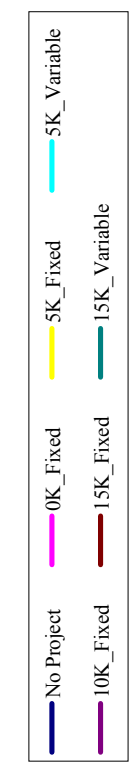
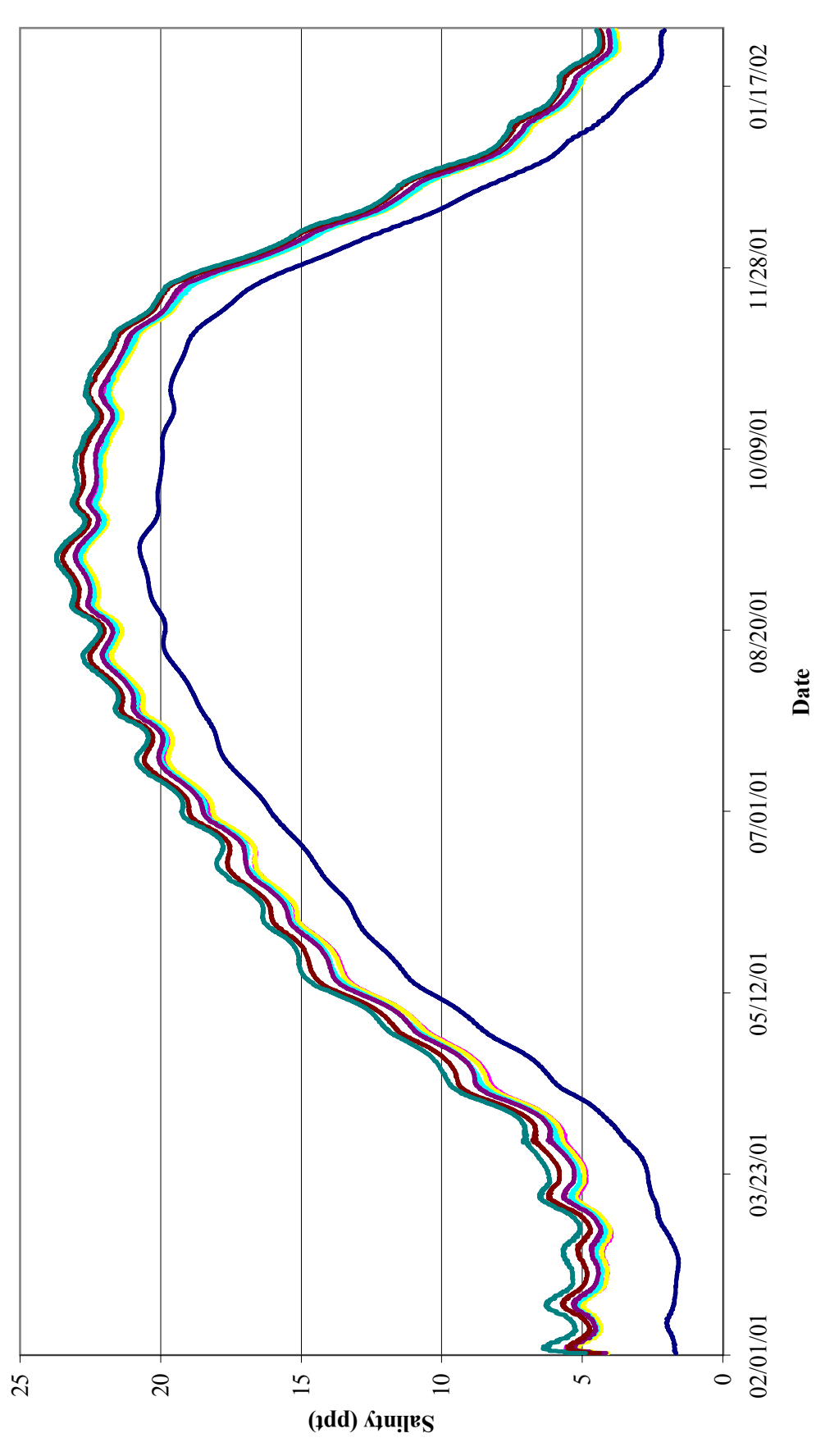


figure 12  
 NSMR P2SI SCWA Technical Memo  
**Slough Salinity at Discharge Location**

PWA Ref#1571-03

