SECTION 4: EVENT ANALYSIS OF DILUTION AND DISPERSION OF CONCENTRATED SEA WATER

4) Event Analysis of Dilution and Dispersion of Concentrated Sea Water

In this section we solve for long term steady state solutions for the dispersion and dilution of the concentrated seawater by-product of the proposed desalination plant at AES Huntington Beach. The objective here is to determine persistent levels of disturbance to the ambient ocean salinity field. We consider a ***low-flow case*** model scenario in which maximum salinity levels are produced in-the-pipe as a consequence of minimum power generation (or standby with 2 pumps on line) and are subsequently discharged into a tranquil, summer-time ocean environment wherein ambient mixing is minimal. We also consider a ***average case*** in which saline levels of discharge for average power generation are evaluated in an ocean environment with mixing due to average annual wind, waves and currents. These two scenarios are run continuously in the model for 30 days, and then the solutions are time averaged. The purpose of running these event scenarios for 30 days was to provide a long enough simulation that would reveal any possible cumulative effects, ie to verify that the receiving waters were fully saturated and that a steady state was achieved. This is common practice for impact assessment modeling. Modeling for shorter periods of time tends to result in slightly lower salinities in the receiving waters. Our sensitivity analyses performed during the development of these solutions show that the receiving waters reach steady state within 5 days for the low flow case scenario, and within 3 days for the average case scenario. Thereafter, there are no significant changes in the event scenario solutions.

A) Description of Low flow-Case Conditions

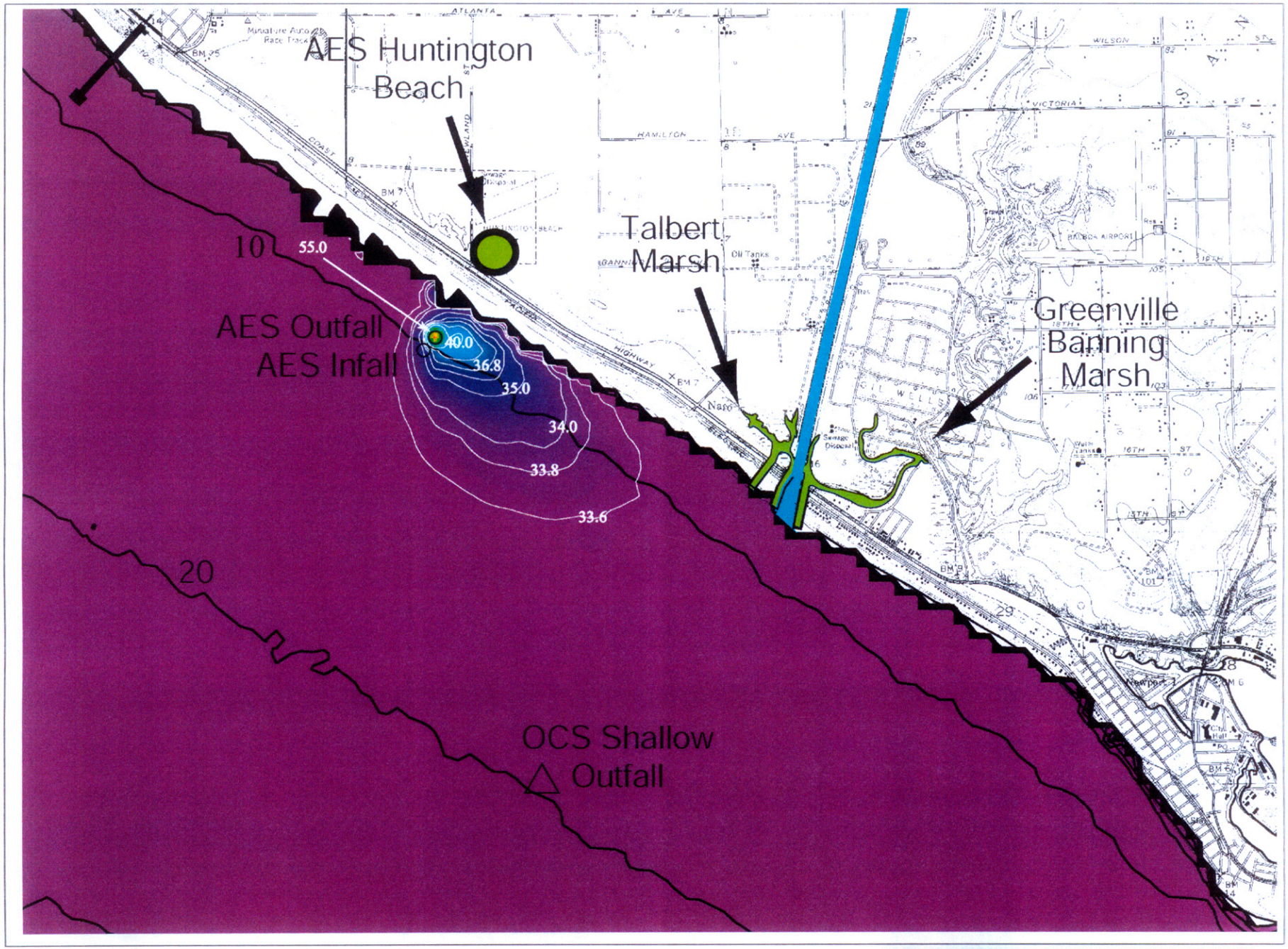
We consider a low flow-case model scenario in which maximum salinity levels at minimum power generation are discharged into a tranquil, summer-time ocean environment wherein ambient mixing is minimal. The source loading for the low flow case dilution and dispersion model scenario is given by the set of operational conditions which produces the highest salinities for the combined discharges of the generating station and the desalination plant when the latter is producing 50 mgd of product water per day. This operational level will give the highest dose level to the benthic and pelagic biology. From Tables 2 & 3 in Section 3, we conclude that this low flow case arises when the generating station is operating only one generating unit and discharging no in-plant waste streams, producing a total discharge of 126.7 mgd from 2 pumps operating at 44,000 gpm each. The R0 unit would withdraw approximately 100 mgd and return 50 mgd of concentrated seawater to the discharge stream. The resulting combined discharge from the plant outfall would be 76.7 mgd at a salinity of 55.37 ppt. The change in specific volume of this effluent (including the thermal effects of the generating station) would be -1.59% relative to ambient seawater and consequently it will be heavier than the receiving water.

To study the minimum possible dilution rates of this low flow-case effluent in a sustained steady state, the 20-yr wave records, in Figure 3.23 & 3.24 were searched with a digital filter to obtain the precise model initialization for low flow case according to the search criteria set forth in Table 3 of Section 3. This search produced the initialization values for low flow case listed in Table 4 of Section 3. These condition are an extremely over-specified low flow-case scenario for a 30-day simulation. Because such benign ocean mixing conditions are typically

summer events when user demand for power is high, this low flow-case combination of environmental and operational conditions is highly unlikely for any protracted period of time. Historically, the recurrence of low flow case environmental extremes is about 1 week every 3 to 7 years, commensurate with the dominant ENSO frequencies. By perpetuating low flow case conditions in the model for 30 continuous days the recurrence interval is actually more rare, about 1 month every 13 to 31 year.

B) Findings for Low flow Month

The model simulation of the 30 day average of the salinity field in the middle of the water column is plotted in Figure 4.1 for an RO production rate of 50 mgd and a plant flow rate of 126.7 mgd during the low flow month conditions. The corresponding salinity distribution on the sea surface is plotted in Figure 4.2 and at the seabed in Figure 4.3. Contours of salinity are in parts per thousand (ppt), where the ambient background ocean salinity is 33.52 ppt. The distribution shown in Figure 4.1 gives the salinity field at approximately the depth of the "end of the pipe" of the infall and outfall, with a region of concentrated sea salts reaching 55.0 ppt found directly over the outfall. The combined discharge of the generating station and RO plant creates a jet of negatively buoyant fluid directed vertically upward at the sea surface with a flow rate of 76.7 mgd. Figure 4.2 shows that this jet broaches the sea surface, creating a "boil" of hyper-saline water with a salinity of 50.1 ppt in the core of the boil. However, this saline boil rapidly subsides in the water column as it is advected downcoast (towards the southeast) in the net tidal transport over a 30 day period. The subsidence of the discharge ultimately leads to a widely dispersed, weakly elevated, saline anomaly at the sea



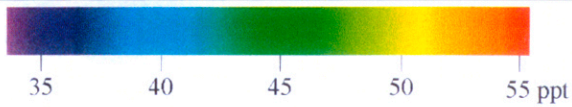
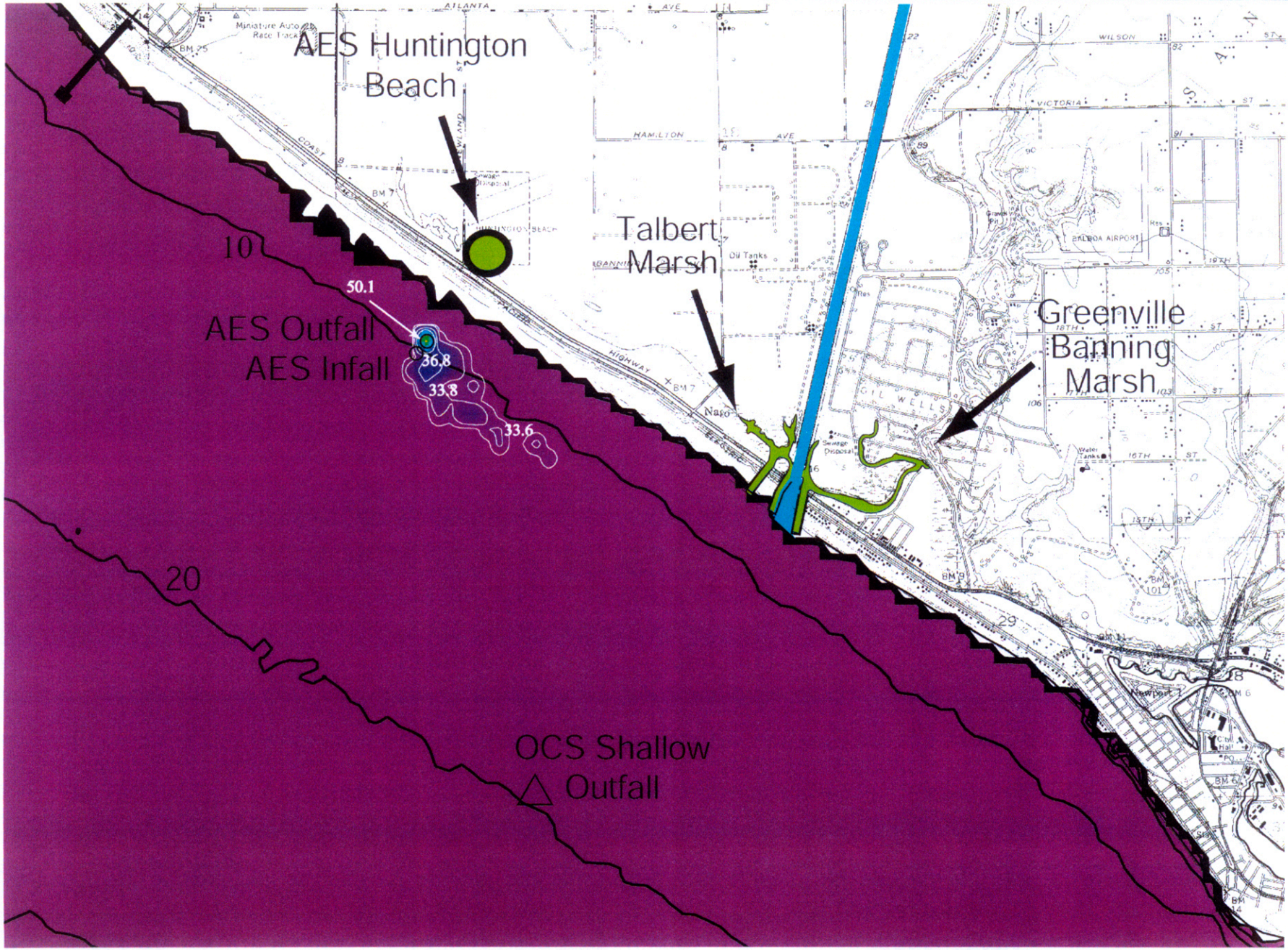


Figure 4.1. 30 day average of salinity at mid water column depth for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, (low flow conditions).

floor throughout the farfield region downdrift of the outfall (Figure 4.3). In the nearfield of the outfall, there is a saline inversion, with bottom salinities at the tow of the outfall reaching only 48.3 ppt. This nearfield inversion is due to the dilution of concentrated seawater that occurs along the discharge trajectory, as it is initially propelled towards the surface and away from the bottom by the discharge flow momentum.

From the salinity fields calculated in Figures 4.1-4.3, the highest salinities are found to occur in the water column at mid-depth directly adjacent to the outfall tower. For low flow month conditions a total of 18.3 acres of pelagic habitat experience a 10% (or greater) increase in salinity. The benthic area effected by 10% increases in salinity is 15.6 acres. Again the smaller impacted area at the seabed is due to the nearfield saline inversion around the outfall tower. However, the footprint of the 1% saline anomaly is greater on the bottom than in the water column due to subsidence in the farfield. The benthic area experiencing a 1% (or greater) increase in salinity is 263 acres for low flow month conditions, while the pelagic area similarly effected is 151 acres.

The model simulation of the 30-day average of the salinity profile in a crossshore section passing through the outfall (Figure 1.1, Section-A) is plotted in Figure 4.4 during the low flow case conditions perpetuated over a 30-day period. The corresponding longshore section of the salinity profile (Figure 1.1, Section-B) is plotted in Figure 4.5. Both plots are scaled identically to Figures 4.1- 4.3 with contours of salinity in parts per thousand (ppt), where the ambient background ocean salinity is 33.52 ppt. The thin, white vertical rectangle rising 4.8 meters above the bottom in Figures 4.4 and 4.5 indicates the location of the outfall tower, where the discharge is directed vertically upward toward the surface from the



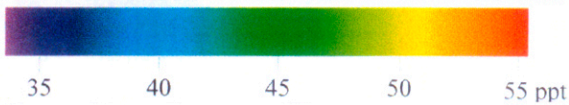


Figure 4.2. 30 day average of salinity on sea surface for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, (low flow conditions).

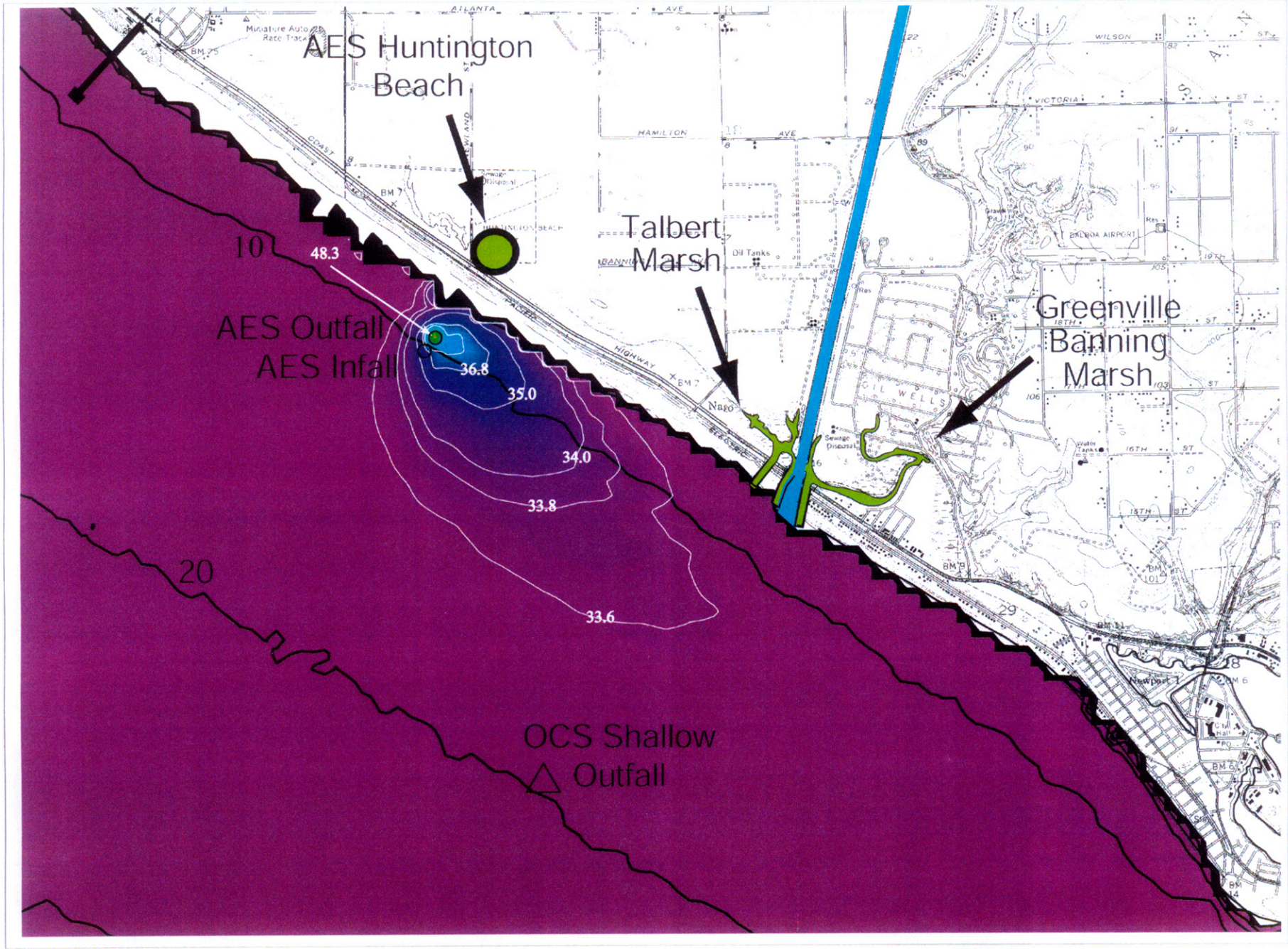
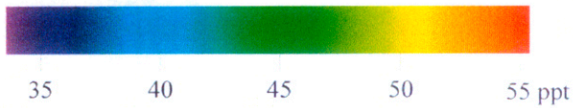


Figure 4.3. 30 day average of salinity on sea bottom for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, (low flow conditions).



top of the rectangle. In Figure 4.4 the cross-shore profile is exaggerated vertically by 40 to 1. In Figure 4.5 the longshore distances are greater so that the vertical exaggeration is increased to 60 to 1. In both plots this was done to delineate vertical structures in the discharge plume.

The cross-shore and longshore profiles shown in Figures 4.4 and 4.5 reveal that the discharge plume consists of two primary features: 1) a high-salinity core that forms a narrow column around the outfall tower, and 2) a broad-scale salt wedge spreading outward from the core in which the salinities are weakly hyper-saline. The core is formed by the initial discharge jet emanating from the top of the outfall tower at a flow rate of 76.7 mgd. The core has two distinct dynamical zones: an inner core comprised of an axi-symmetric turbulent jet whose momentum is directed vertically upward, and an outer core comprised of a collapsing inversion zone around the jet. The maximum salinity in the center of jet is 55.0 ppt immediately above the outfall tower, but the turbulence of the jet quickly dilutes salinities in the inner core to about 50 ppt, with sufficient residual momentum to broach the sea surface, creating a "surface boil" of hyper-saline water. In the outer core surrounding the jet, entrainment of water leads to formation of a vertical column of convective cells in which the salinity dilutes from 50 ppt to 38 ppt. The radius of the inner core varies between 40 and 50 meters (measured from the center of the outfall). The outer core is asymmetric, extending outward to a maximum distance of 150 meters from the outfall in the cross shore direction and 300 meters in the longshore direction toward the southeast (down-drift bias). The upward momentum of the initial jet discharge supports the weight of the core above the bottom which otherwise is "top heavy" relative to the surrounding water mass. Thus, along the outer edges of the core

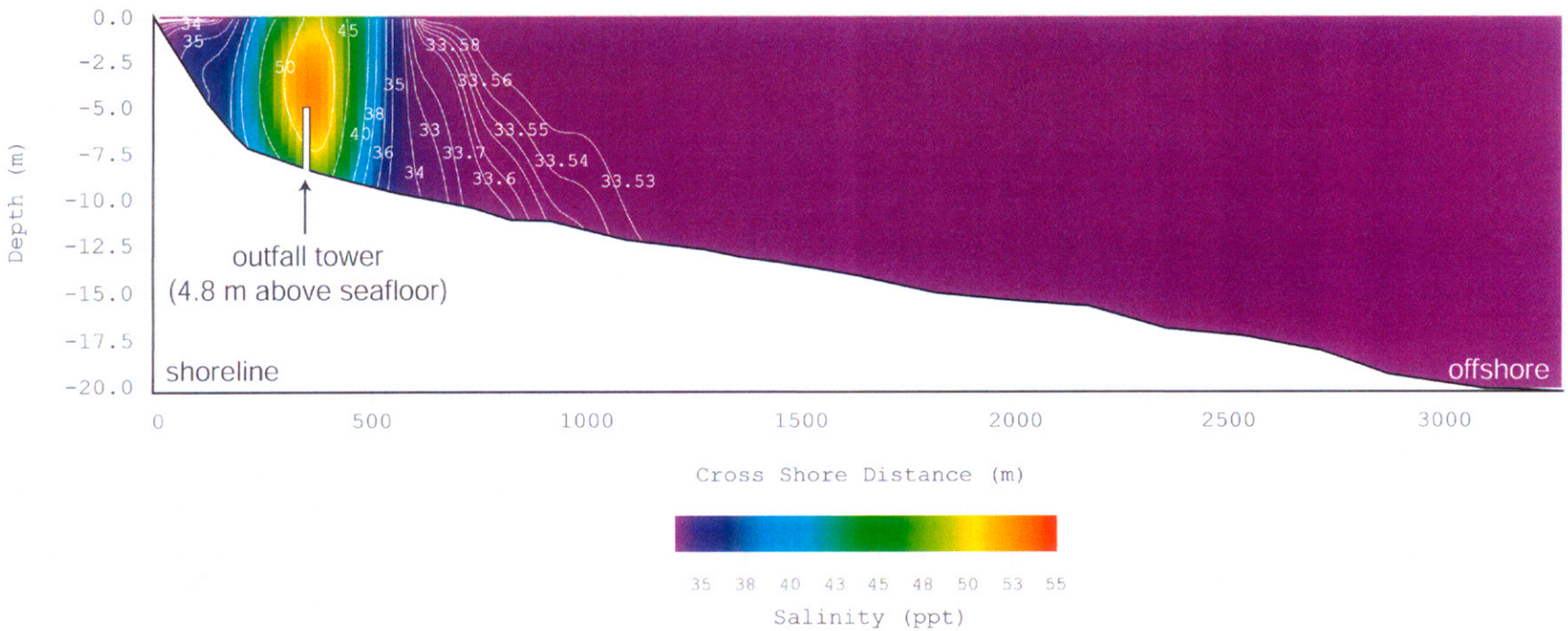


Figure 4.4. Cross shore salinity profile through the AES Huntington outfall along Section-A (see Figure 1). 30-day average of salinity for concentrated sea water discharge using: R.O. = 50 mgd, Power Plant Flow Rate = 126.7 mgd, (low flow conditions). (Profile corresponds to results in Figures 4.1 - 4.3.)

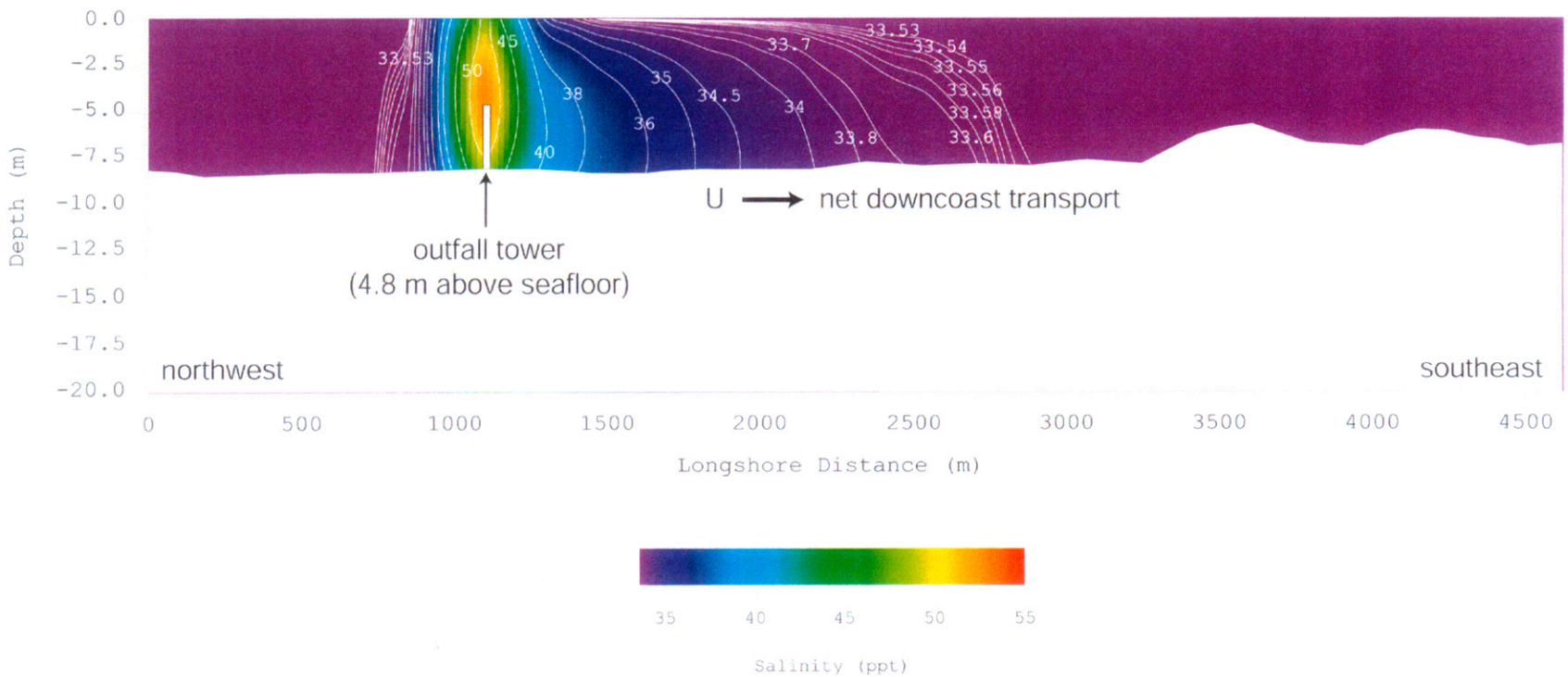


Figure 4.5. Longshore salinity profile through the AES Huntington outfall along Section-B (see Figure 1). 30-day average of salinity for concentrated sea water discharge using: R.O. = 50 mgd, Power Plant Flow Rate = 126.7 mgd, (low flow conditions). (Profile corresponds to results in Figures 4.1 - 4.3.)

where there is insufficient upward jet momentum to support the weight core water in a vertical column structure, the core collapses and subsides into the ambient water mass, forming a salt wedge that spreads outward as a slowly creeping density flow. The salt wedge spreads predominantly downslope (offshore) in the cross shore direction (Figure 4.4) under the influence of gravity, and downdrift in the alongshore direction (Figure 4.5) as it is advected towards the southeast by the net tidal transport. To a lesser degree, there is also some dispersion of the discharge plume shoreward and upcoast (towards the northwest) due to mixing of the salt wedge under the influence of shoaling waves. Salinities in the salt wedge nominally range from about 1.5 ppt above ambient (4% salinity anomaly) to only 0.0 1 ppt above ambient (0.1% salinity anomaly), well within the envelope of natural variability. The salt wedge is highly asymmetric, with a large offshore and downdrift bias toward the southeast. The salt wedge extends 800 meters offshore of the outfall and 1800 meters downdrift toward the Santa Ana River mouth.

The corresponding dilution fields of concentrated seawater in the middle of the water column, at the sea surface and on the seabed are plotted in Figures 4.6-4.8, respectively. Dilution contours are shown in a log-10 scale relative to the raw concentrate (at twice ambient ocean salinity). Inspection of Figure 4.6 (showing minimum nearfield dilution) indicates that the dilution of concentrated seawater is 31 to 1 at the plant infall. Thus, about 2% of the sea salts from reverse osmosis might become re-circulated back through the production unit for this 30 day low flow case scenario which has a return probability of between 0.27% and 0.64% depending on the length of ENSO cycles. Figure 4.7 shows that dilution in the saline boil at the sea surface is extremely rapid and sharp-edged due to the subsidence of the negatively buoyant combined effluent. Seabed dilution (Figure

4.8) is faster in the nearfield of the discharge tower then in the water column or at the sea surface, but slower in the farfield. Minimum dilution of concentrated seawater at the shoreline is 32 to 1. The recently completed CEC study (KOMEX,2003: Jones and Major, 2003) found that dye discharged from the HBGS outfall is diluted by a minimum of 36 to 1 at the shoreline. Thus the model results presented in Figures 4.6- 4.8 (that were derived two years before the KOMEX field study) appear to be well confirmed. Given these dilution findings in combination with offshore measurements of indicator bacteria, both studies have concluded that the dilution associated with the AES outfall is sufficiently large that it can not account for the high bacteria levels measured at the shoreline.

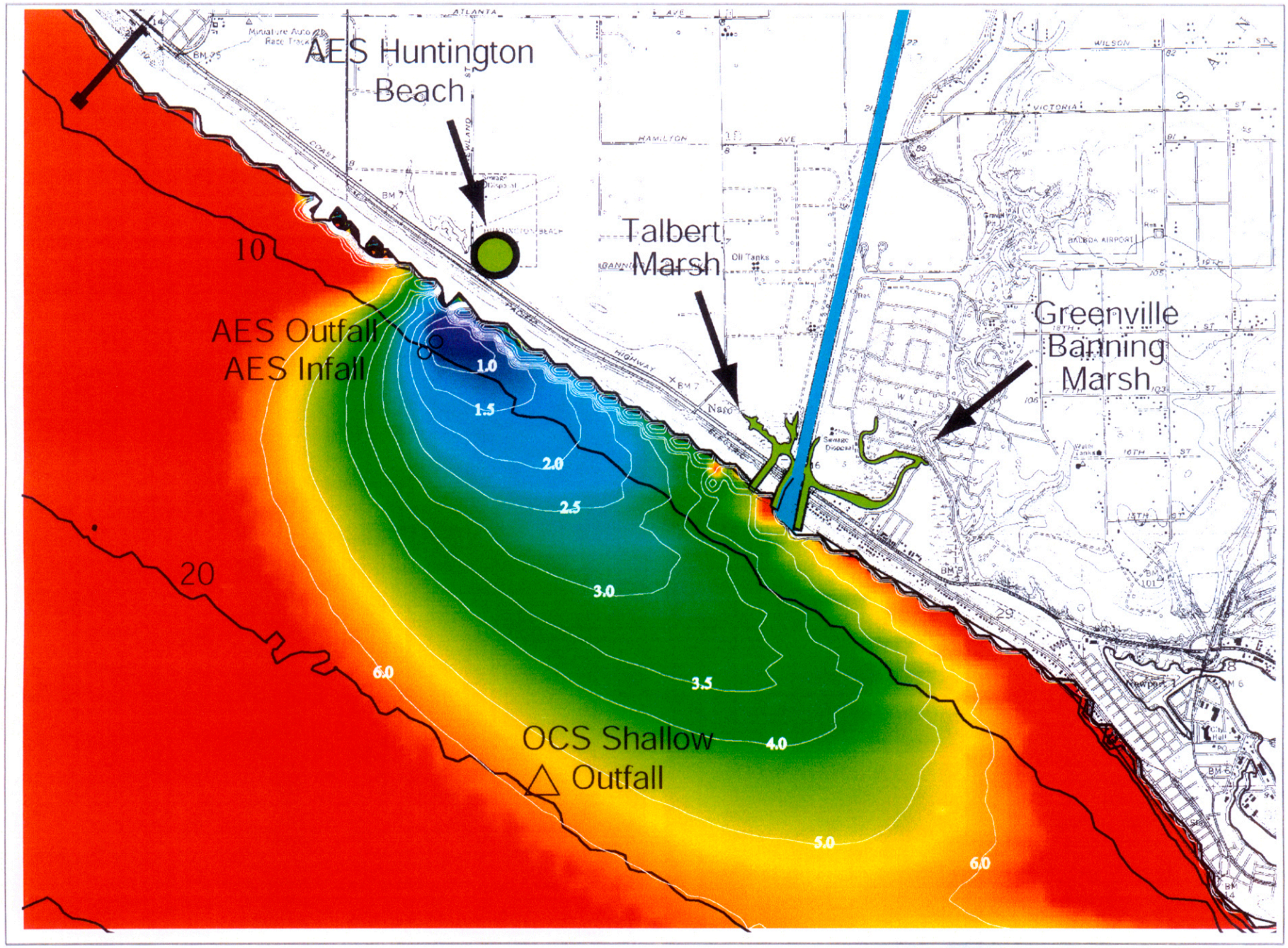
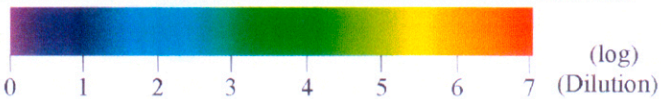


Figure 4.6. 30 day average dilution of concentrated sea water, mid water column depth, from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, (low flow conditions).



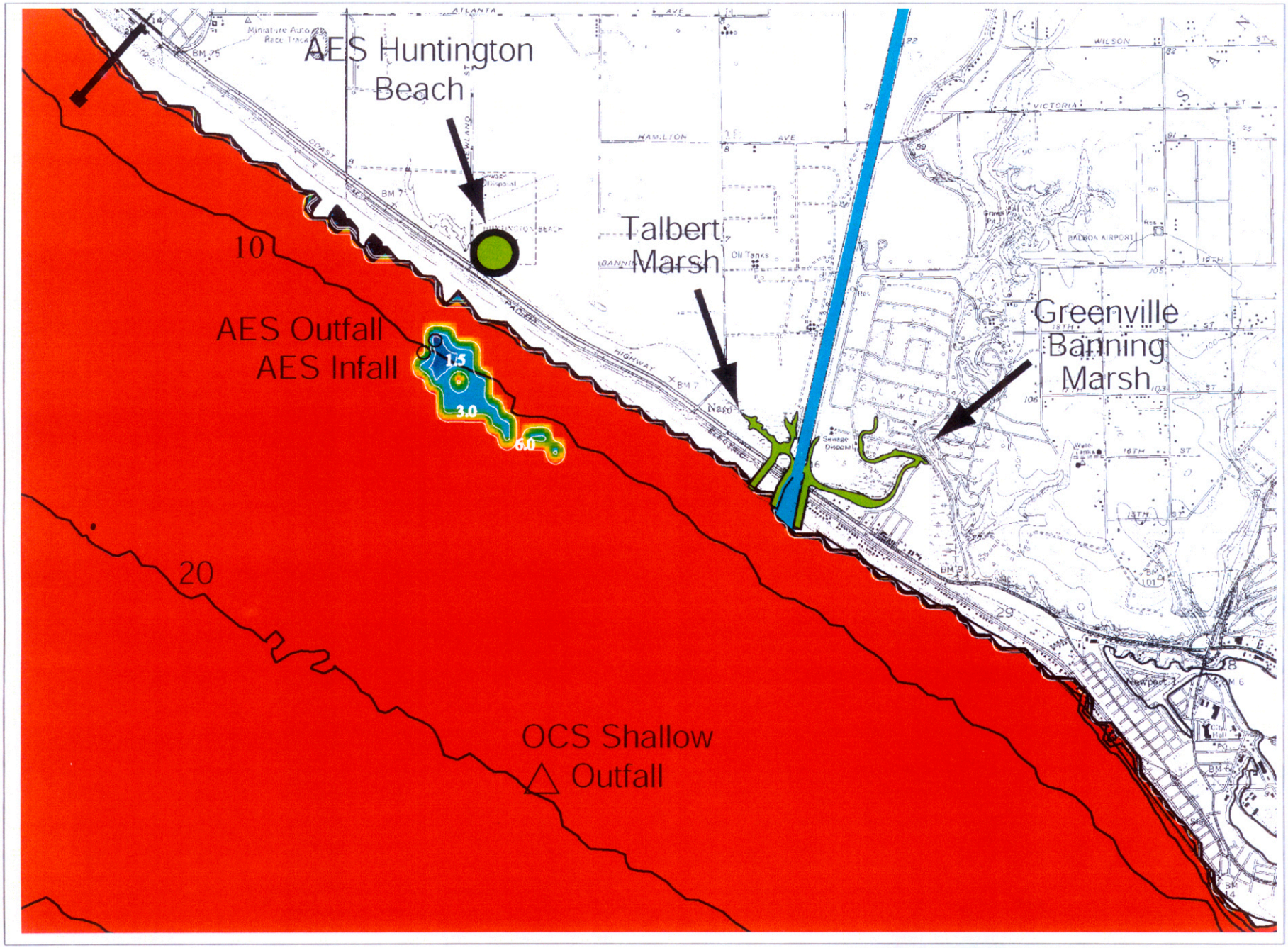
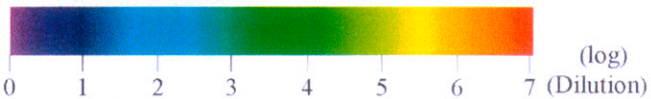
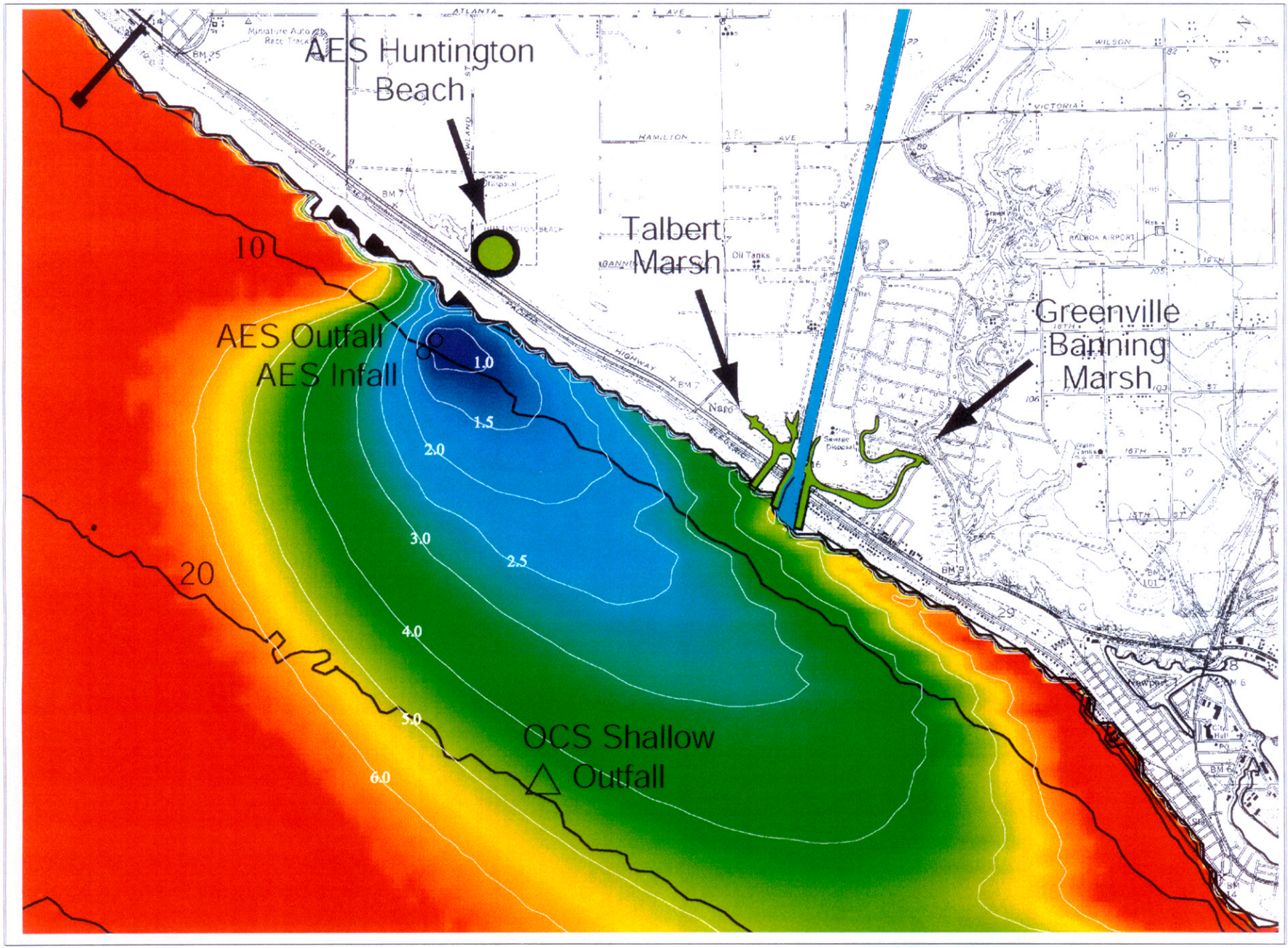


Figure 4.7. 30 day average dilution of concentrated sea water at sea surface from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, (low flow conditions).





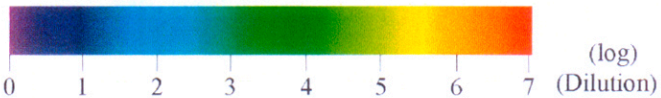


Figure 4.8. 30 day average of bottom dilution of concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 126.7 mgd, (low flow conditions).

C) Description Average-Case Conditions

For the evaluation of dilution and saline impacts on the receiving body during more typical or nominal operating levels, we consider two generating units to be online. We assume no storm water discharge (summer conditions) so that the power plant flow rate is 253.4 mgd due to 2 generating units being on line with 4 operating circulation pumps and heating the seawater to discharge temperature of $\Delta T = 10^{o}$ C, (Table 2). With the RO unit producing 50 mgd of product water, the effluent stream from the plant outfall will have an end-of-the-pipe salinity of 41.76 ppt and a combined flow rate (cooling plus RO concentrate) of 203.4 mgd (see Tables 2 & 5, Section 3). This gives the combined effluent (including thermal expansion) a -0.44% change in specific volume relative to ambient seawater, (i.e., lighter than the effluent of the low flow case scenario but still heavier than ambient seawater).

The average case scenarios were found by a statistical search of the records for the 7 variables occurring over the 20.5 year period of record (Figures 3.23 & 3.24). This procedure produced the selection of inputs to represent average case conditions listed in Table 5 in Section 3. Wave forcing for the bottom mixing action on this effluent is provided by the average annual wave whose properties were calculated from averaging the height, period, and direction of the 20-year wave record (Figure 3.24a). The statistical average wave was run continuously throughout the 30-day simulation of the normal operational impacts. The current mixing in the 30-day simulation was due purely to tidal flow and was provided by a mean range pair of spring neap cycles. The wind mixing was set for a diurnal sea breeze with a 5.6 knot 24 hr mean (Figure 3.24c).

D) Findings for Average Month

The model simulations for the 30 day average of the salinity fields at mid-depth, sea surface, and sea floor are plotted in Figures 4.9 - 4.13 for an RO production rate of 50 mgd and a plant flow rate of 253.4 mgd during the average month conditions. Contours of salinity are in parts per thousand (ppt), where the ambient ocean salinity is 33.52 ppt. The corresponding dilution fields of the concentrated seawater by-product are plotted in Figures 4.14-4.16. Dilution contours are in a log-10 scale relative to the raw concentrate. Comparing salinity fields in Figures 4.9-4.11 with the low flow month simulations in Figures 4.1-4.3, we find that the regions of elevated salinity in the water column are muted for average month conditions and that the footprint of the saline anomalies are smaller. In either case, the dispersion patterns over a 30 day period spread out downdrift towards the southeast due to the net tidal transport. The high salinity regions in the water column are reduced in intensity because the higher plant flow rates for an average month result in greater "in-the-pipe" dilution, (combined flow rate for power generation and RO production is 203.4 mgd). The increased dilution in the pipe is also combined with increased ambient ocean mixing for an average month, thereby increasing the rate of dilution in the receiving water and reducing the size of the footprints of the saline anomalies.

For an average month the maximum area of pelagic habitat subjected to a 10% (or greater) increase in salinity is reduced to only 8.3 acres, in which the maximum salinity is 41.7 ppt in the core of the discharge jet (Figure 4.9). Salinities in the surface boil reach a maximum of 38.3 ppt before subsidence ensues (Figure 4.10). Maximum seabed salinities (Figure 4.11) are only 37.6 ppt at the base of the outfall and the area of benthic habitat subjected to a 10% increase in salinity is 6.8

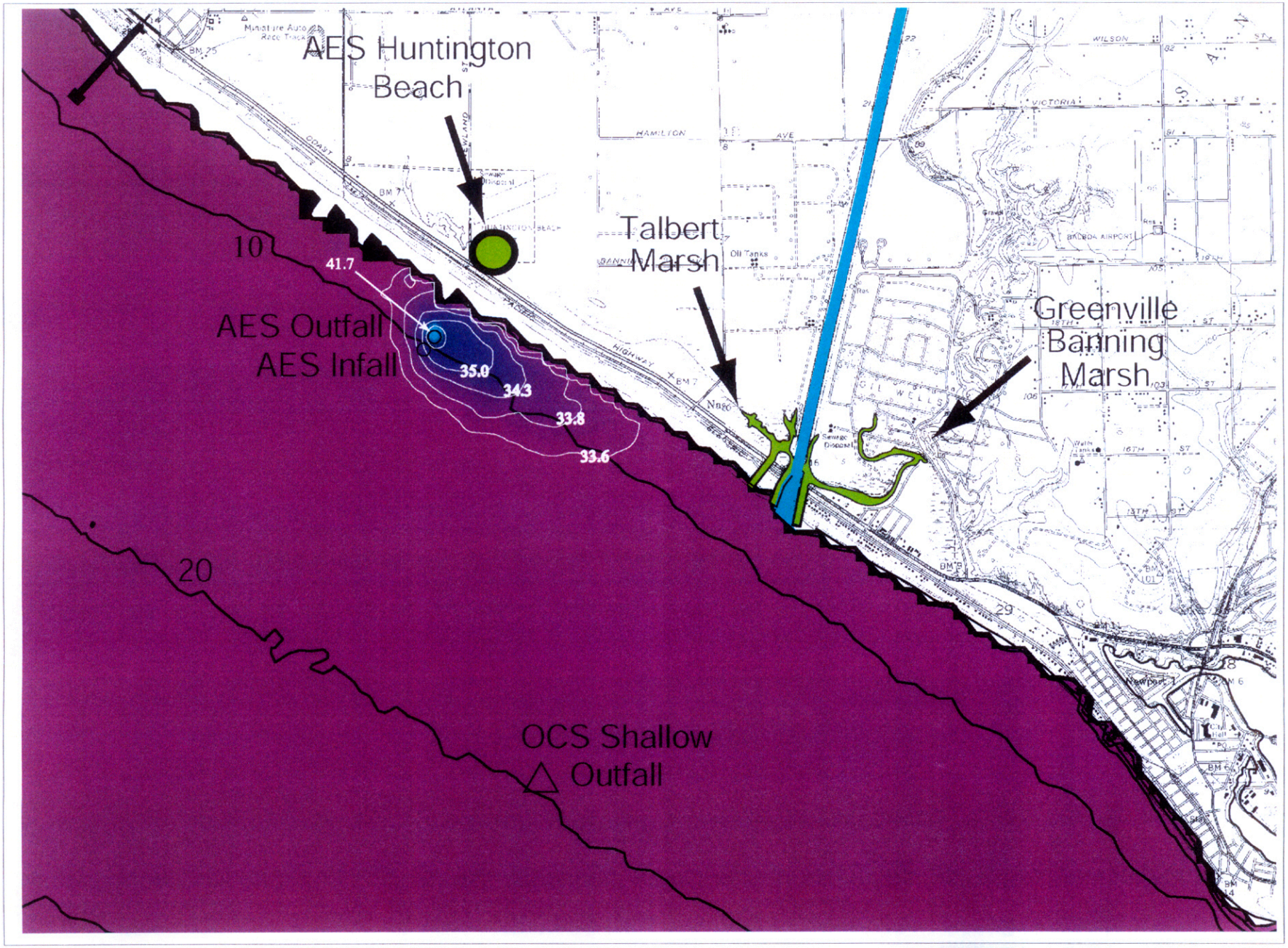
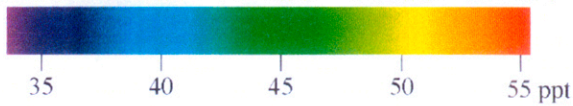
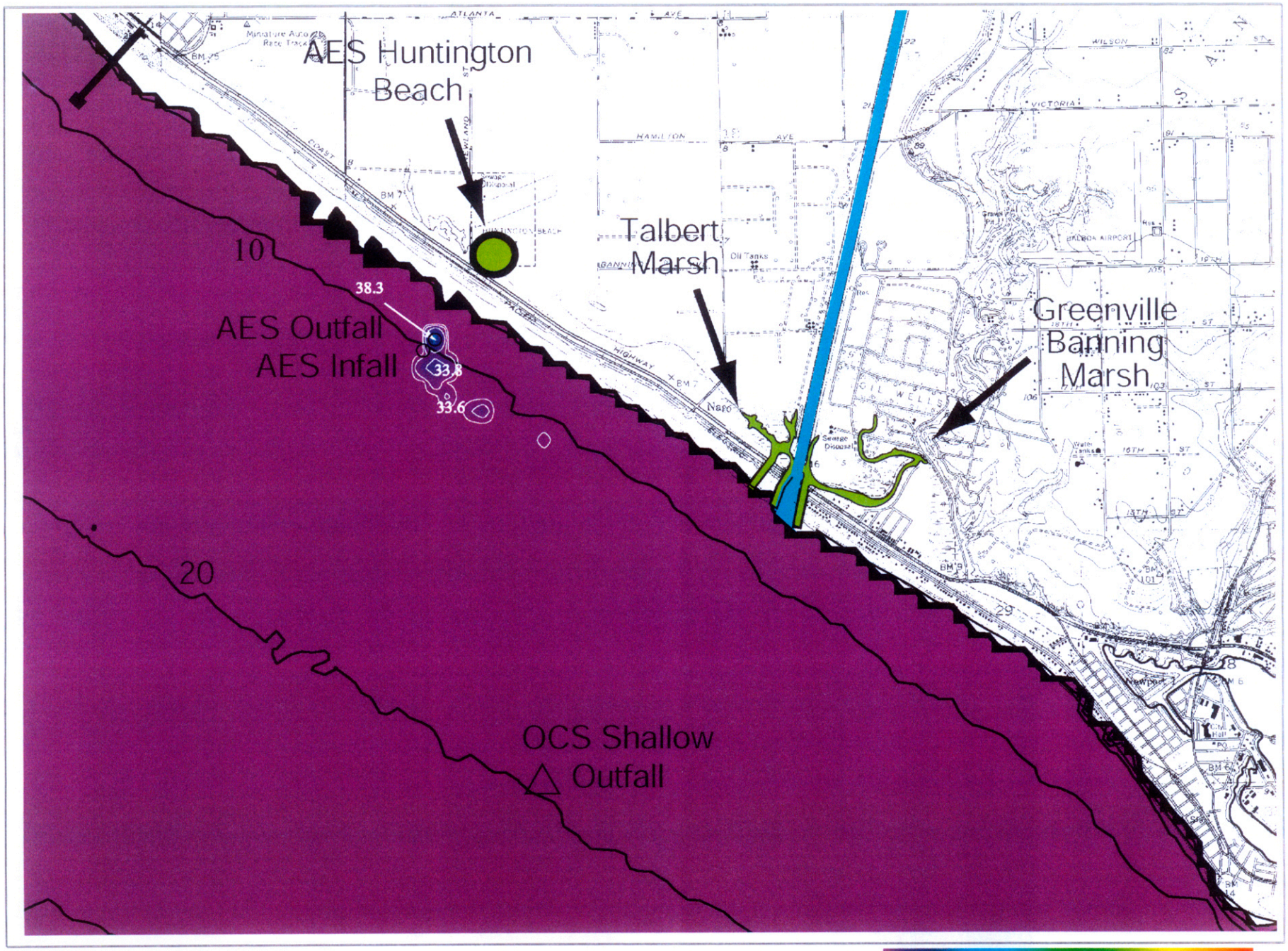


Figure 4.9. 30 day average of salinity at mid water column depth for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, (average flow conditions).





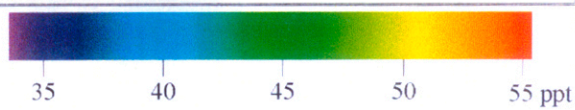


Figure 4.10. 30 day average of salinity on sea surface for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, (average flow conditions).

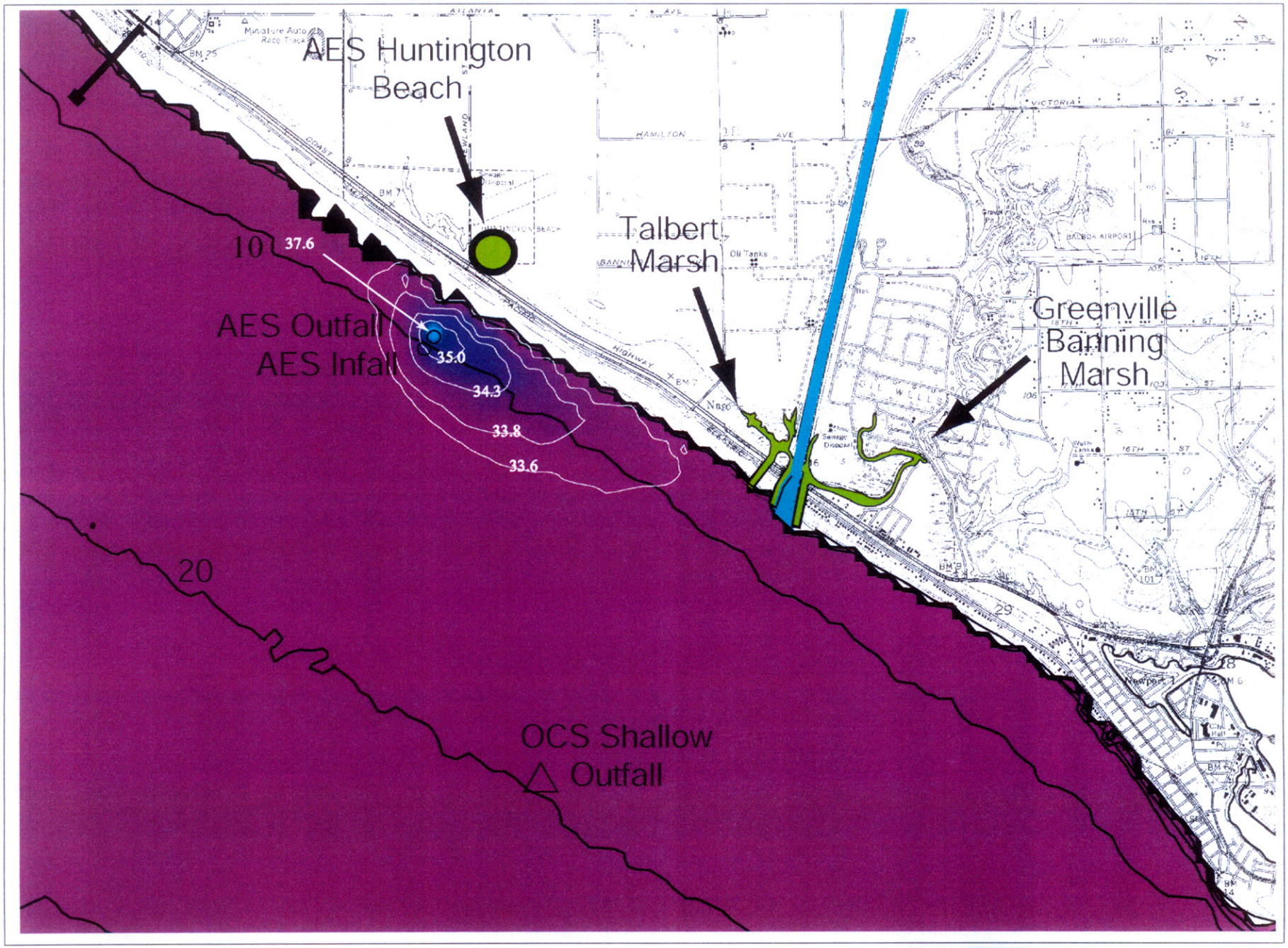
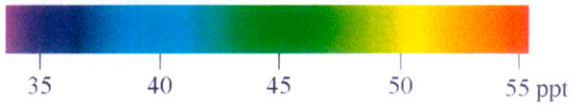


Figure 4.11. 30 day average of salinity at seabed for concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, (average flow conditions).



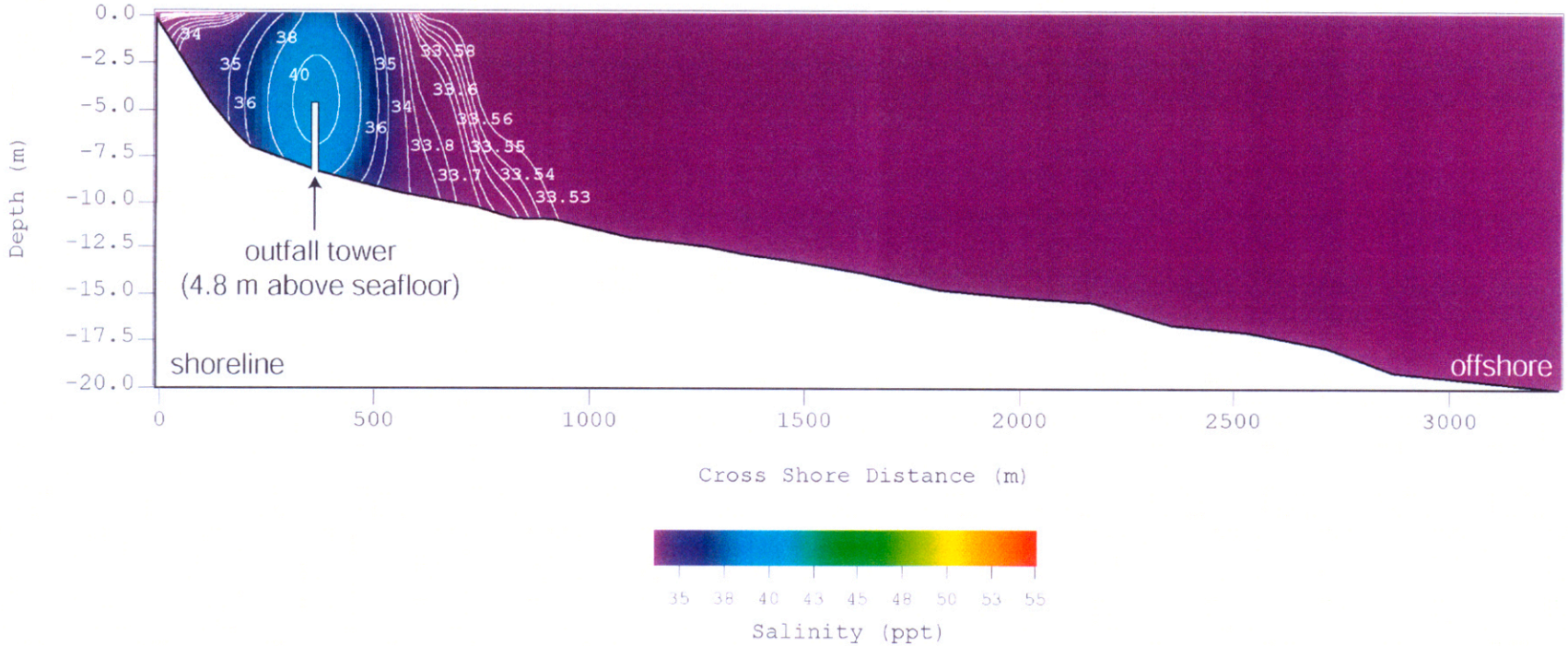


Figure 4.12. Cross shore salinity profile through the AES Huntington outfall along Section-A (see Figure 1). 30-day average of salinity for concentrated sea water discharge using: R.O. = 50 mgd, Power Plant Flow Rate = 253.4 mgd, (average flow conditions). (Profile corresponds to results in Figures 4.9 - 4.11.)

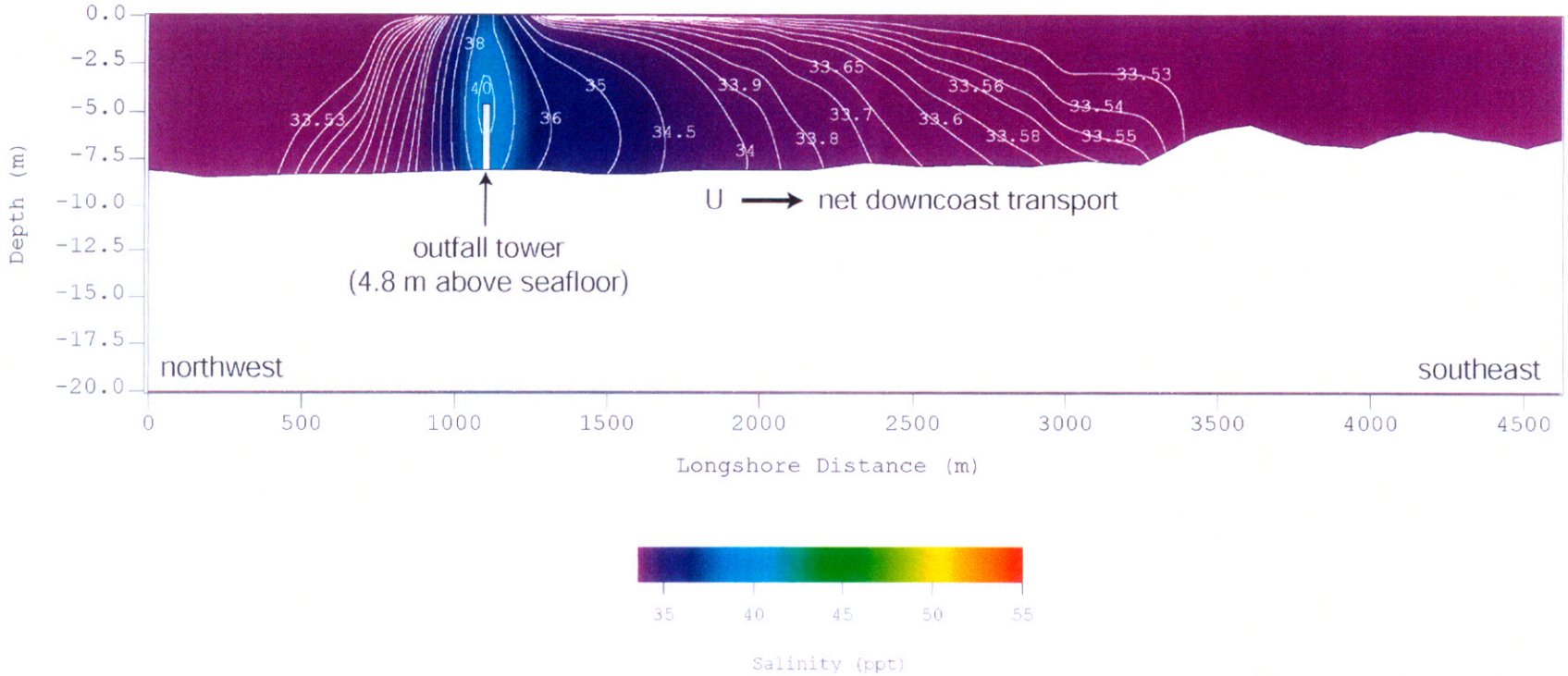


Figure 4.13. Longshore salinity profile through the AES Huntington outfall along Section-B (see Figure 1). 30-day average of salinity for concentrated sea water discharge using: R.O. = 50 mgd, Power Plant Flow Rate = 253.4 mgd, (average flow conditions). (Profile corresponds to results in Figures 4.9 - 4.11.)

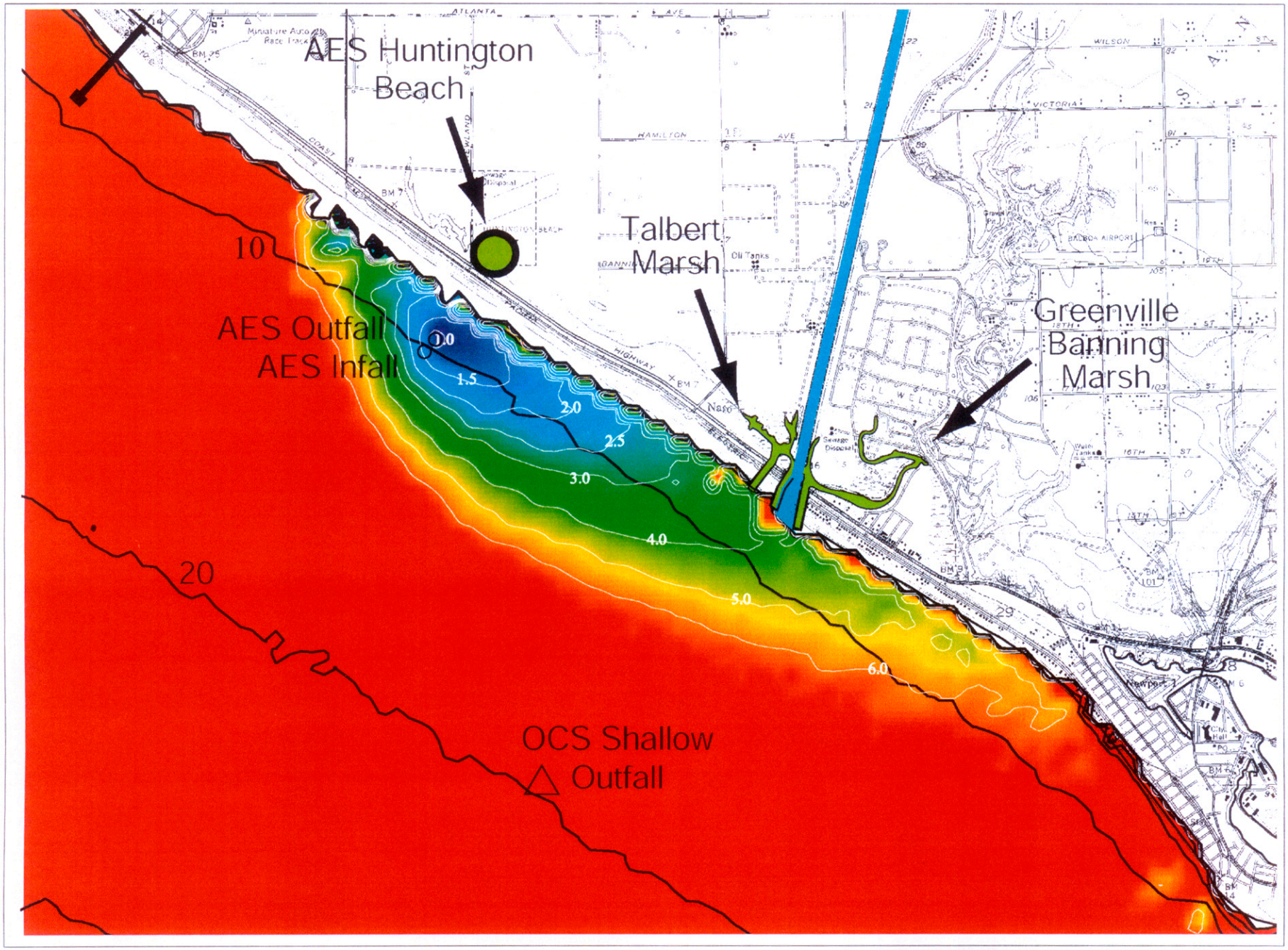
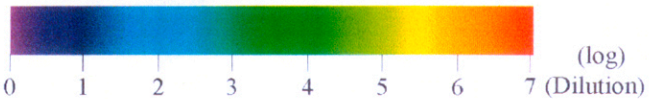
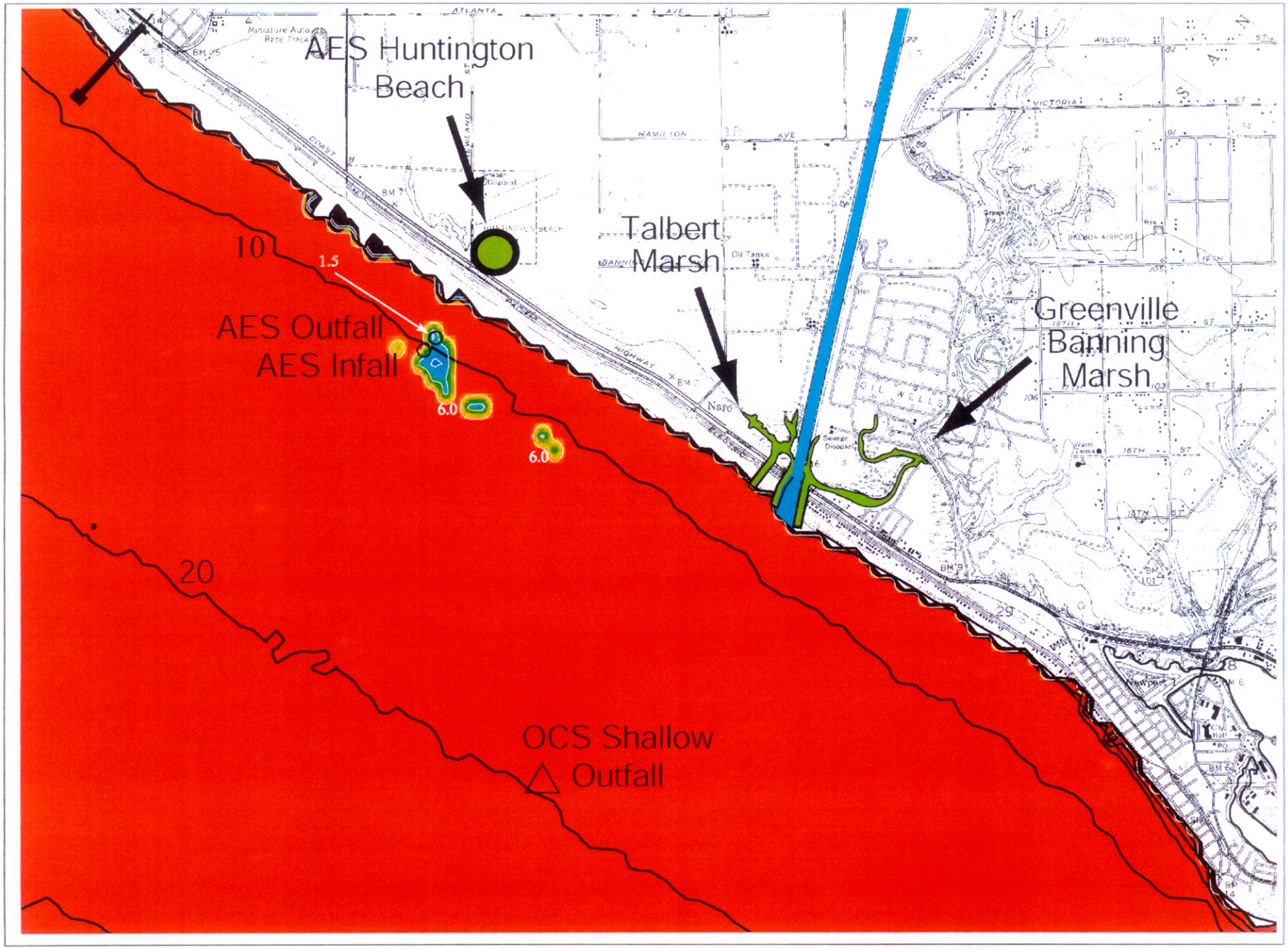


Figure 4.14. 30 day average dilution of concentrated sea water, mid water column depth, from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, (average flow conditions).





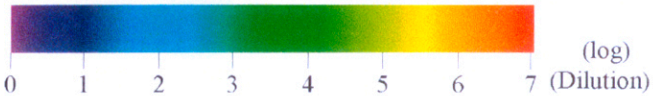


Figure 4.15. 30 day average dilution of concentrated sea water at sea surface from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, average conditions.

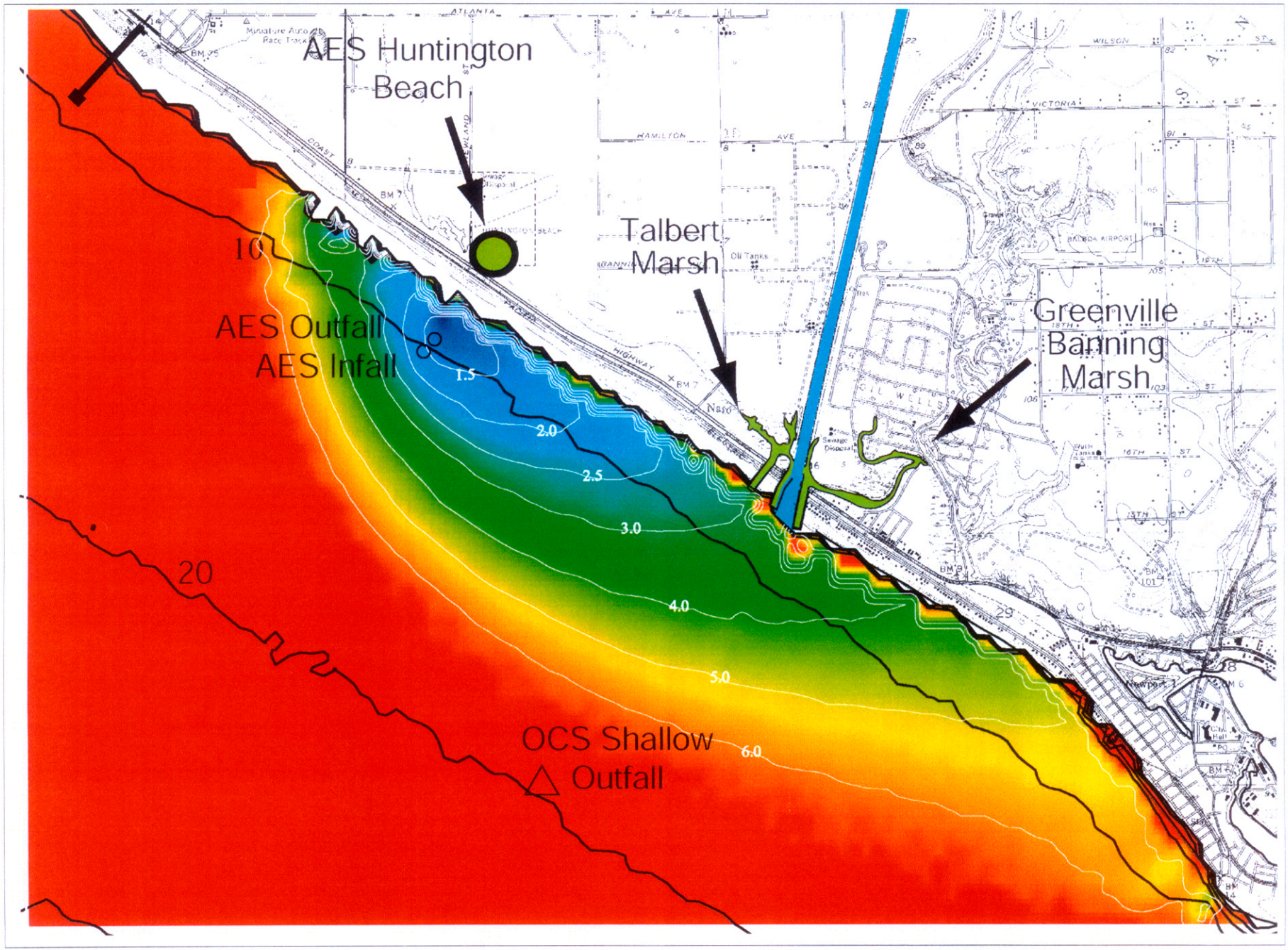
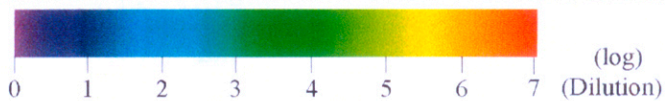


Figure 4.16. 30 day average of bottom dilution of concentrated sea water from: R.O. = 50 mgd, Plant Flow Rate = 253.4 mgd, (average flow conditions).



acres. The footprint of the 1% saline anomaly covers a maximum area of 130 acres in the water column and 172 acres at the seabed.

The model simulation of the salinity profile in a cross-shore section passing through the outfall (Section-A, Figure 1.1) is plotted in Figure 4.12 for an RO production rate of 50 mgd and a plant flow rate of 253.4 mgd during the average month conditions. The corresponding longshore section of the salinity profile (Section-B) is plotted in Figure 4.13. Both plots are scaled identically to Figures 4.9 - 4.11 with contours of salinity in parts per thousand (ppt), where the ambient background ocean salinity is 33.52 ppt. It is apparent that the core salinities are substantially diminished for average month conditions, reaching a maximum of only 41.7 ppt with a nominal value of 38 ppt in the inner core, and nominally 36 ppt in the outer core. However both the inner and outer cores are enlarged relative to low flow case, with a nominal radius of 90 - 115 meters for the inner core and 170-440 meters to the outer fringes of the outer core where salinities have declined to 35 ppt. The enlarged core structures with lower salinity anomalies are a result of higher "in-the-pipe" dilutions and more vigorous ocean mixing during average case operational and environmental conditions. The salt wedge is similarly enlarged along shore and more diffuse due to the higher net longshore currents during average month oceanographic conditions. Nominal salinities in the salt wedge are only 33.65 ppt (0.38% anomaly) with a maximum detectable limit spreading 570 meters offshore and 2,200 meters downdrift from the outfall. The offshore spreading of the plume is diminished for average conditions because the lower core salinities reduce the downslope gravitational forces acting to move the plume in that direction. Concurrent with diminished downslope gravity are larger waves with longer periods that exert a larger shoreward directed wave transport (Stokes Drift)

to counter downslope gravity.

The dilution of concentrated seawater at the generating station infall is 32 to 1 (Figure 4.14) and hence only 0.7% of the sea salts from reverse osmosis are potentially re-circulated during an average month. Minimum dilution of concentrated seawater at the shoreline is 190 to 1 (Figure 4.16) and minimum dilution at 1000 ft in any direction from the outfall is 20 to 1.

E) Summary of Dilution and Dispersion Results:

Low flow case dilution calculations are summarized in the first column of Table 6 for low-flow conditions and in the third column for standby mode. Simulations in Figures 4.1-4.8 indicate that the desalination project will result in a tear-drop-shaped saline plume around a jet of water discharged vertically upward toward the sea surface from the outfall tower. In the core of this jet, the highest salinity reaches 55.0 at mid depth in the water column for low flow conditions and 55.2 ppt for standby mode. The difference between the discharge salinity and the background seawater salinity rapidly decreases with increasing distance from the discharge outfall tower. Taking the average radius of the tear-drop-shaped plume, salinity in the water column decreases to 40 ppt (20 percent above background salinity) within 283 feet from the discharge outfall tower for low-flow conditions and within 360 ft for standby mode. Water column salinity decreases to 10 % above background seawater salinity (37 ppt) within 504 feet from the outfall tower for low-flow conditions and within 528 ft for standby mode. The total pelagic area of the plume within the 10% saline anomaly is 18.3 acres for low-flow and 20.1 acres for standby mode. The size and strength of the plume are a bit less on the seafloor than in the water column. On the seafloor, the highest salinity is at the base of the outfall tower and is 48.3 ppt for low-flow conditions . The

Table 6: Summary of Event Analysis of Dispersion and Dilution

Model Conditions	Composite Low-flow Month	Composite Average Month	Composite Standby Month
Recurrence Probability	0.27% - 0.64%	50.0%	0.04% - 0.1%
Maximum Seabed Salinity	48.3 ppt	37.6 ppt	50.4 ppt
Maximum Mid-Water Column Salinity	55.0 ppt	41.7 ppt	55.2 ppt
Maximum Surface Salinity	50.1 ppt	38.3 ppt	53.1 ppt
Maximum Benthic Area of 10% Saline Anomaly	15.6 acres	6.8 acres	18.2 acres
Maximum Pelagic Area of 10% Saline Anomaly	18.3 acres	8.3 acres	20.1 acres
Maximum Benthic Area of 1% Saline Anomaly	263 acres	172 acres	284 acres
Maximum Pelagic Area of 1% Saline Anomaly	151 acres	130 acres	163 acres
Dilution of Concentrated Seawater at Plant Infall[a]	100 to 1	500 to 1	90 to 1
Minimum Saline Dilution 305 m from Discharge Structure[a]	10 to 1	20 to 1	8 to 1
Minimum Saline Dilution at Shoreline[a]	32 to 1	190 to 1	30 to 1

[a] Dilution of Raw Concentrate from RO Process

bottom salinity maximum is 50.4 ppt at the base of the tower for standby mode. The bottom salinity drops to 40 ppt within 236 feet from the discharge for low flow conditions, and within 300 ft for standby mode. The bottom discharge salinity is reduced to 10 % of the background salinity within 465 feet from the

outfall tower for low-flow conditions, and within 502 ft for standby mode. This 10 % bottom salinity anomaly covers 15.6 acres of the seafloor for low-flow conditions and 18.2 acres for standby mode.

Dispersion and dilution contours of sea salts for the theoretical extreme of the standby mode are very similar to those shown in Figures 4.1 through 4.8. The absence of power plant heat produces a heavier combined discharge that is more slowly assimilated by the receiving waters. As a result, the high salinity inner core of the standby mode discharge plume collapses earlier under larger forces of gravity, entraining less ambient water during subsidence and diluting more slowly. Dilution is also impeded by less thermal agitation in the unheated discharge.

Under average conditions, the maximum salinity anywhere is at mid water column depth in the core of the discharge jet, and reaches is 41.7 ppt, which is only 25 percent higher than the background salinity. Along the long-axis of the tear-drop-shaped plume (Figures 4.9 & 4.13), the discharge salinity in the water column decreases to 38.5 ppt (15 percent above background salinity) within 200 feet from the discharge outfall tower. Within 339 feet from the outfall tower, the average discharge salinity in the water column will be only 10 percent higher than the background seawater salinity (37 ppt) over an area of 8.3 acres. On the seafloor, salinity never reaches 40 ppt (20% over ambient) due to entrainment by the collapsing inner core as it subsides. The highest salinity on the seafloor for average conditions is found at the base of the outfall tower and is 37.6 ppt (only 12 % above background salinity). The bottom salinity drops to less than 10 % above the background salinity over an average distance 307 feet away from the discharge, subjecting no more than 6.8 acres of seabed to salinity on the order of 37 ppt.

F) Drift Rates and Exposure Time

Pelagic organisms drifting in the nearshore currents can be carried through the discharge plume along trajectories governed by the *Lagrangian drift* (Batchelor, 1970). The Lagrangian drift is the mean motion of a particle that would be observed by following that particle along its drift trajectory. The concept of Lagrangian mean motion is particularly important in the problem at hand because the water velocity in and around the plume varies from point to point due to the cross shore variation in the wave and tidal currents and the local velocity variation due to the discharge of the outfall. (Such variations in the local velocity field are referred to as *velocity gradients,* and were resolved by the model over the entire nearshore domain by the wave and current algorithms described Sections 2 and 3. The drift rates of organisms passing through these velocity gradients are not the same as the mean current speed measured by a fixed current meter located near the outfall. The current meter will have an error in drift rate estimates due to the effects of velocity gradients acting on the organism at places away from the current meter location. A hydrodynamic model can correct for such errors because it can reconstruct the entire velocity gradient structure that is required to calculate the actual drift rate of a particle moving in a variable velocity field. The drift rate of an organism passing through the plume is calculated as described below subject to the assumption that the organism is represented by a neutrally buoyant particle.

The maximum exposure time to elevated salinity for a drifting pelagic organism is plotted as a red line in Figure 4.17 for low flow case conditions. The salinity bins used for the drift trajectory calculations are indicated by red crosses. Exposure to the maximum salinity of the inner core (53-55 ppt) occurs for at most 7 minutes, while about 35 minute exposure could occur along the fringes of the

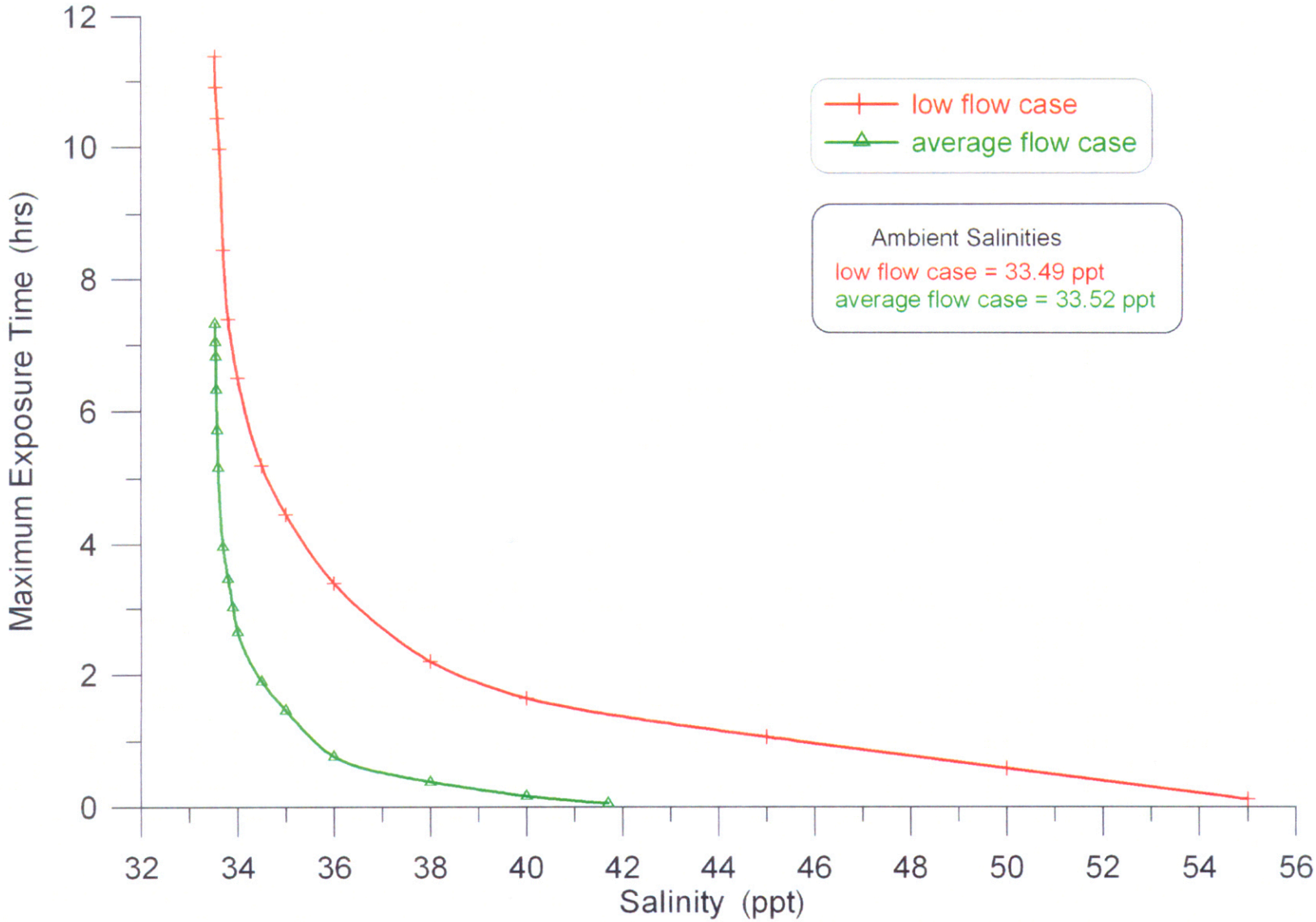


Figure 4.17. Maximum exposure time of a drifting organism passing through the discharge plume of concentrated seawater from the AES Huntington Beach outfall for low flow case conditions (red, plant flow rate = 126.7 mgd) and average case conditions (green, plant flow rate = 253.4 mgd).

inner core (40-50 meters from the outfall) where salinities are 50 ppt. In the outer core where salinities are nominally 45 ppt, the exposure time of a drifting organism would be about 1 hour, and about 2.2 hours along the outer fringes of the outer core where salinities decline to 38 ppt. In the salt wedge where salinities are nominally 34 ppt (equivalent to the seasonal maximum during the 1998 El Nino), the exposure time would be 6.5 hrs. At the outer limit of the salt wedge where the effect of the discharge from desalination is barely detectable above ambient mean salinities, the exposure time would be 11.4 hours.

The maximum exposure time to elevated salinity for a drifting pelagic organism is plotted as a green line in Figure 4.17 for average month conditions. The salinity bins used for the drift trajectory calculations are indicated by green triangles. Exposure to the maximum salinity of the inner core (40- 41.7 ppt) occurs for at most 10 minutes, while about 23 minute exposure could occur along the fringes of the inner core (90-115 meters from the outfall) where salinities are 38 ppt. In the outer core where salinities are nominally 36 ppt, the exposure time of a drifting organism would be about 46 minutes, and about 1.5 hours along the outer fringes of the outer core where salinities decline to 35 ppt. In the salt wedge where salinities are nominally 33.65 ppt (equivalent to the seasonal maximum of an average year), the exposure time would be 4.5 hrs. At the outer limit of the salt wedge where the effect of the discharge from desalination is barely detectable above ambient mean salinities, the exposure time would be 7.3 hours.

While passive exposure of pelagic organisms to the discharge plume is limited by the Lagrangian drift rates in the water mass around the outfall, the benthic organisms will experience exposure to low flow case conditions for as long as the environmental and operational conditions contributing to low flow case

persist. (In the model those conditions are perpetuated artificially for 30 consecutive days when in fact these conditions are likely to occur only 0.27% to 0.64 % of the time). The red curve in Figure 4.18 gives the variation in the bottom salinity for low flow-case conditions in a cross-shore section through the outfall (Figure 4.4) and in a longshore section (Figure 4.5). The highest bottom salinity found anywhere is 48.3 ppt at the base of the outfall tower, rapidly falling to 41 ppt at the outer fringes of the inner core. In the outer core and salt wedge, bottom salinities are slightly in excess of those in the water column for a given distance from the outfall. At the outer fringes of the outer core, bottom salinities are 38 ppt, while the structure of the salt wedge affords weakly elevated salinities out to greater distances along the bottom than in the water column. The total longshore expanse of the detectable presence of the salt wedge along the seabed is about 2,150 meters but the bottom salinities over most of this distance are no greater than the inter-annual maximum occurring naturally during a strong El Nino.

The green curve in Figure 4.18 gives the variation in the bottom salinity during average month conditions in a cross-shore section through the outfall (Figure 4.12) and in a longshore section (Figure 4.13). The highest bottom salinity found anywhere is about 37.6 ppt at the base of the outfall tower, rapidly falling to 35 ppt at the outer fringes of the core. Though out the preponderance of the salt wedge, bottom salinities are typically elevated no more than 0. 1 to 0.3 ppt above ambient. The total longshore expanse of the detectable presence of the salt wedge over the seabed is about 3000 meters but the bottom salinities over most of this distance are no greater than the inter-annual. maximums of an average year.

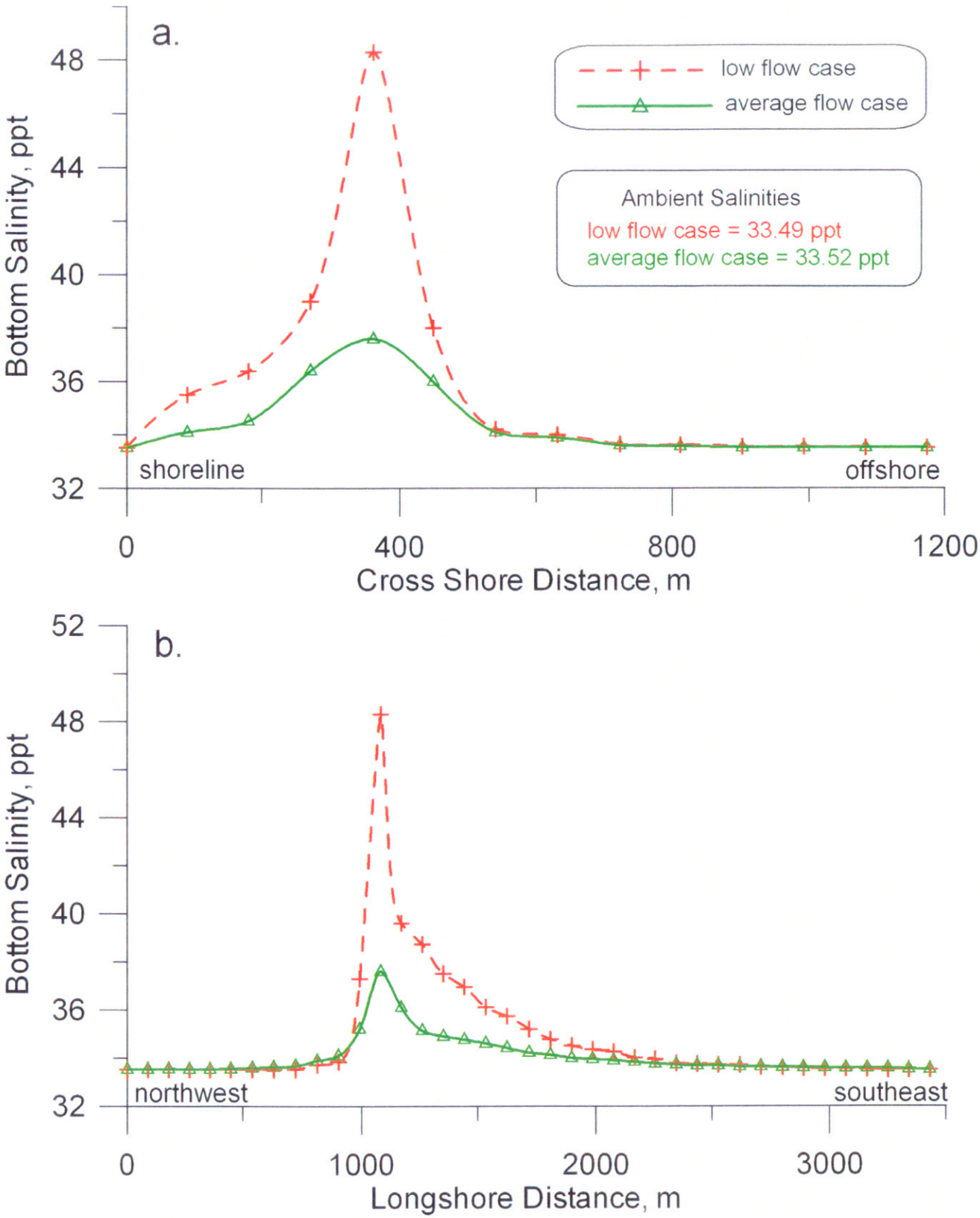


Figure 4.18. Thirty day average of bottom salinity for low flow and average flow case months along: a) crossshore profile (Section A), b) longshore profile (Section B).