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HYDRODYNAMICS AND CONTAMINANT TRANSPORT IN CHARLESTON BARBOR ESTUARY CNC CHARLESTON SC
1/1/2001
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Hydrodynamics + Contaminant Transport
Charleston Harbor Estuary. Presentation

Hydrodynamics and Contaminant Transport in Charleston Harbor Estuary

by: Ivan B. Chou, P.E.

ECT
Environmental Consulting & Technology, Inc.

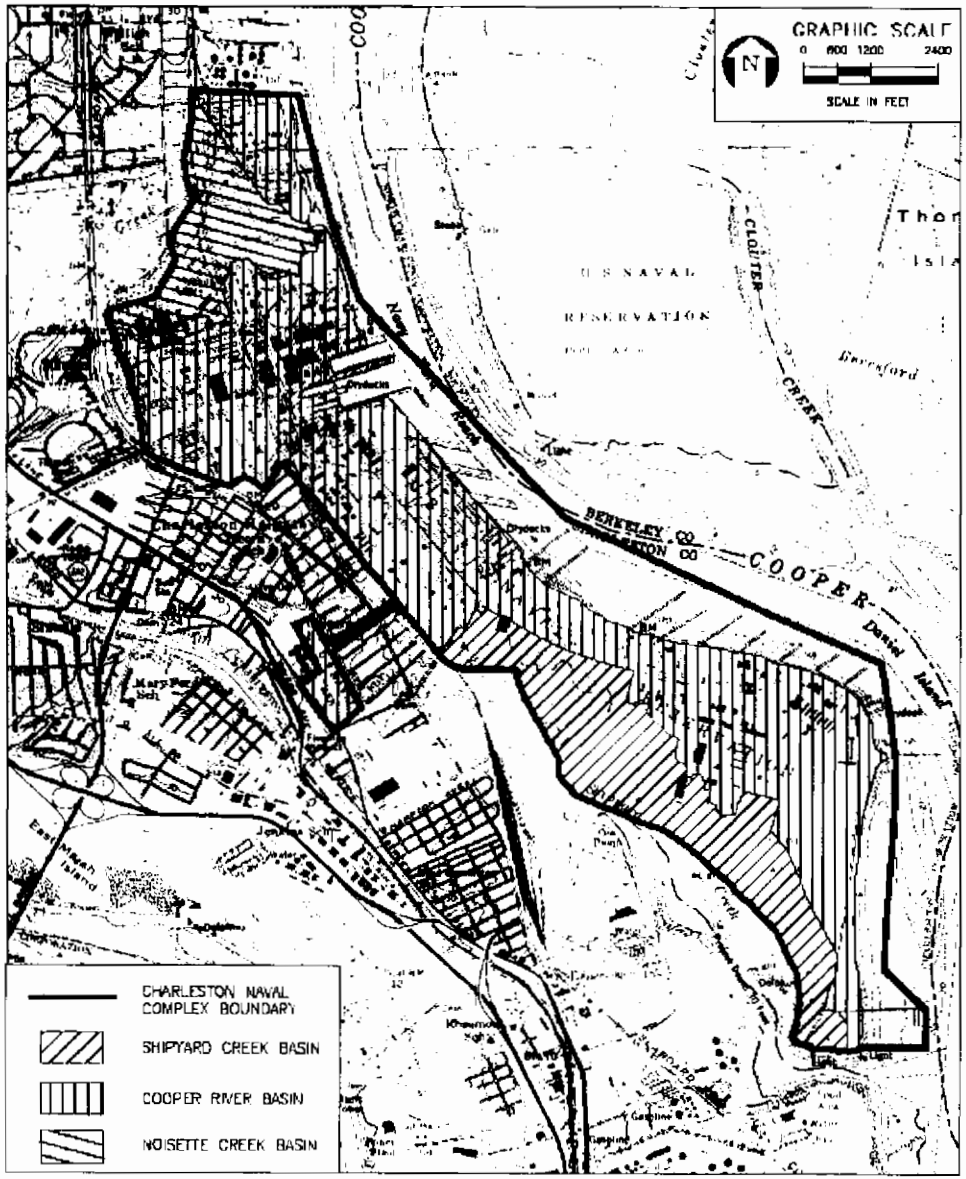
Naval Facilities Engineering Command
Southern Division

ENSAFE
Environmental and Management Consultants

Purpose

To evaluate potential contaminant migration pathway in the surface water around Charleston Naval Complex and Charleston Harbor Estuary

Charleston Naval Complex



Factors Affecting Estuarine Hydrodynamics

- Tide
- Freshwater inflow
- Bathymetry and boundary geometry
- Wind
- Density stratification

Factors Affecting Pollutant Transport

- Tidal current
- Pollutant source location
- Effluent quantity
- Effluent quality
- Sedimentation/resuspension
- Biochemical processes

Pollutant Transport Process

- Nearfield processes:
  - Turbulent jet entrainment
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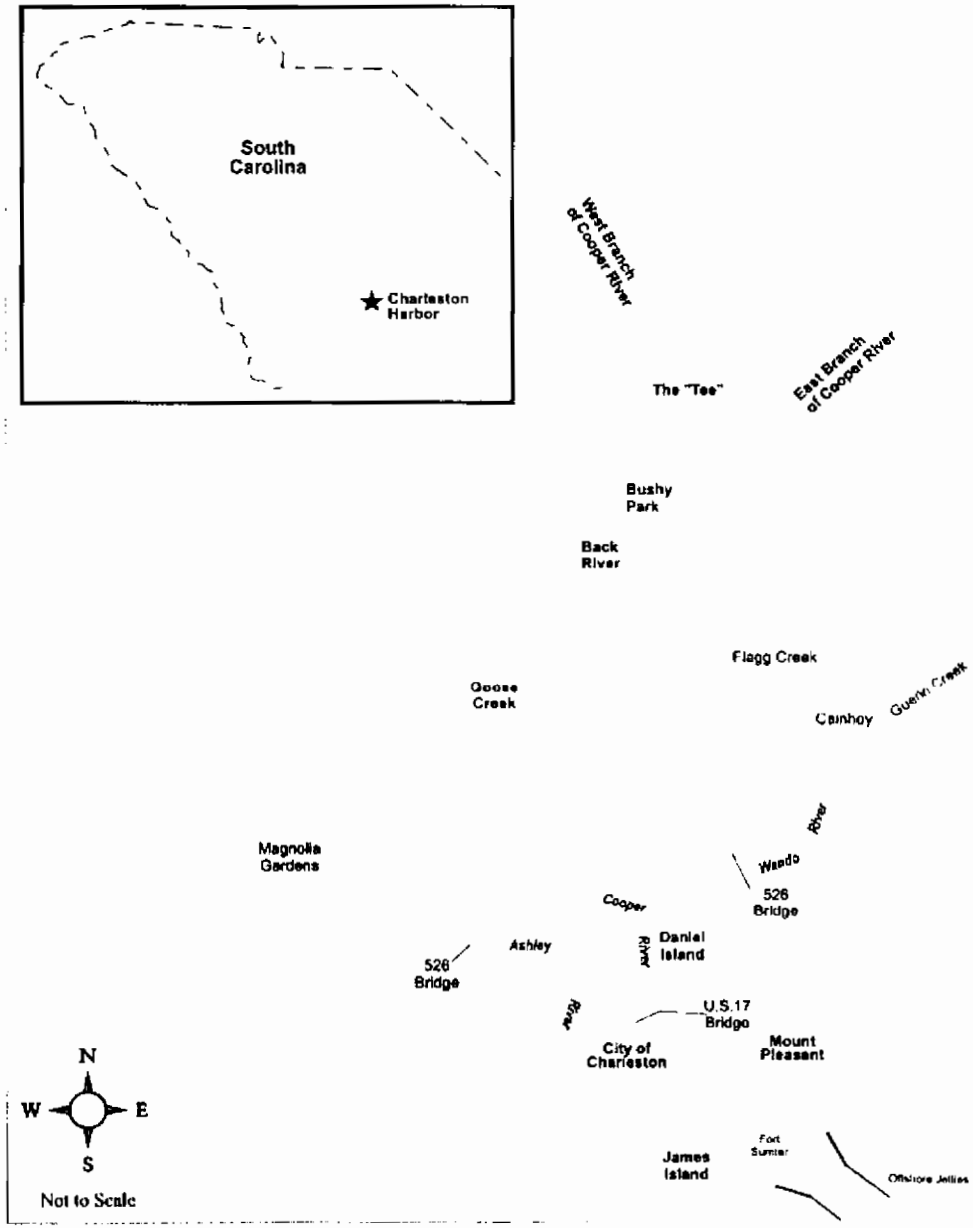
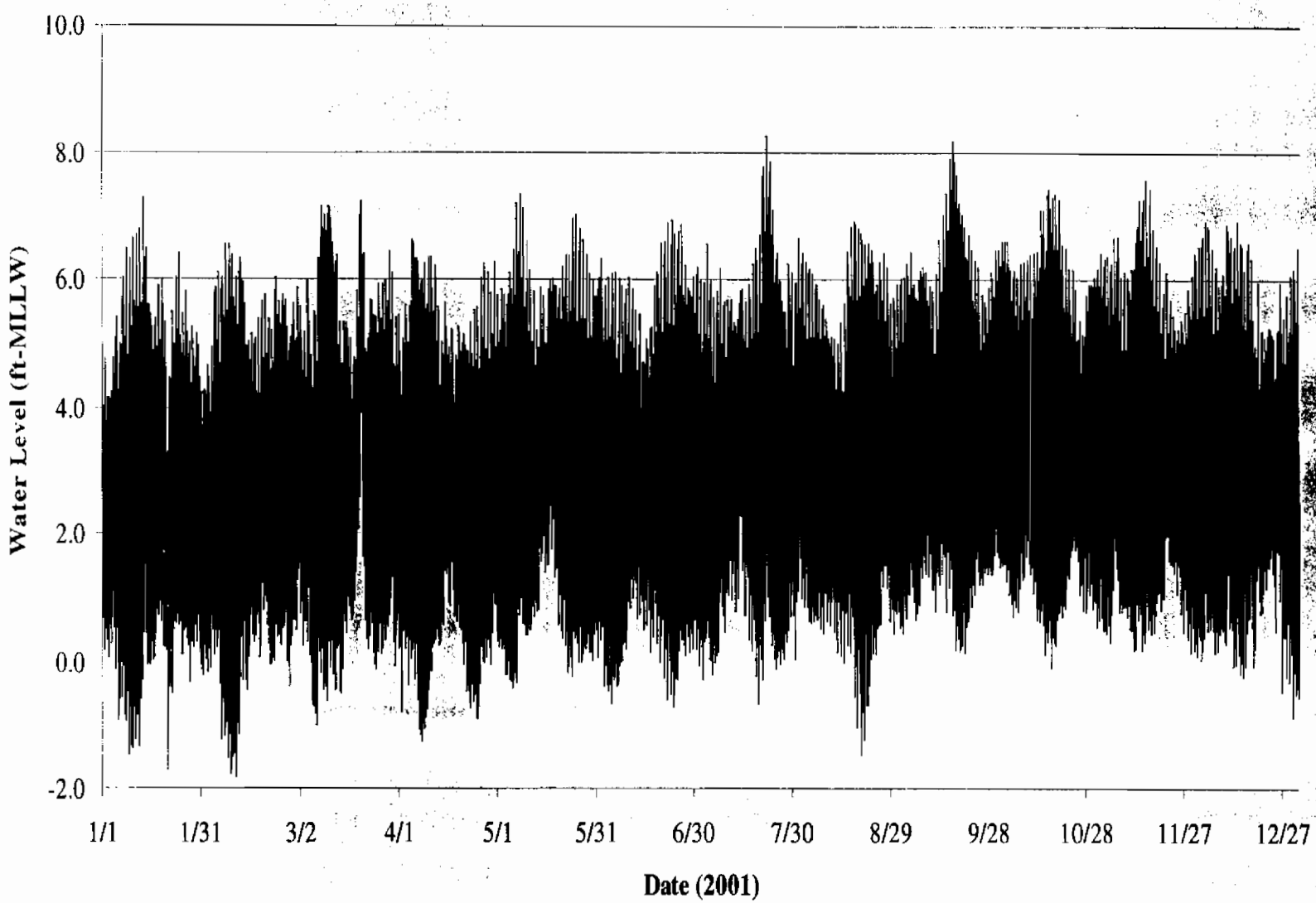
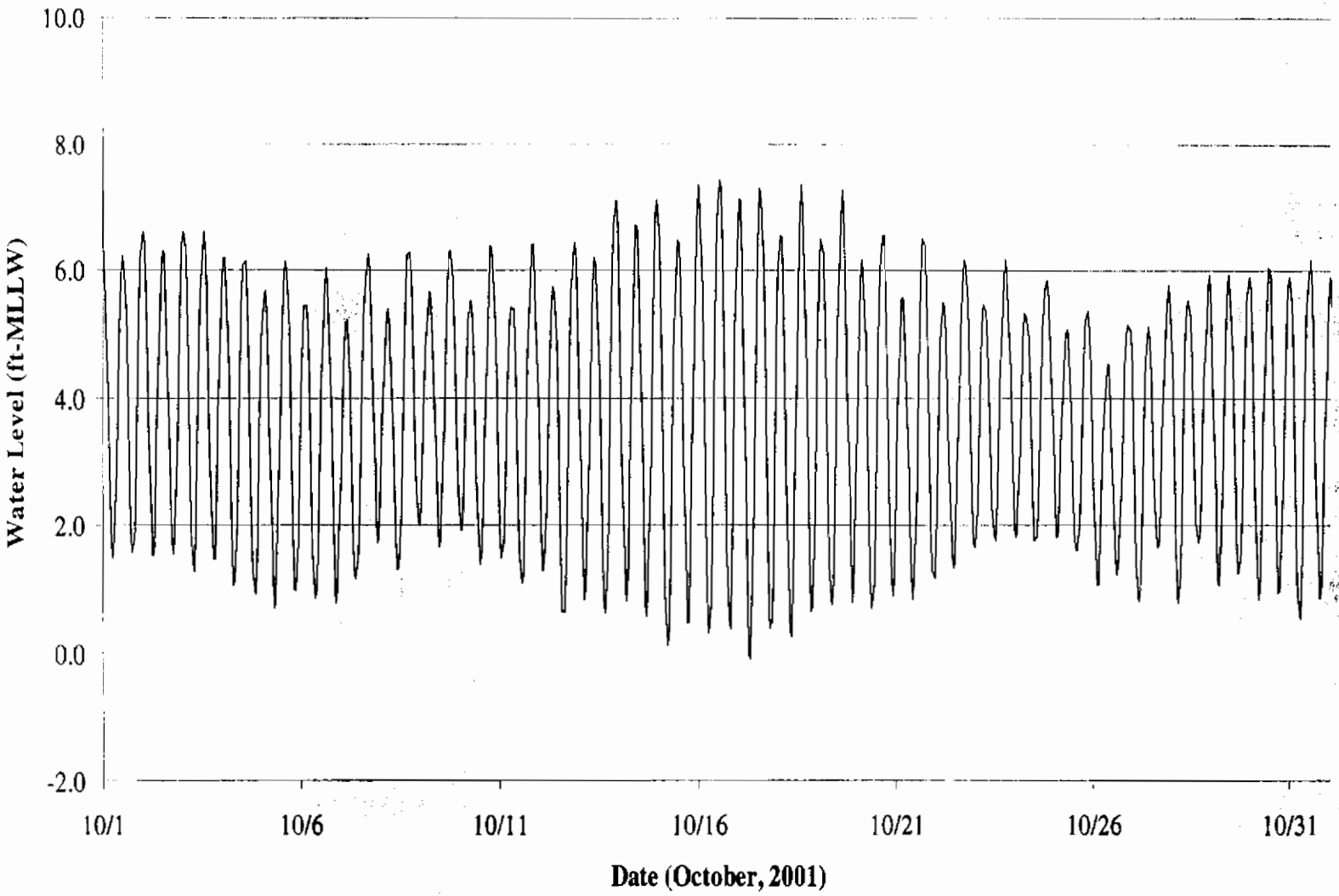


Tidal Level at Cooper River Entrance (2001)



Tidal Level at Cooper River Entrance (October 2001)



Tidal Ranges and Phases in Charleston Harbor/Cooper River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Charleston (Customhouse Wharf)	5.27	6.11	0.00
Shipyard Creek	5.30	6.10	0.33
Cooper River at Clouter Creek, south entrance	5.40	6.26	0.32
Cooper River at Clouter Creek, north entrance	5.48	6.36	0.55
Cooper River at Snow Point	5.36	6.22	0.75
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Cooper River at Dupon, Dean Hall	3.43	3.98	2.12
Cooper River at Old Rice Mill, West Branch	2.60	3.02	2.93
Cooper River at Pimlico, West Branch	1.70	1.97	3.90

Note: Phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Ranges and Phases in Ashley River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
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Tidal Ranges and Phases in Wando River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
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Wando River at Hobcaw Point	5.76	6.68	0.18
Wando River at Parker Island	5.76	6.68	0.47
Wando River at Cainhoy	6.15	7.13	0.50
Wando River at Big Paradise Island	6.54	7.59	0.87
Wando River at Woodville	6.30	7.30	1.37

Note: The phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Charleston Harbor Entrance, between jetties	1.8	1.8	-0.02
Charleston Harbor off Ft. Sumter	1.7	2.0	0.00
South Channel at Buoy "32"	0.8	1.0	-0.02
South Channel, 0.8 mile ENE of Fort Johnson	0.8	2.6	0.72
South Channel, 0.4 mile NW of Fort Johnson	0.7	1.9	1.17
The Cove, entrance on the Cove Range	1.2	0.9	0.47
Shutes Reach, Buoy "8"	1.3	1.5	0.30
Hog Island Channel	0.8	0.8	-0.65
Folly Reach at Buoy "5"	1.2	1.6	0.03
Folly Reach north of Fort Johnson	1.2	1.1	-0.85
0.6 miles SW of Castle Pinckney	0.7	1.3	-0.35
0.4 miles west of Shutes Folly Island	0.8	2.2	0.88
Customhouse Reach off Customhouse	1.0	1.3	0.82
Customhouse Reach	1.0	1.8	0.77
Horse Reach	1.4	1.9	0.60
Hog Island Reach, Buoy "12"	1.2	1.3	0.22
Drum Island, east of bridge	1.2	2.0	0.50
Town Creek Lower Reach	1.1	2.2	0.57
Town Creek, 0.2 mile above bridge	0.8	2.5	1.10
Drum Island Reach at Buoy"45"	0.6	1.0	0.43
Cooper River, 0.2 mile above Drum Island	1.1	2.4	1.20
Cooper River at Daniel Island Reach, Buoy "48"	1.2	1.3	1.02
Cooper River at Shipyard Creek entrance	0.5	1.5	0.68
Cooper River at Daniel Island Reach	1.3	2.3	1.48
Cooper River at Daniel Island Bend	1.2	2.1	0.92
Cooper River at North Charleston	1.1	1.7	1.43
Cooper River at Filbin Creek Reach	1.2	1.8	1.52
Cooper River at Filbin Creek Reach, Buoy "58"	1.1	1.3	1.30

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

(Continued, Page 2 of 2)

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Cooper River at Ordnance Reach	1.0	1.2	1.58
Cooper River at Yellow House Creek	0.7	1.4	2.10
Cooper River at 1 mile NW of Yellow House Landing	0.7	1.8	2.43
Cooper River at SE of Woods Point	0.8	1.0	1.80
Copper River at Woods Point	0.9	1.4	2.68
Cooper River at 0.5 mile North of Snow Point	1.1	1.4	2.25
Cooper River off Amoco Pier	0.7	0.9	2.15
Cooper River at 0.5 mile below Moreland	1.9	2.0	3.54
Cooper River at 1 mile below Hagan Island	1.3	1.4	3.54
Cooper River at 0.4 mile SW of The "Tee"	1.0	1.7	4.37
Cooper River at The "Tee"	0.9	1.0	3.00
Cooper River at Childsbury, S.A.L. RR Bridge	0.7	1.7	4.72

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Ashley River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Ashley River SW of Battery	1.2	1.8	0.27
Ashley River off Wappoo Creek	1.1	1.2	0.12
Ashley River at highway bridge	1.2	1.1	-0.15
Ashley River at 0.1 mile below SCL railroad bridge	1.0	1.1	-0.10
Ashley River at 1.5 mile above SCL railroad bridge	1.2	1.5	0.37
Ashley River at State Highway 7 bridge	1.0	1.0	0.10
Ashley River at 0.1 mile east of West Marsh Island	0.7	1.0	0.38
Ashley River at Bees Ferry Bridge	1.9	2.3	1.22

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Wando River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Wando River at 0.2 mile NW of Ramley Point	1.3	1.8	-0.23
Wando River at Upper Reach, Turning Basin	1.0	1.2	-0.23
Wando River at Rathall Creek Entrance	1.3	1.7	0.42
Wando River off Nowell Creek, Buoy "19"	0.8	1.0	-0.13
Wando River at 0.2 mile above Horbeck Creek entrance	1.0	0.9	0.47
Wando River at 2.5 miles north of Horbeck Creek	0.8	1.3	0.50

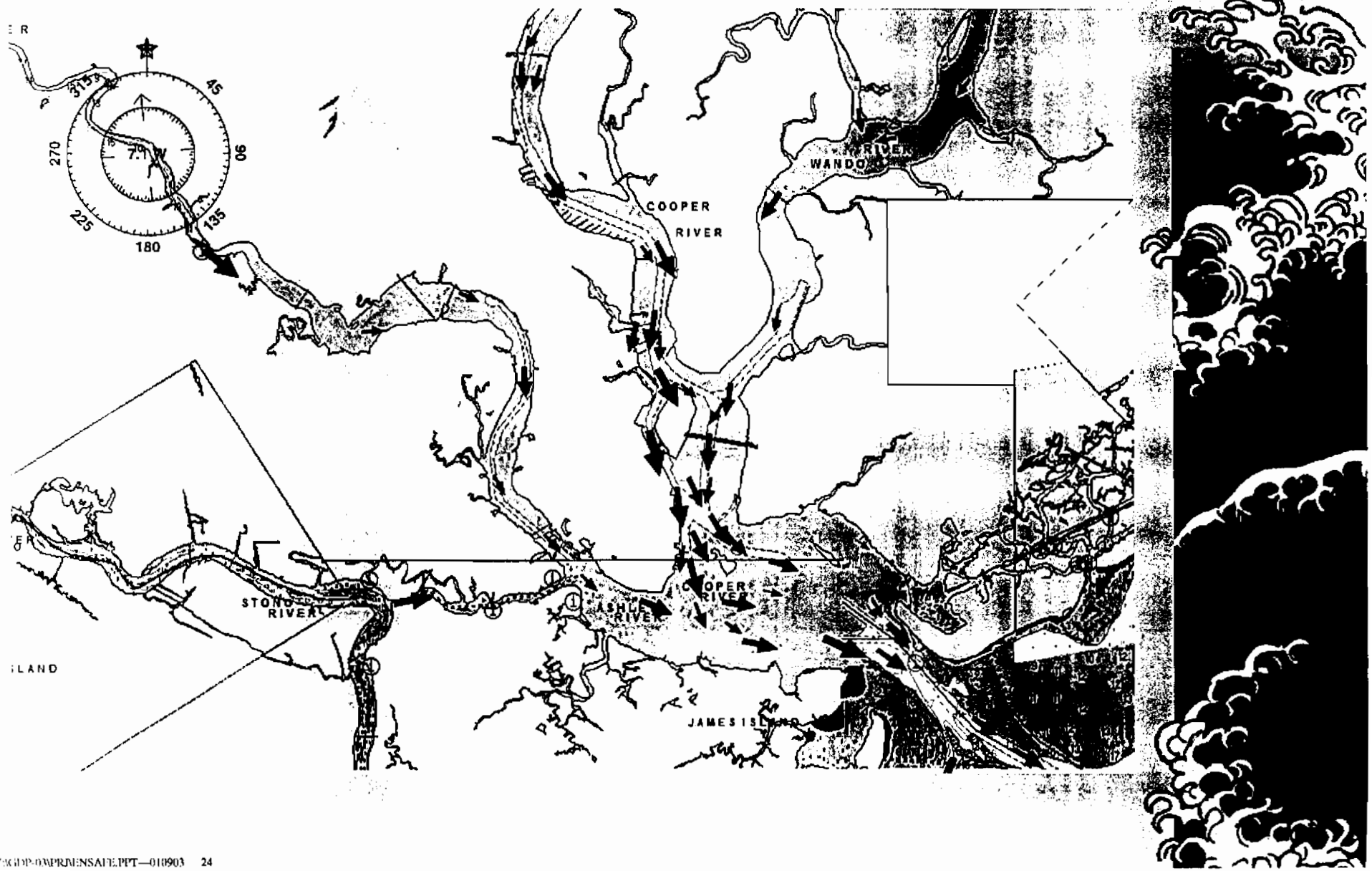
Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

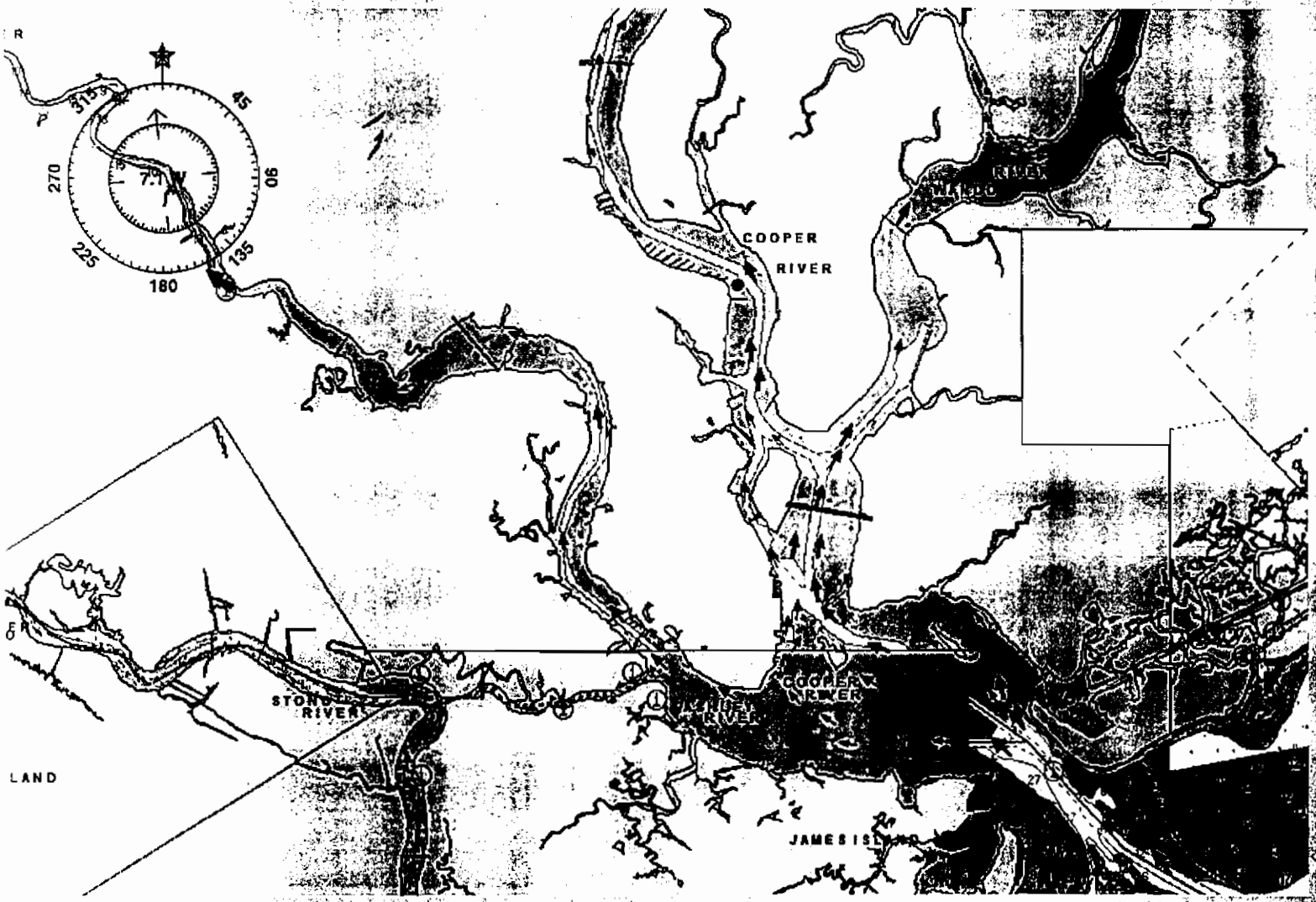
Cooper River Flows

- Average freshwater flow of Cooper River = 4,500 cfs
- Tidal flows (measured in September 1996):
  - Cooper River at Daniel Island = -150,000 to +160,000 cfs
  - Cooper River at Drum Island = -320,000 to +360,000 cfs

Ebb Currents



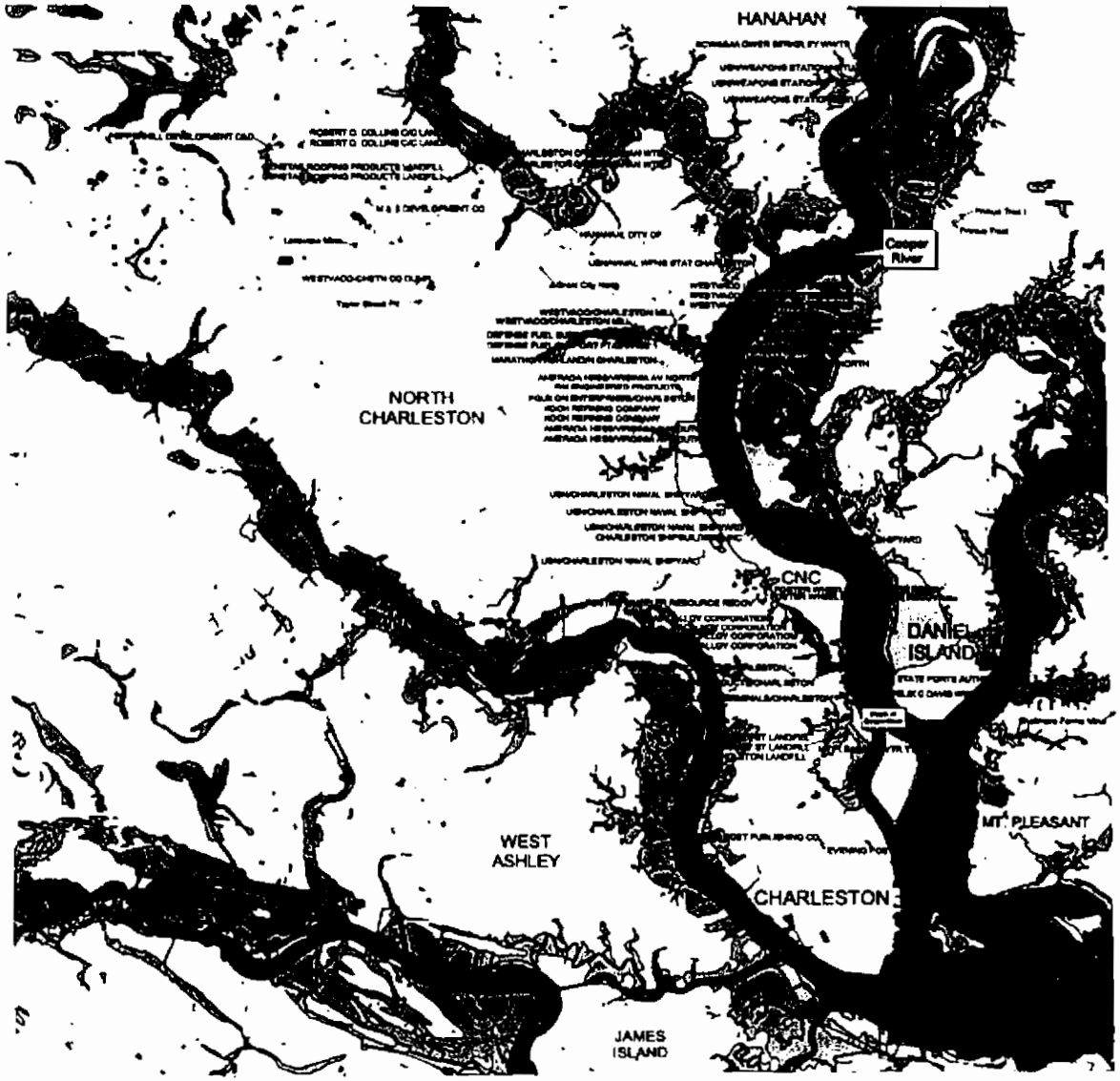
Flood Currents



Excursion Analysis

- Tidal excursion: the average travel distance of a water particle on the flood tide
- Methodology: Particle tracking by Lagrangian integration
- Results:
  - Cooper River = 4.3 miles north of CNC northern boundary
  - Ashley River = 3.5 miles upstream of river entrance
  - Wando River = 5.6 miles upstream of river entrance

Tidal Excursion Limits

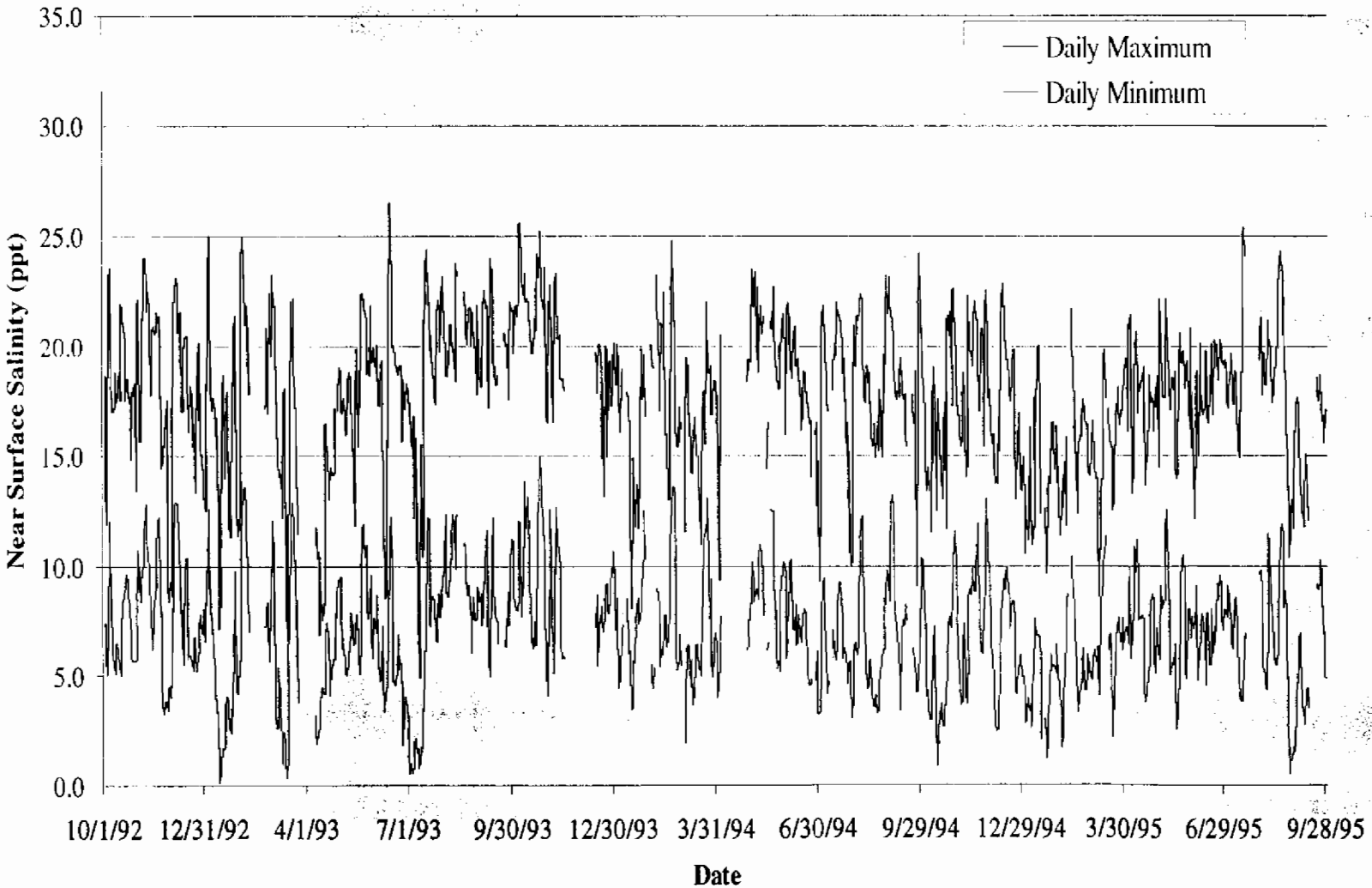


3 0 3 Miles

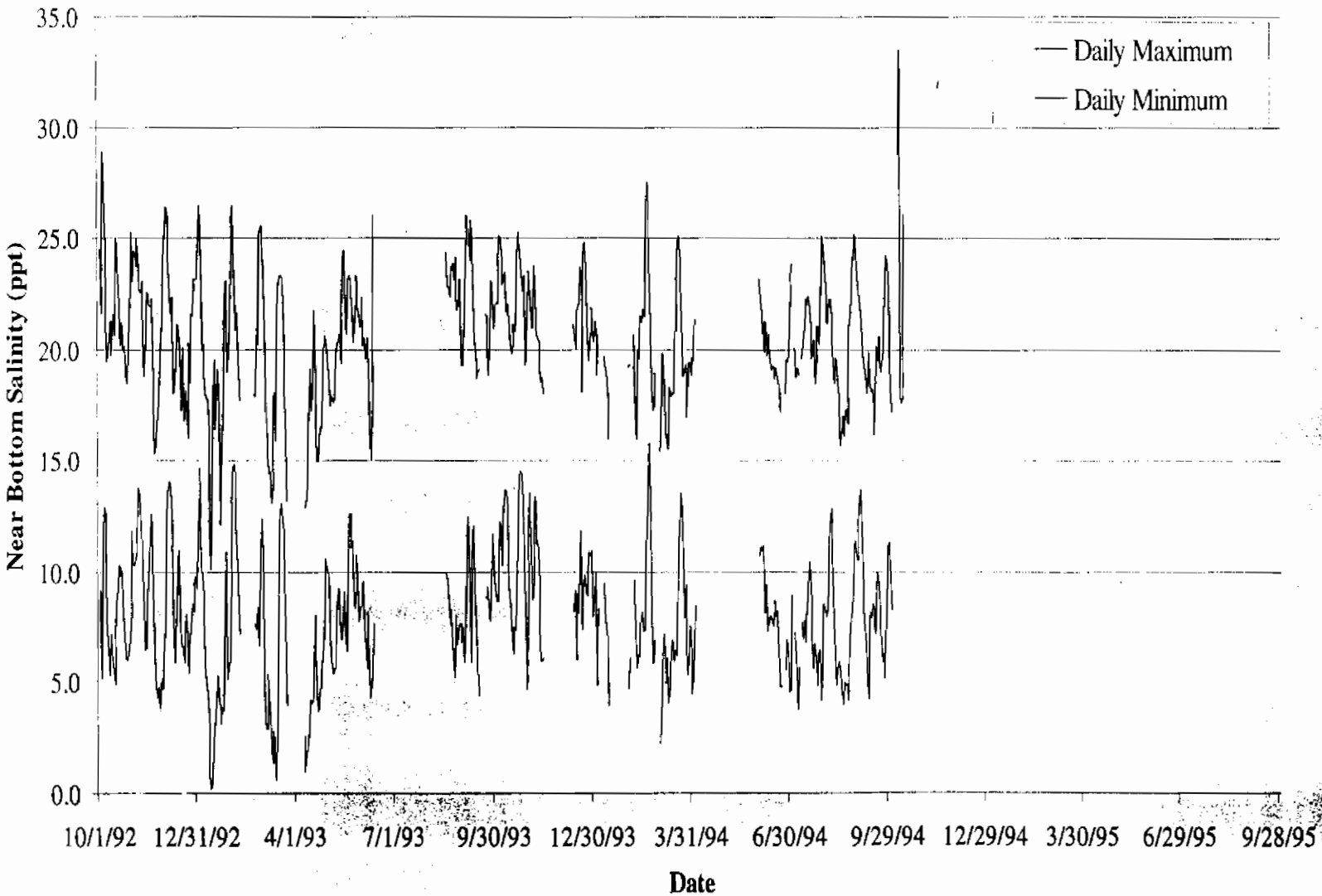
ZONE J
POINT OF ENTRY
EFFLUENT SAMPLING WORK PLAN
CHARLESTON NAVAL COMPLEX
CHARLESTON, SC

The data used to create this map was collected and created by SC DHEC. This information is contained in the Watershed Water Quality Management Strategy Report.

Cooper River Surface Salinity Near Army Depot



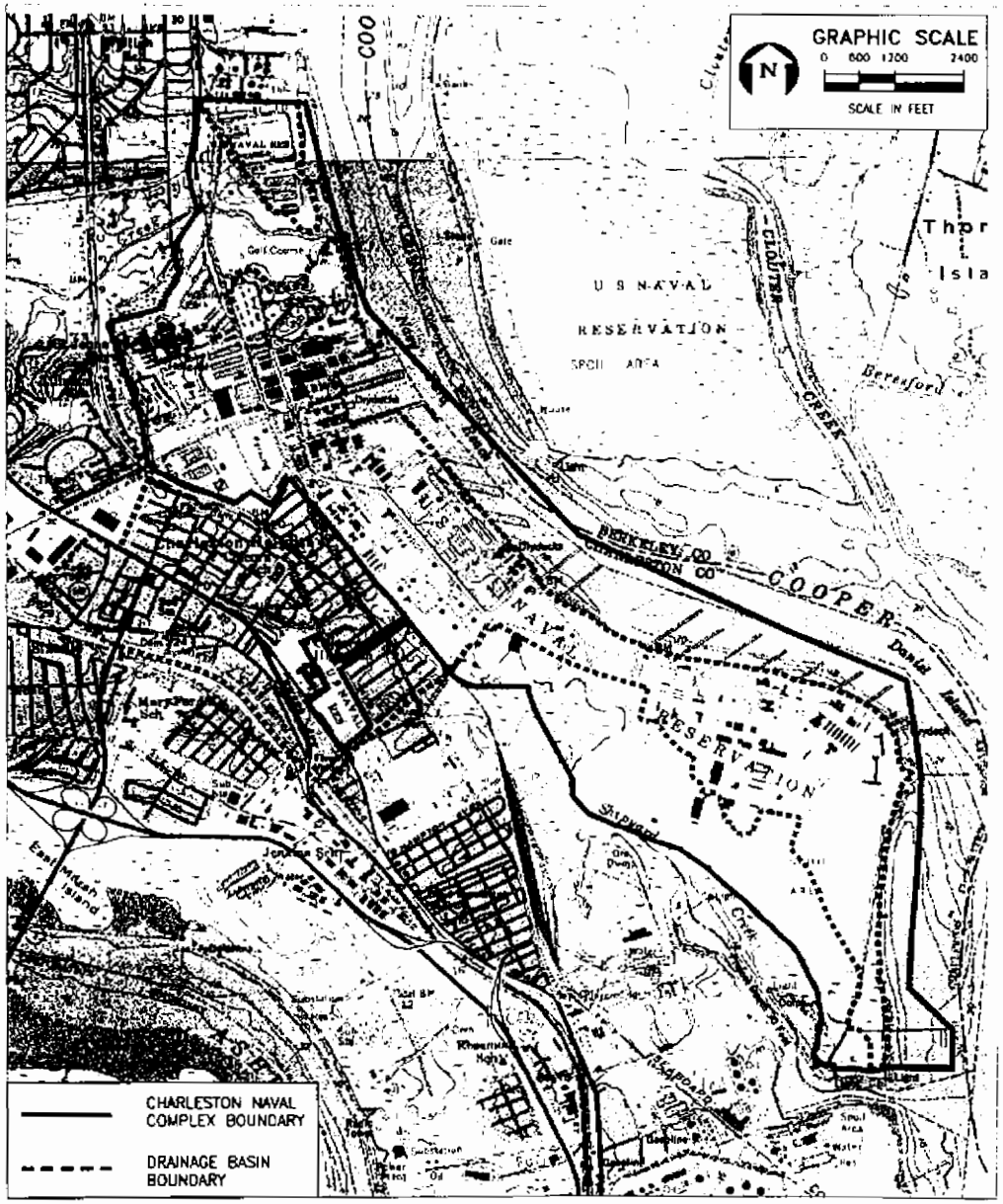
Cooper River Bottom Salinity Near Army Depot



Cooper River Salinity Near CNC

	Surface (ppt)	Bottom (ppt)
Average daily mean	11.3	14.3
Average daily minimum	7.1	8.5
Average daily maximum	17.8	20.6
Minimum	0.1	0.3
Maximum	26.4	33.9

Cooper River Watershed



Areas Draining to Cooper River

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	886	440	1,326
Upland	849	433	1,282
Tidal marsh and wetland	37	7	44

Summary of Surface Runoff to Cooper River Along the CNC Shoreline

	Mean Event	Return Period (Years) 2	5	10	25	50	100
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak Runoff Rate (cfs)	—	1,939	2,607	3,065	3,568	4,077	4,685
Total Runoff Volume (acre-ft)	53.0	385.8	524.7	621.8	730.3	839.1	970.2
Runoff from CNC (acre-ft)	34.9	265.4	358.8	424.0	496.7	589.6	657.4

Source: ECT, 2002.

Sediment Loads from Cooper River Basin

- Annual average: 700,000 lb/yr (288 cubic yards per year)
- Wet season = 280,000 lb/yr (115 cubic yards per year)

Percentage of Particle Mass in Stormwater as Related to Average Settling Velocity

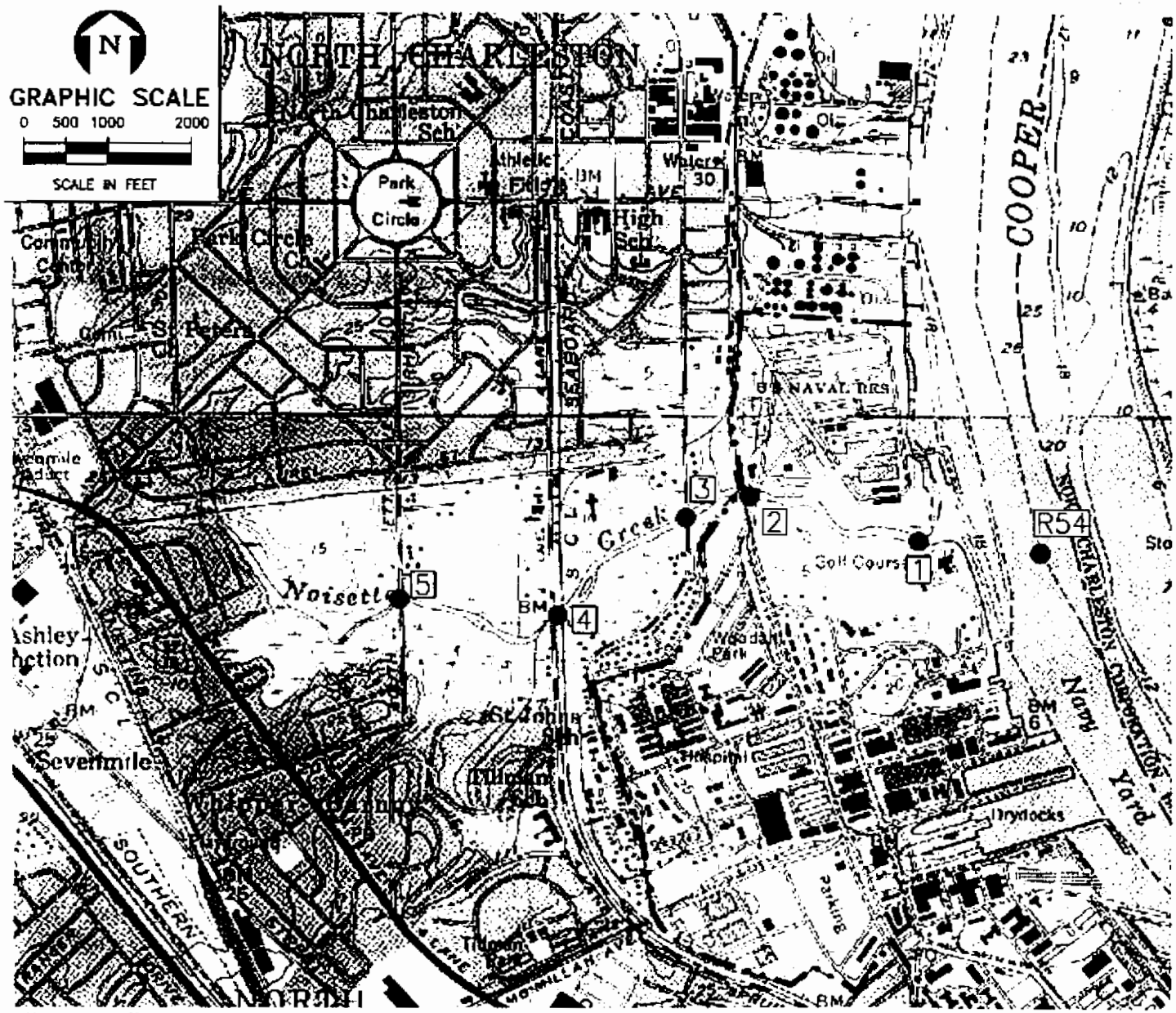
Cumulative Percent of Mass in Urban Runoff	Average Settling Velocity (ft/hour)	Settling Time in 40 ft of Water (hour)
0 to 20	0.03	1,670
20 to 40	0.33	152
40 to 60	1.5	27
60 to 80	7	5.7
80 to 100	70	0.6

Sources: Wanielista and Yousef, 1993.
EPA, 1983.
ECT, 2002.

Potential Depositional Areas

- Dry dock area in Zone E
- Shipyard Creek
- Nearshore shallow area in Zone I
- Middle ground
- Shallow area near Crab Bank
- South of Hog Island and Mount Pleasant
- Near Morris Island

Monitoring Station Locations



Noisette Creek Bathymetry

Station	Width (ft)	Depth at Low Tide (ft)
1	—	4
2	108	5
3	112	2.5
4	92	<1
5	51	<1

Source: ECT, 2003.

Noisette Creek Salinity Data (December 6 & 7, 2000)

Station	Low Tide* (ppt)	High Tide* (ppt)
1	14.3	15.9
2	12.7	15.2
3	11.9	13.8
4	11.1	13.5
5	9.8	13.6
Cooper River	17.7	22.4

*Vertical average salinity.

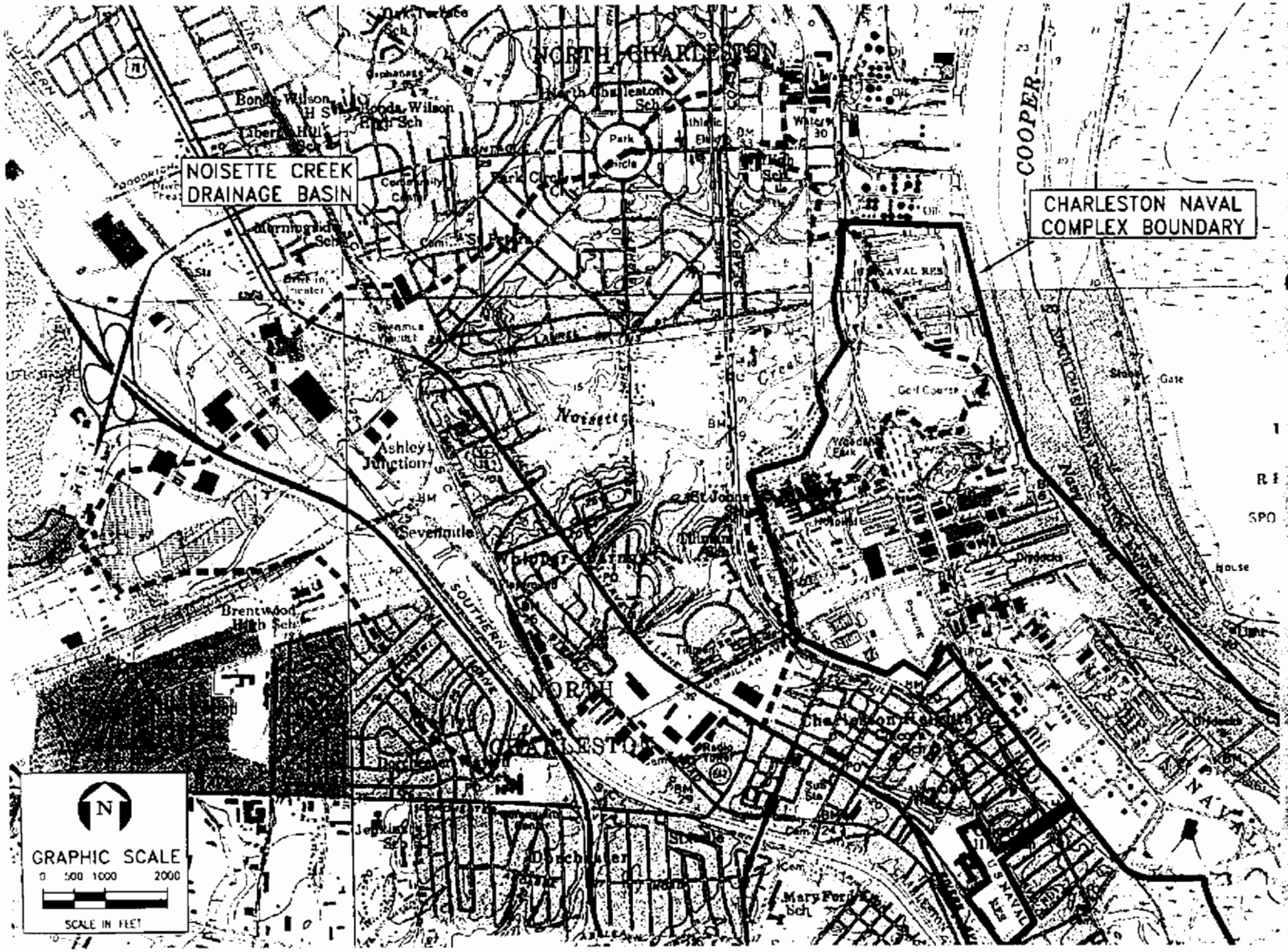
Source: ECT, 2003.

Noisette Creek Current Velocity

Station	Peak Current Speed Flood (fps)	Peak Current Speed Ebb (fps)
1	0.83	0.82
2	0.49	0.98
3	0.48	0.65
4	0.72	1.12
5	0.59	0.30

Source: ECT, 2003.

Noisette Creek Drainage Map



Noisette Creek Drainage Basin

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	123	1,624	1,747
Upland	118	1,481	1,599
Open water at low tide	5	9	14
Tidal marsh	0	134	134

Source: ECT, 2003.

Noisette Creek Runoff Summary

	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak runoff (cfs)	—	2,380	3,179	3,720	4,333	4,936	5,659
Runoff volume (acre-ft)	92.8	523.2	707.3	835.7	979.1	1,123.0	1,296.0
Runoff from CNC (acre-ft)	6.3	35.3	47.7	56.4	66.1	75.8	87.5

Source: ECT, 2002.

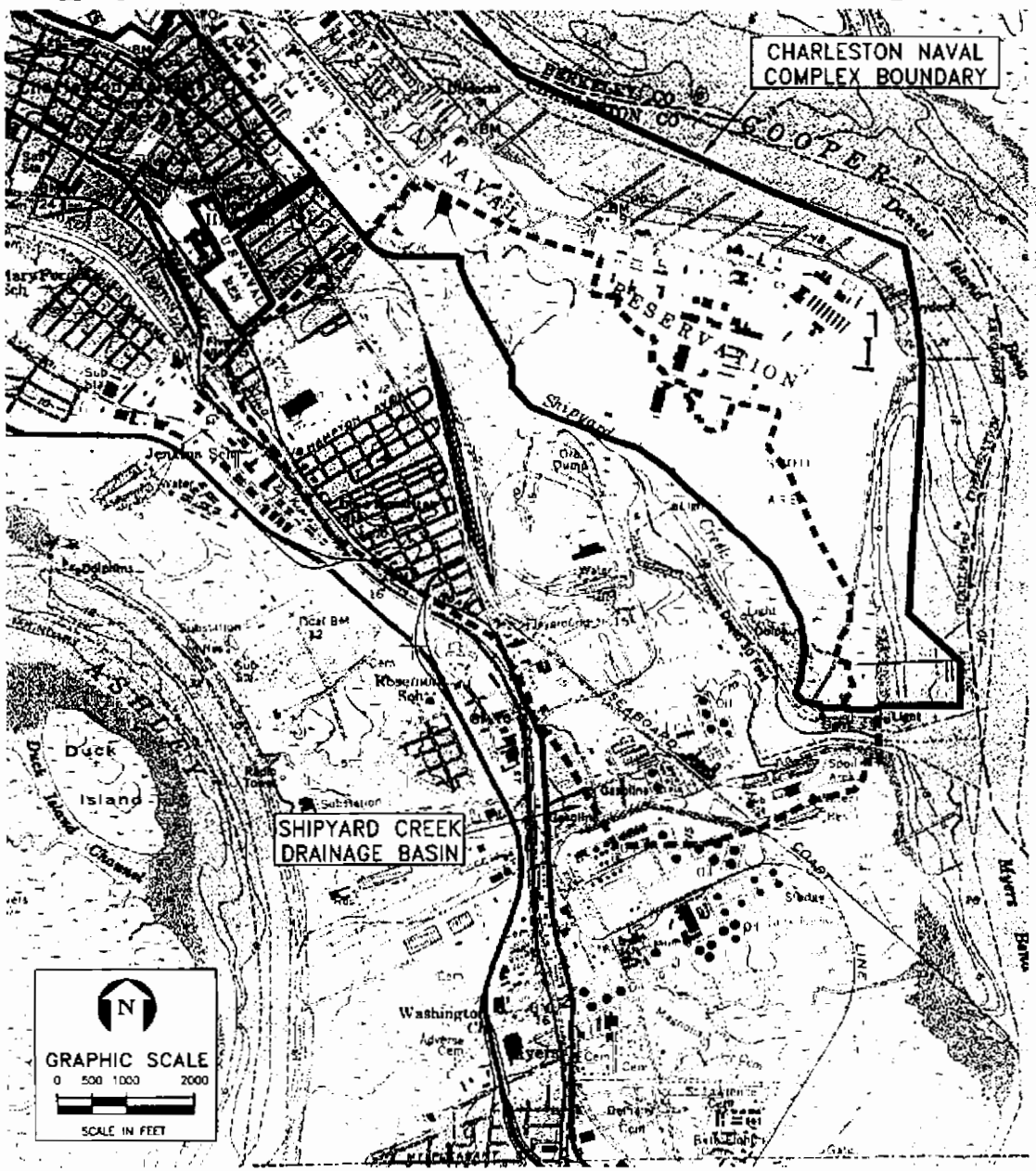
Tidal Flushing and Dilution in Noisette Creek

- Low tide volume = 46 acre-ft
- Tidal prism = 344 acre-ft
- Average tidal flow = 670 cfs
- Peak tidal flow = 1,053 cfs
- 88 percent of creek water can be flushed out in one tidal cycle
- Tidal dilution to CNC runoff is 55 to 1 during an average storm
- Tidal dilution to Noisette Creek runoff is 3.7 to 1 during an average storm
- Noisette Creek runoff/CNC runoff = 14.7
- Noisette Creek hydraulics are dominated by stormwater during severe storms

Shipyard Creek

- Outer turning basin depth = 50 ft @ MLW
- Ship channel and inner turning basin depth = 44 ft @ MLW
- Dredged area = 46 acres
- Open water = 91 acres
- Tidal marsh = 105 acres
- Entrance channel width = 600 ft
- Average tide range = 5.3 ft
- Spring tide range = 6.1 ft
- Average peak current speed at entrance channel = 0.05 ft/sec

Shipyard Creek Drainage Map



Shipyard Creek Drainage Area

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	279	878	1,157
Upland	279	682	961
Marsh	0	105	105
Open water	0	91	91

Source: ECT, 2003.

Shipyard Creek Runoff Summary

	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak runoff (cfs)	—	1,427	1,959	2,328	2,736	3,142	3,627
Runoff volume (acre-ft)	49.3	308.9	427.8	511.3	605.0	699.3	813.0
Runoff from CNC (acre-ft)	5.9	66.5	95.7	116.6	140.2	164.1	193.0

Source: ECT, 2002.

Sediment Loads

- Noisette Creek Basin = 890,000 lb/yr (366 cy/yr)
- Shipyard Creek Basin = 580,000 lb/yr (239 cy/yr)

Tidal Flushing and Dilution in Shipyard Creek

- Tidal prism = 692 acre-ft
- Low tide volume = 2,620 acre-ft
- Average tidal flow = 1,348 cfs
- Peak tidal flow = 2,118 cfs
- Average storm runoff volume = 49.3 acre-ft
- Tidal prism/average storm runoff = 14
- Tidal flushing time (dilute to 10 percent) = 5.2 days
- Shipyard Creek is a low energy area

Conclusion

- Potential contaminants from CNC can travel to a large area in the estuary
- Contaminants found in Cooper River near CNC may come from remote areas
- Large tidal dilution at Cooper River
- Noisette Creek has efficient flushing
- Shipyard Creek is near stagnant and has inefficient flushing

Hydrodynamics and Contaminant Transport in Charleston Harbor Estuary

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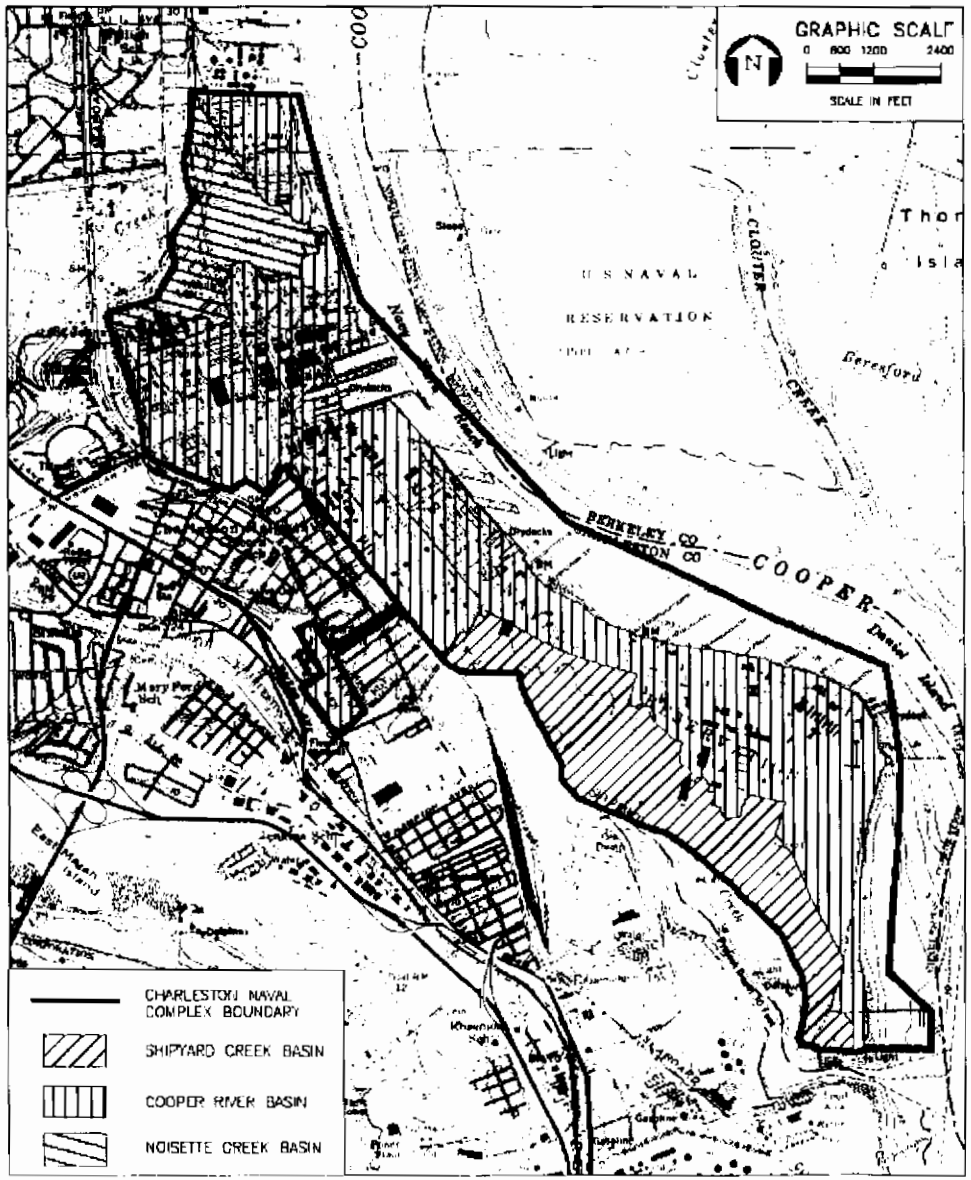

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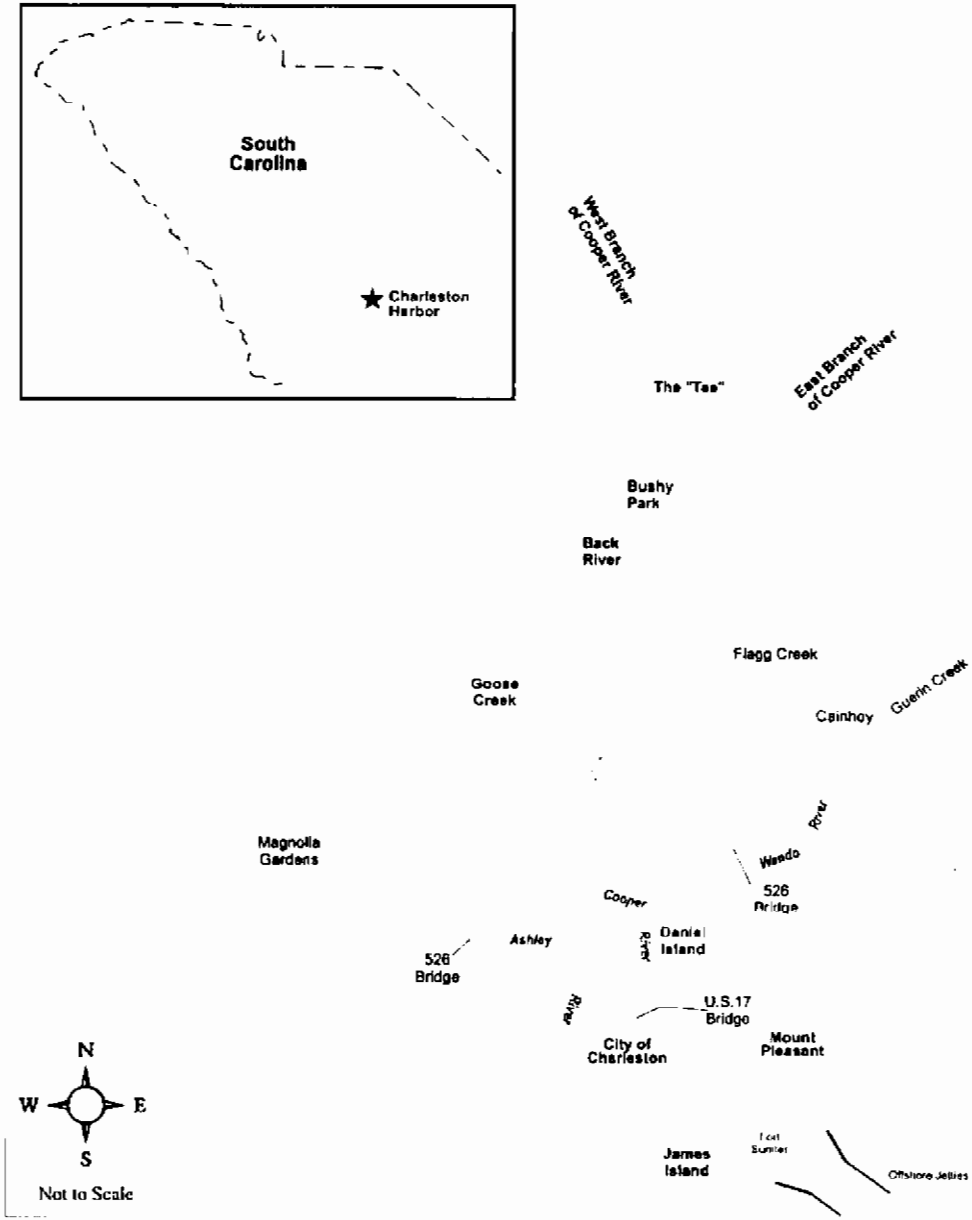

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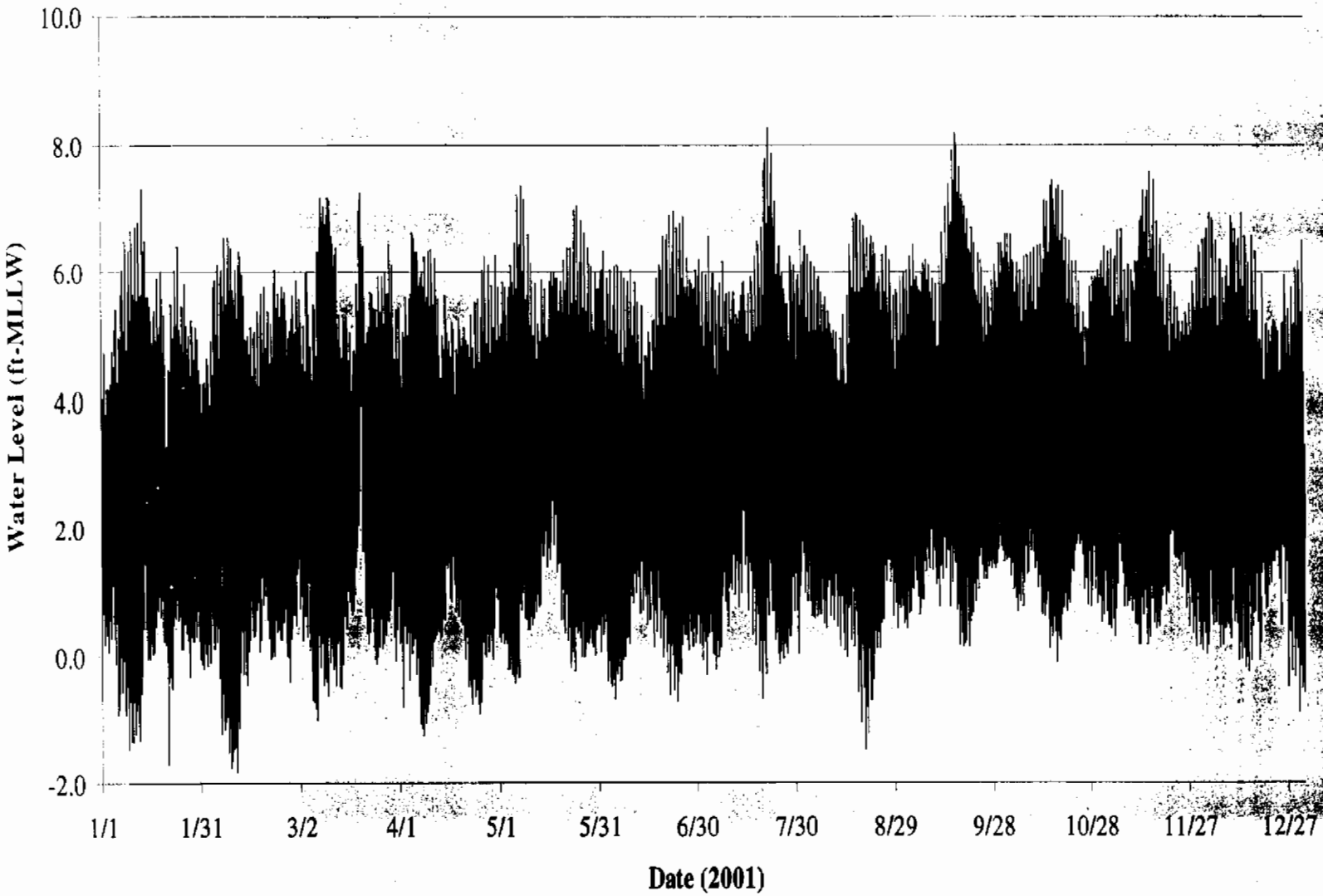

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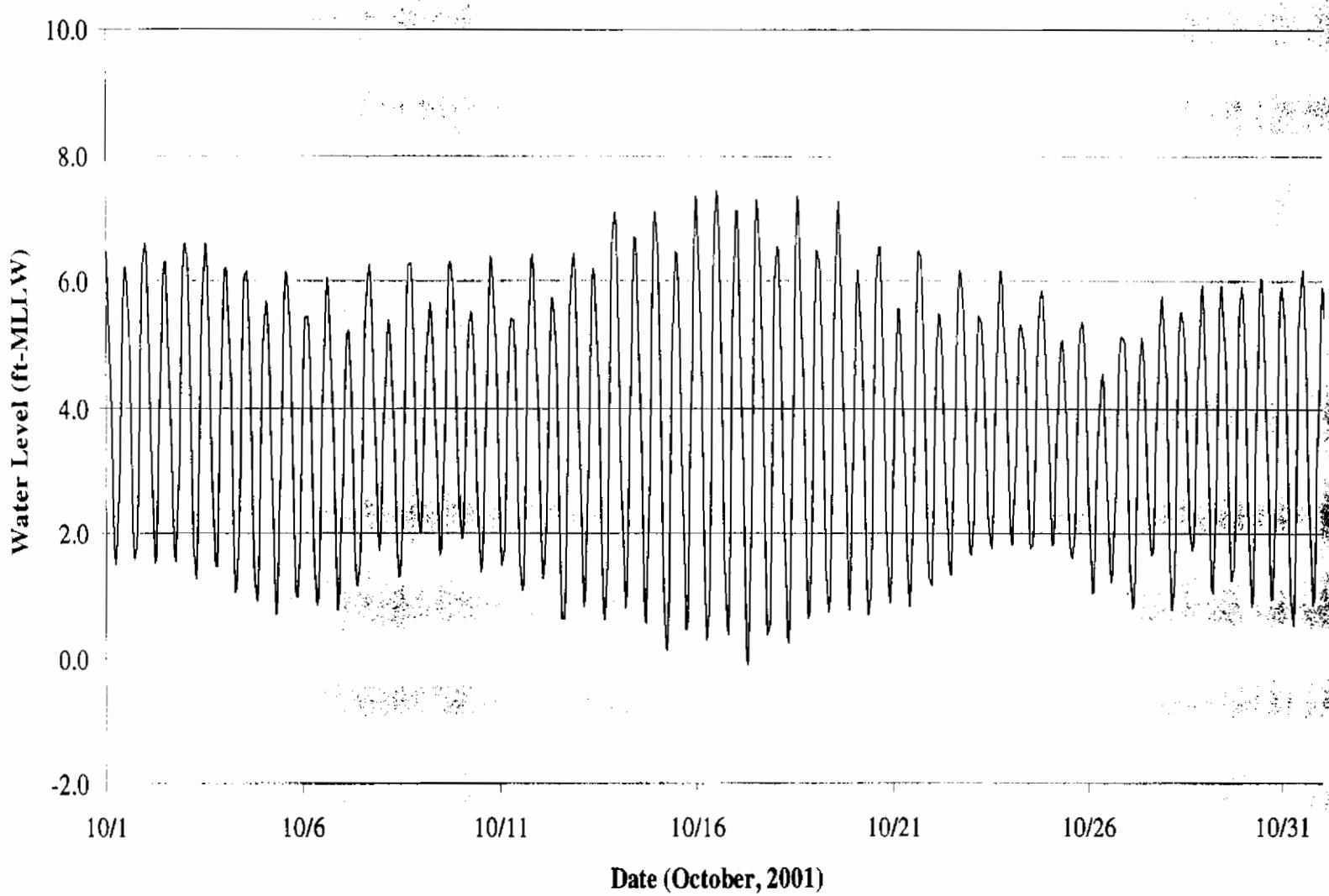

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Cooper River at Old Rice Mill, West Branch	2.60	3.02	2.93
Cooper River at Pimlico, West Branch	1.70	1.97	3.90

Note: Phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

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Note: The phase lag is relative to the tide phase at Customhouse.

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Wando River at Cainhoy	6.15	7.13	0.50
Wando River at Big Paradise Island	6.54	7.59	0.87
Wando River at Woodville	6.30	7.30	1.37

Note: The phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Charleston Harbor Entrance, between jetties	1.8	1.8	-0.02
Charleston Harbor off Ft. Sumter	1.7	2.0	0.00
South Channel at Buoy "32"	0.8	1.0	-0.02
South Channel, 0.8 mile ENE of Fort Johnson	0.8	2.6	0.72
South Channel, 0.4 mile NW of Fort Johnson	0.7	1.9	1.17
The Cove, entrance on the Cove Range	1.2	0.9	0.47
Shutes Reach, Buoy "8"	1.3	1.5	0.30
Hog Island Channel	0.8	0.8	-0.65
Folly Reach at Buoy "5"	1.2	1.6	0.03
Folly Reach north of Fort Johnson	1.2	1.1	-0.85
0.6 miles SW of Castle Pinckney	0.7	1.3	-0.35
0.4 miles west of Shutes Folly Island	0.8	2.2	0.88
Customhouse Reach off Customhouse	1.0	1.3	0.82
Customhouse Reach	1.0	1.8	0.77
Horse Reach	1.4	1.9	0.60
Hog Island Reach, Buoy "12"	1.2	1.3	0.22
Drum Island, east of bridge	1.2	2.0	0.50
Town Creek Lower Reach	1.1	2.2	0.57
Town Creek, 0.2 mile above bridge	0.8	2.5	1.10
Drum Island Reach at Buoy"45"	0.6	1.0	0.43
Cooper River, 0.2 mile above Drum Island	1.1	2.4	1.20
Cooper River at Daniel Island Reach, Buoy "48"	1.2	1.3	1.02
Cooper River at Shipyard Creek entrance	0.5	1.5	0.68
Cooper River at Daniel Island Reach	1.3	2.3	1.48
Cooper River at Daniel Island Bend	1.2	2.1	0.92
Cooper River at North Charleston	1.1	1.7	1.43
Cooper River at Filbin Creek Reach	1.2	1.8	1.52
Cooper River at Filbin Creek Reach, Buoy "58"	1.1	1.3	1.30

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

(Continued, Page 2 of 2)

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Cooper River at Ordnance Reach	1.0	1.2	1.58
Cooper River at Yellow House Creek	0.7	1.4	2.10
Cooper River at 1 mile NW of Yellow House Landing	0.7	1.8	2.43
Cooper River at SE of Woods Point	0.8	1.0	1.80
Copper River at Woods Point	0.9	1.4	2.68
Cooper River at 0.5 mile North of Snow Point	1.1	1.4	2.25
Cooper River off Amoco Pier	0.7	0.9	2.15
Cooper River at 0.5 mile below Moreland	1.9	2.0	3.54
Cooper River at 1 mile below Hagan Island	1.3	1.4	3.54
Cooper River at 0.4 mile SW of The "Tee"	1.0	1.7	4.37
Cooper River at The "Tee"	0.9	1.0	3.00
Cooper River at Childsbury, S.A.L. RR Bridge	0.7	1.7	4.72

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Ashley River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Ashley River SW of Battery	1.2	1.8	0.27
Ashley River off Wappoo Creek	1.1	1.2	0.12
Ashley River at highway bridge	1.2	1.1	-0.15
Ashley River at 0.1 mile below SCL railroad bridge	1.0	1.1	-0.10
Ashley River at 1.5 mile above SCL railroad bridge	1.2	1.5	0.37
Ashley River at State Highway 7 bridge	1.0	1.0	0.10
Ashley River at 0.1 mile east of West Marsh Island	0.7	1.0	0.38
Ashley River at Bees Ferry Bridge	1.9	2.3	1.22

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Wando River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Wando River at 0.2 mile NW of Ramley Point	1.3	1.8	-0.23
Wando River at Upper Reach, Turning Basin	1.0	1.2	-0.23
Wando River at Rathall Creek Entrance	1.3	1.7	0.42
Wando River off Nowell Creek, Buoy "19"	0.8	1.0	-0.13
Wando River at 0.2 mile above Horbeck Creek entrance	1.0	0.9	0.47
Wando River at 2.5 miles north of Horbeck Creek	0.8	1.3	0.50

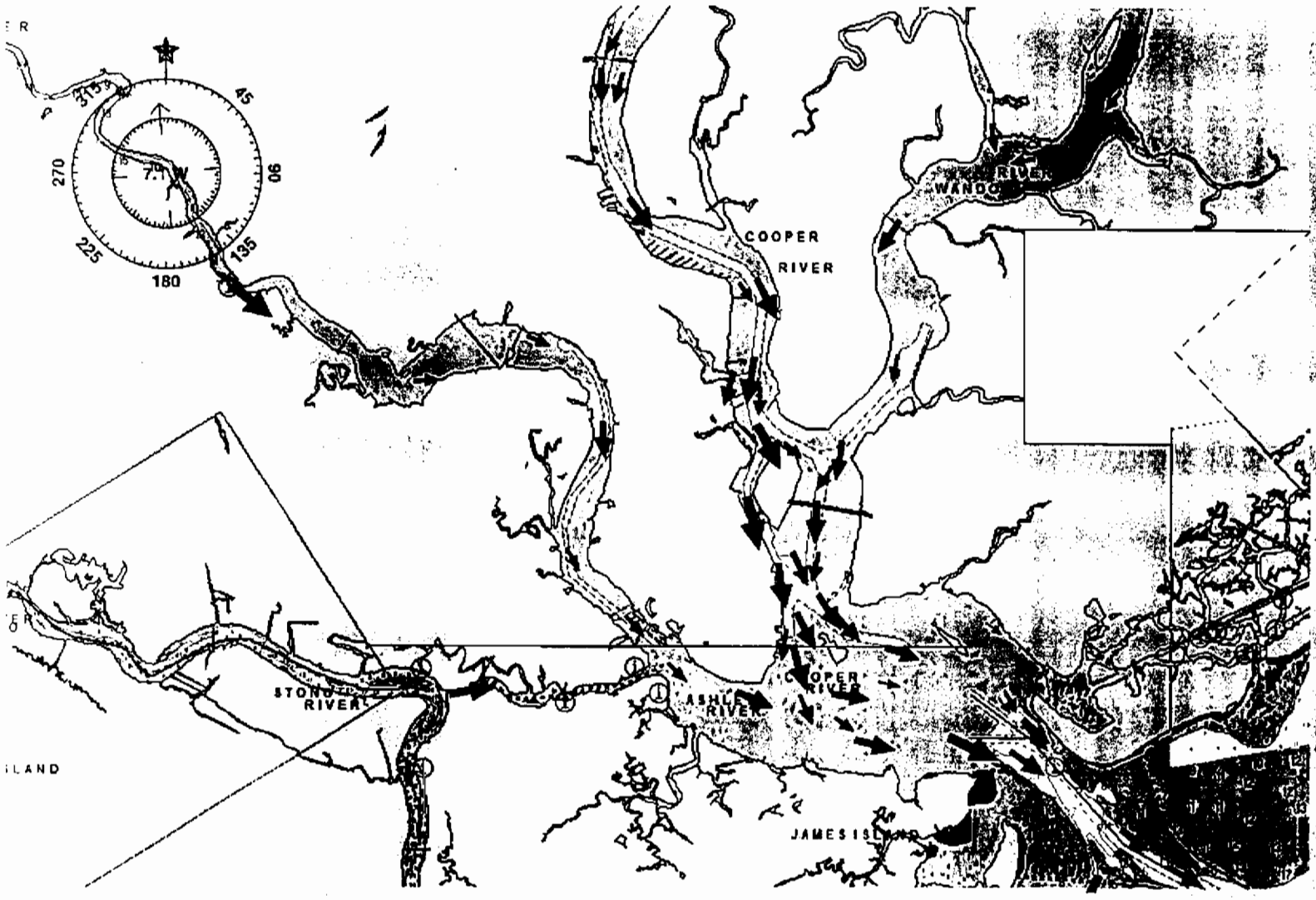
Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

Cooper River Flows

- Average freshwater flow of Cooper River = 4,500 cfs
- Tidal flows (measured in September 1996):
  - Cooper River at Daniel Island = -150,000 to +160,000 cfs
  - Cooper River at Drum Island = -320,000 to +360,000 cfs

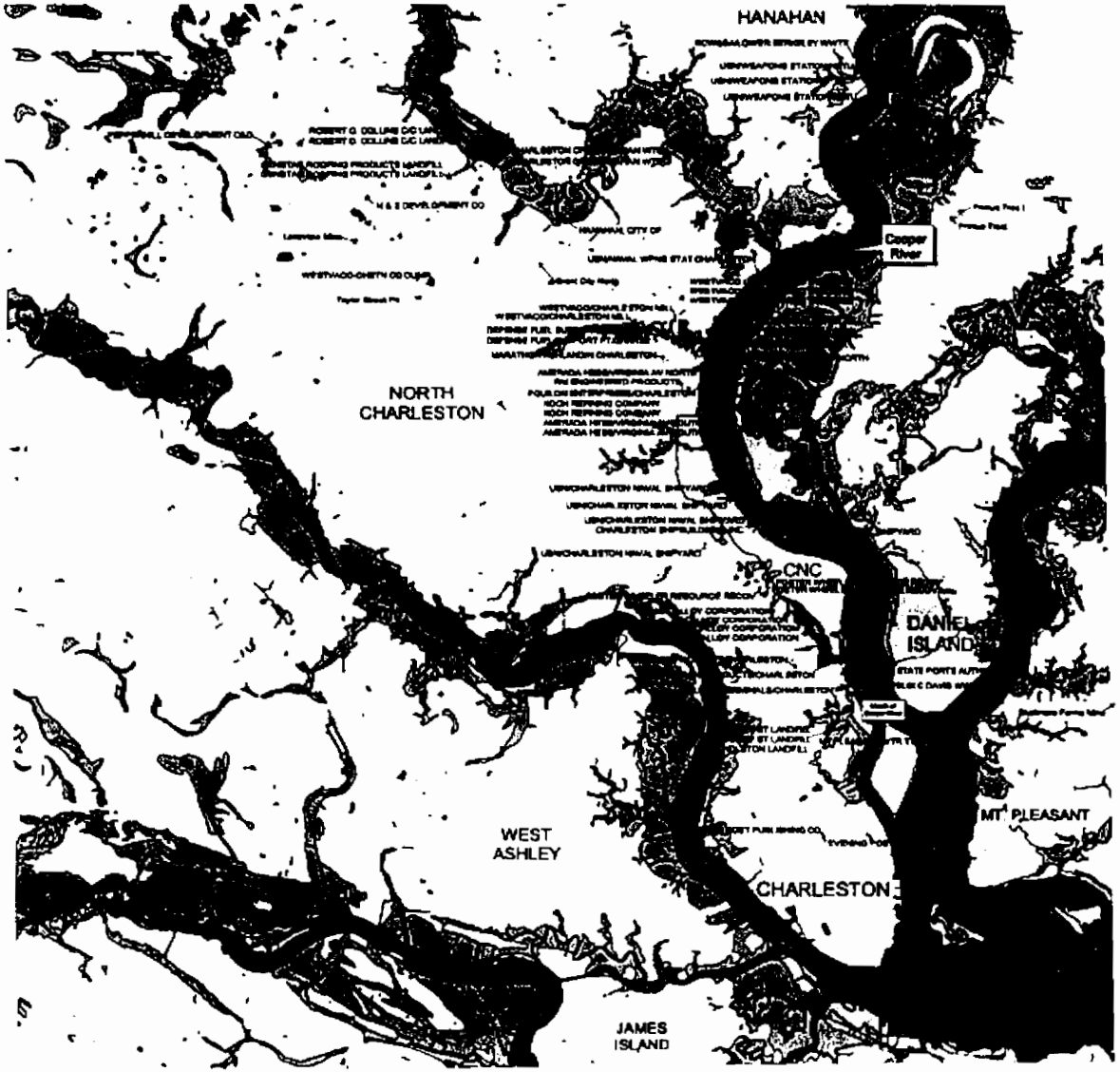
Ebb Currents



Excursion Analysis

- Tidal excursion: the average travel distance of a water particle on the flood tide
- Methodology: Particle tracking by Lagrangian integration
- Results:
  - Cooper River = 4.3 miles north of CNC northern boundary
  - Ashley River = 3.5 miles upstream of river entrance
  - Wando River = 5.6 miles upstream of river entrance

Tidal Excursion Limits

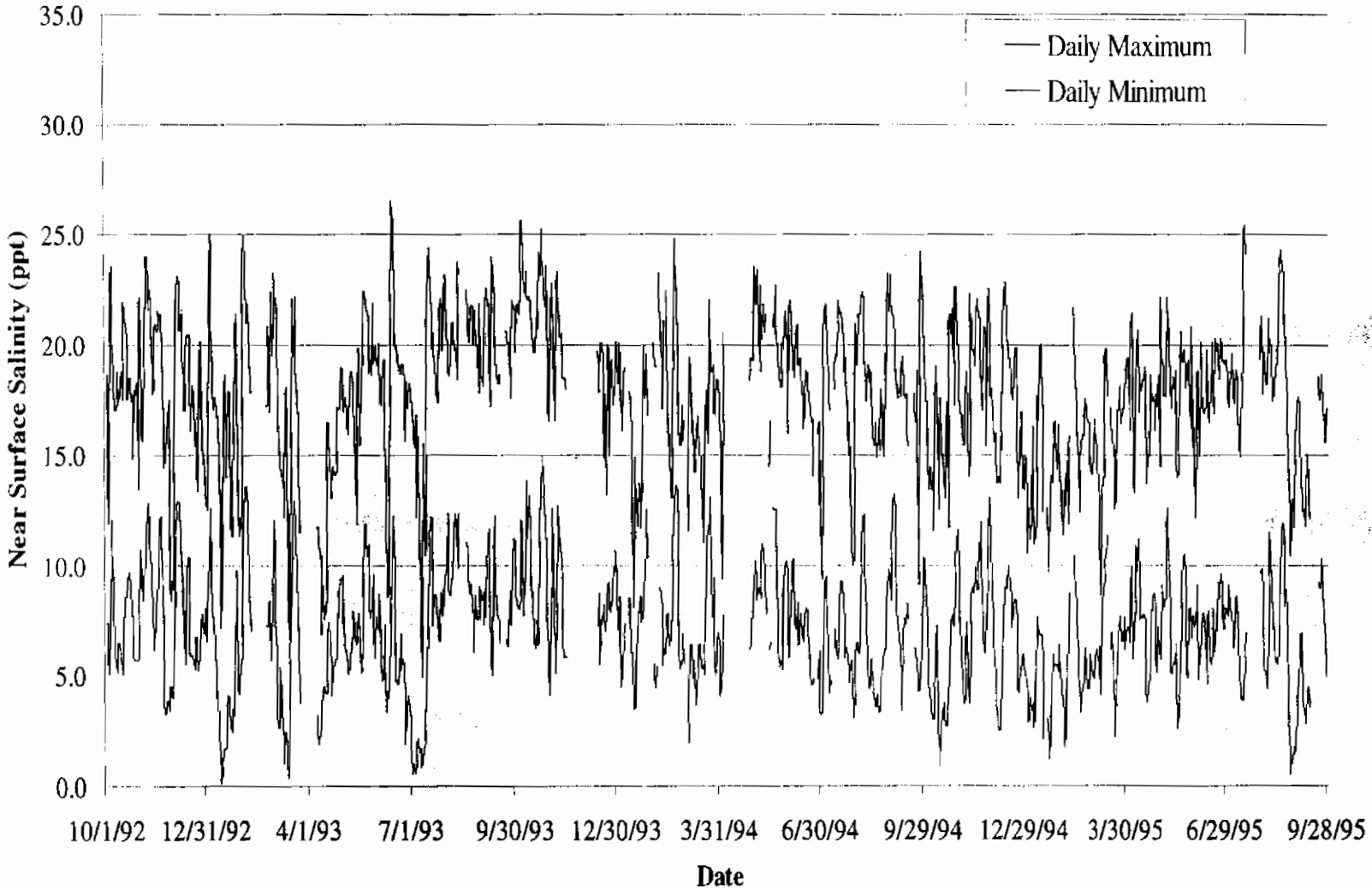


ZONE J
POINT OF ENTRY
EFFLUENT SAMPLING WORK PLAN
CHARLESTON NAVAL COMPLEX
CHARLESTON, SC

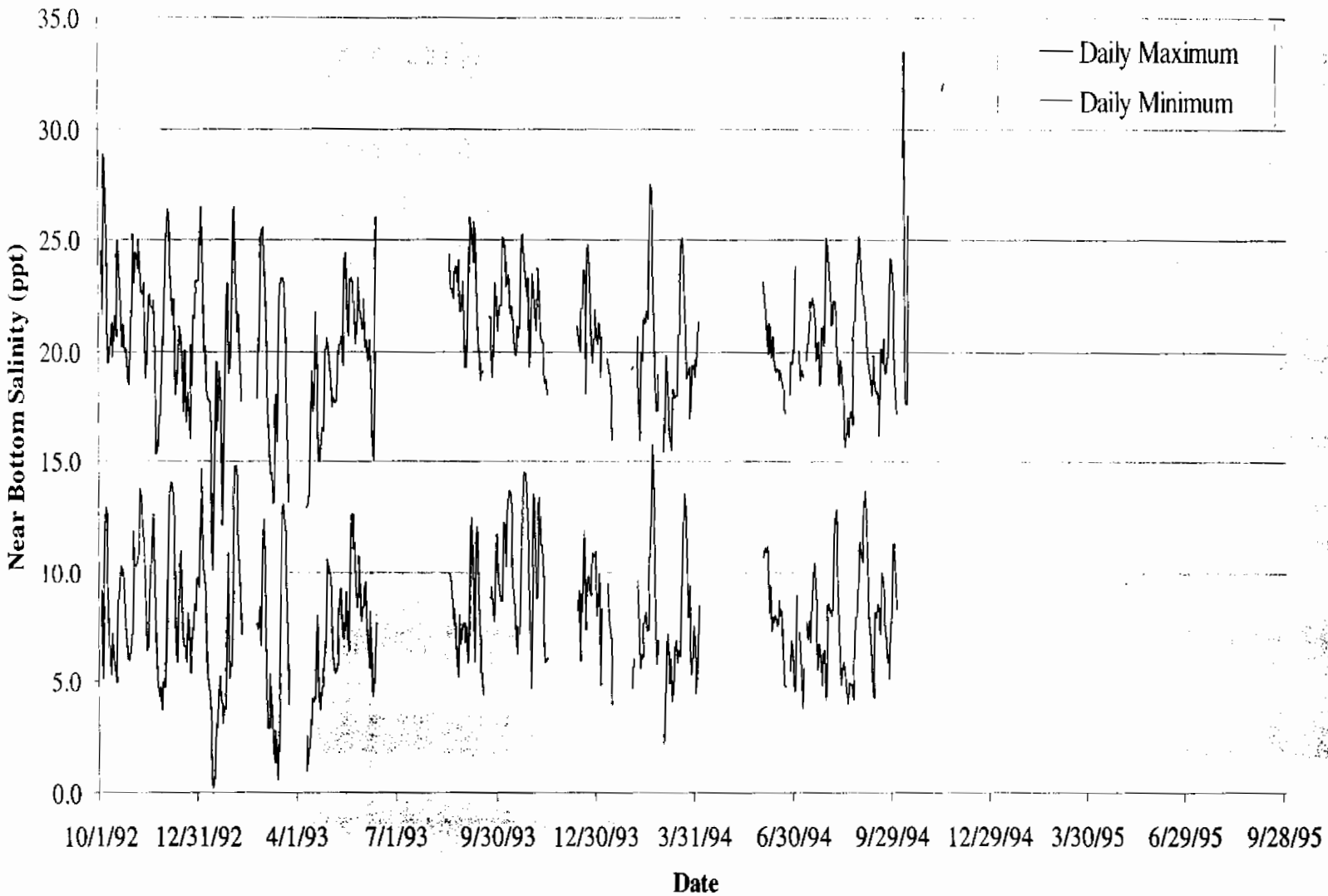
3 0 3 Miles

The data used to create this map was collected and created by SC DHEC. This information is contained in the Watershed Water Quality Management Strategy Report.

Cooper River Surface Salinity Near Army Depot



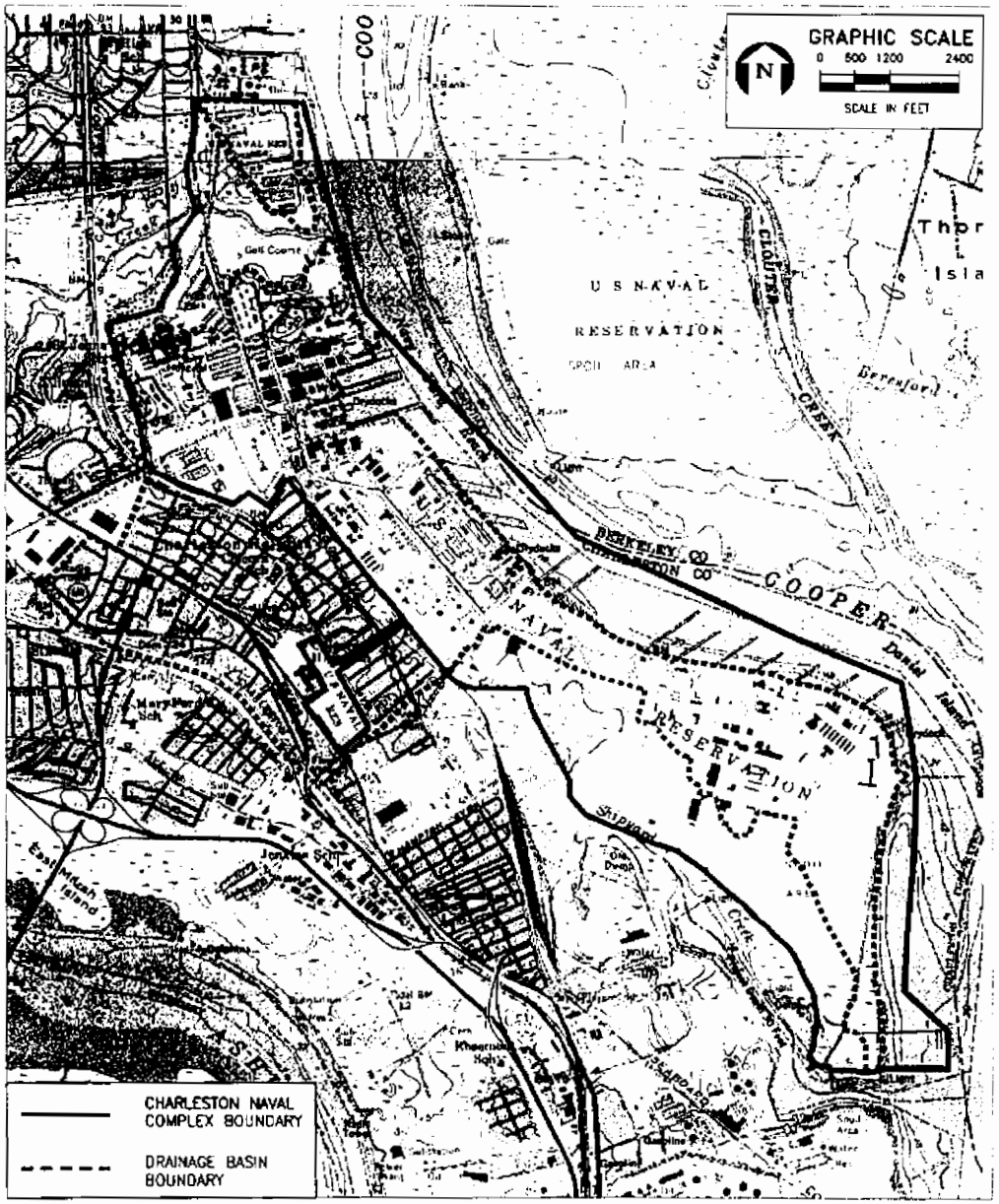
Cooper River Bottom Salinity Near Army Depot



Cooper River Salinity Near CNC

	Surface (ppt)	Bottom (ppt)
Average daily mean	11.3	14.3
Average daily minimum	7.1	8.5
Average daily maximum	17.8	20.6
Minimum	0.1	0.3
Maximum	26.4	33.9

Cooper River Watershed



Areas Draining to Cooper River

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	886	440	1,326
Upland	849	433	1,282
Tidal marsh and wetland	37	7	44

Summary of Surface Runoff to Cooper River Along the CNC Shoreline

	Mean Event	Return Period (Years)					
		2	5	10	25	50	100
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak Runoff Rate (cfs)	—	1,939	2,607	3,065	3,568	4,077	4,685
Total Runoff Volume (acre-ft)	53.0	385.8	524.7	621.8	730.3	839.1	970.2
Runoff from CNC (acre-ft)	34.9	265.4	358.8	424.0	496.7	589.6	657.4

Source: ECT, 2002.

Sediment Loads from Cooper River Basin

- Annual average: 700,000 lb/yr (288 cubic yards per year)
- Wet season = 280,000 lb/yr (115 cubic yards per year)

Percentage of Particle Mass in Stormwater as Related to Average Settling Velocity

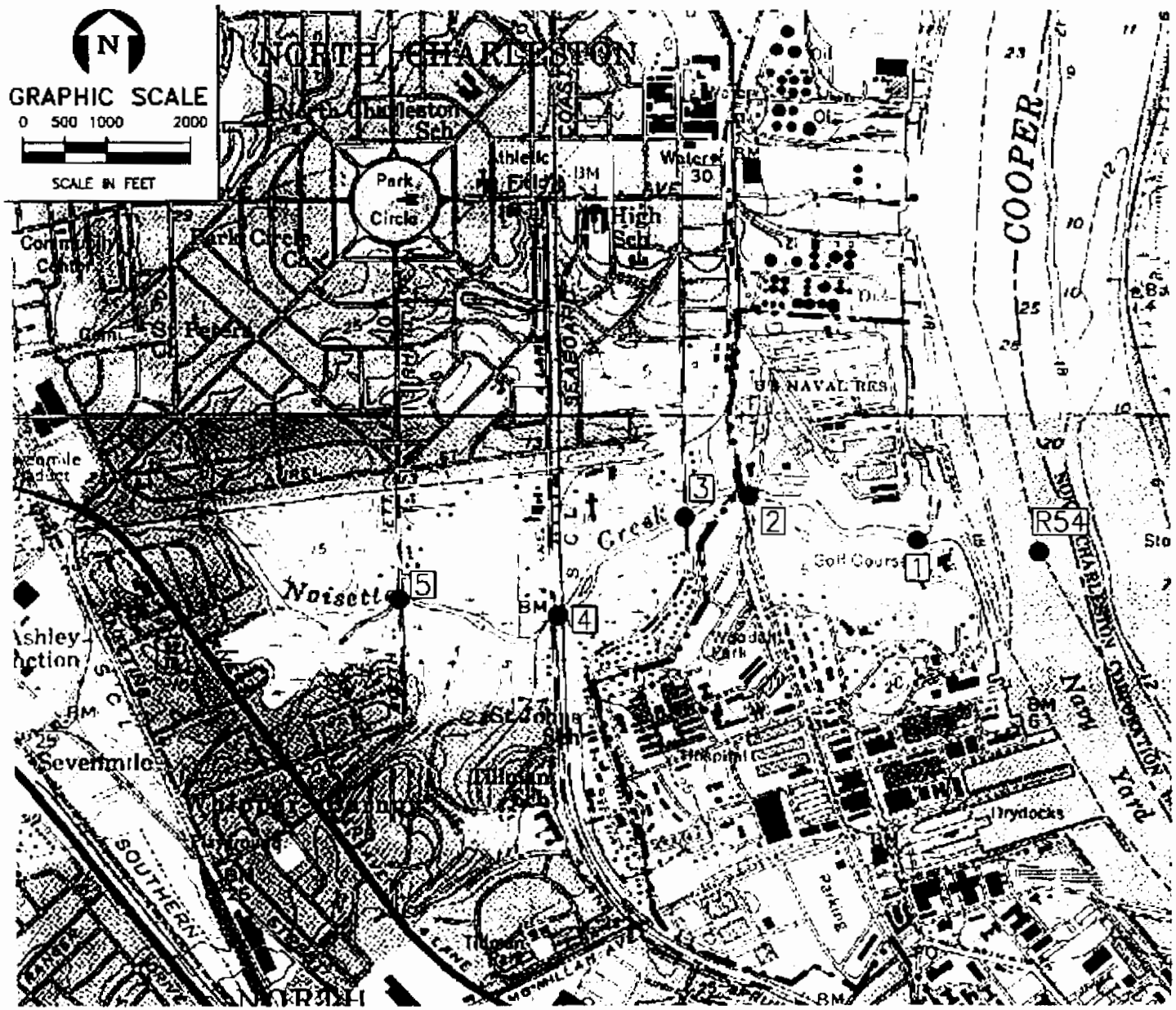
Cumulative Percent of Mass in Urban Runoff	Average Settling Velocity (ft/hour)	Settling Time in 40 ft of Water (hour)
0 to 20	0.03	1,670
20 to 40	0.33	152
40 to 60	1.5	27
60 to 80	7	5.7
80 to 100	70	0.6

Sources: Wanielista and Yousef, 1993.
EPA, 1983.
ECT, 2002.

Potential Depositional Areas

- Dry dock area in Zone E
- Shipyard Creek
- Nearshore shallow area in Zone I
- Middle ground
- Shallow area near Crab Bank
- South of Hog Island and Mount Pleasant
- Near Morris Island

Monitoring Station Locations



Noisette Creek Bathymetry

Station	Width (ft)	Depth at Low Tide (ft)
1	—	4
2	108	5
3	112	2.5
4	92	<1
5	51	<1

Source: ECT, 2003.

Noisette Creek Salinity Data (December 6 & 7, 2000)

Station	Low Tide* (ppt)	High Tide* (ppt)
1	14.3	15.9
2	12.7	15.2
3	11.9	13.8
4	11.1	13.5
5	9.8	13.6
Cooper River	17.7	22.4

*Vertical average salinity.

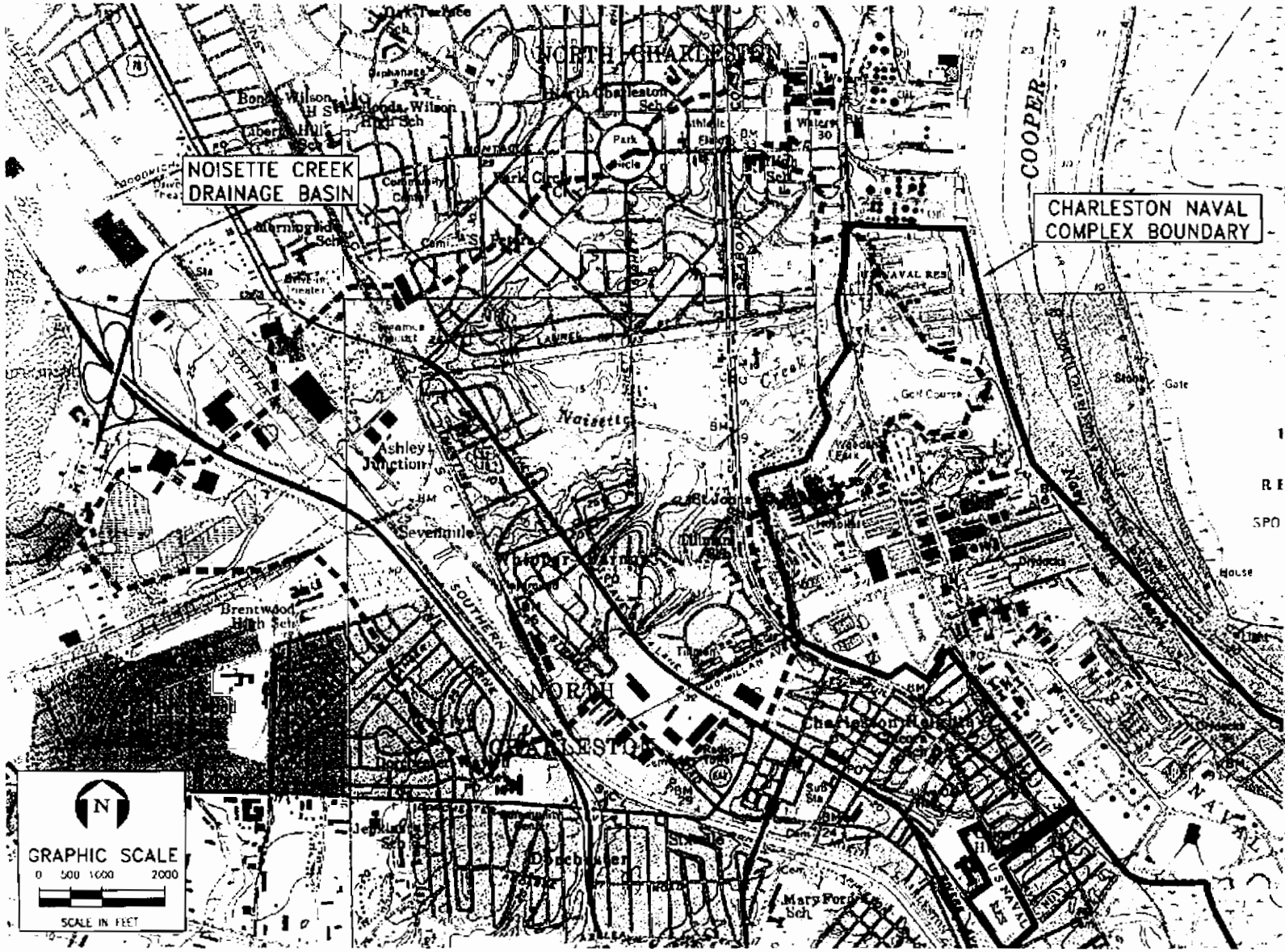
Source: ECT, 2003.

Noisette Creek Current Velocity

Station	Peak Current Speed	
	Flood (fps)	Ebb (fps)
1	0.83	0.82
2	0.49	0.98
3	0.48	0.65
4	0.72	1.12
5	0.59	0.30

Source: ECT, 2003.

Noisette Creek Drainage Map



Noisette Creek Drainage Basin

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	123	1,624	1,747
Upland	118	1,481	1,599
Open water at low tide	5	9	14
Tidal marsh	0	134	134

Source: ECT, 2003.

Noisette Creek Runoff Summary

	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak runoff (cfs)	—	2,380	3,179	3,720	4,333	4,936	5,659
Runoff volume (acre-ft)	92.8	523.2	707.3	835.7	979.1	1,123.0	1,296.0
Runoff from CNC (acre-ft)	6.3	35.3	47.7	56.4	66.1	75.8	87.5

Source: ECT, 2002.

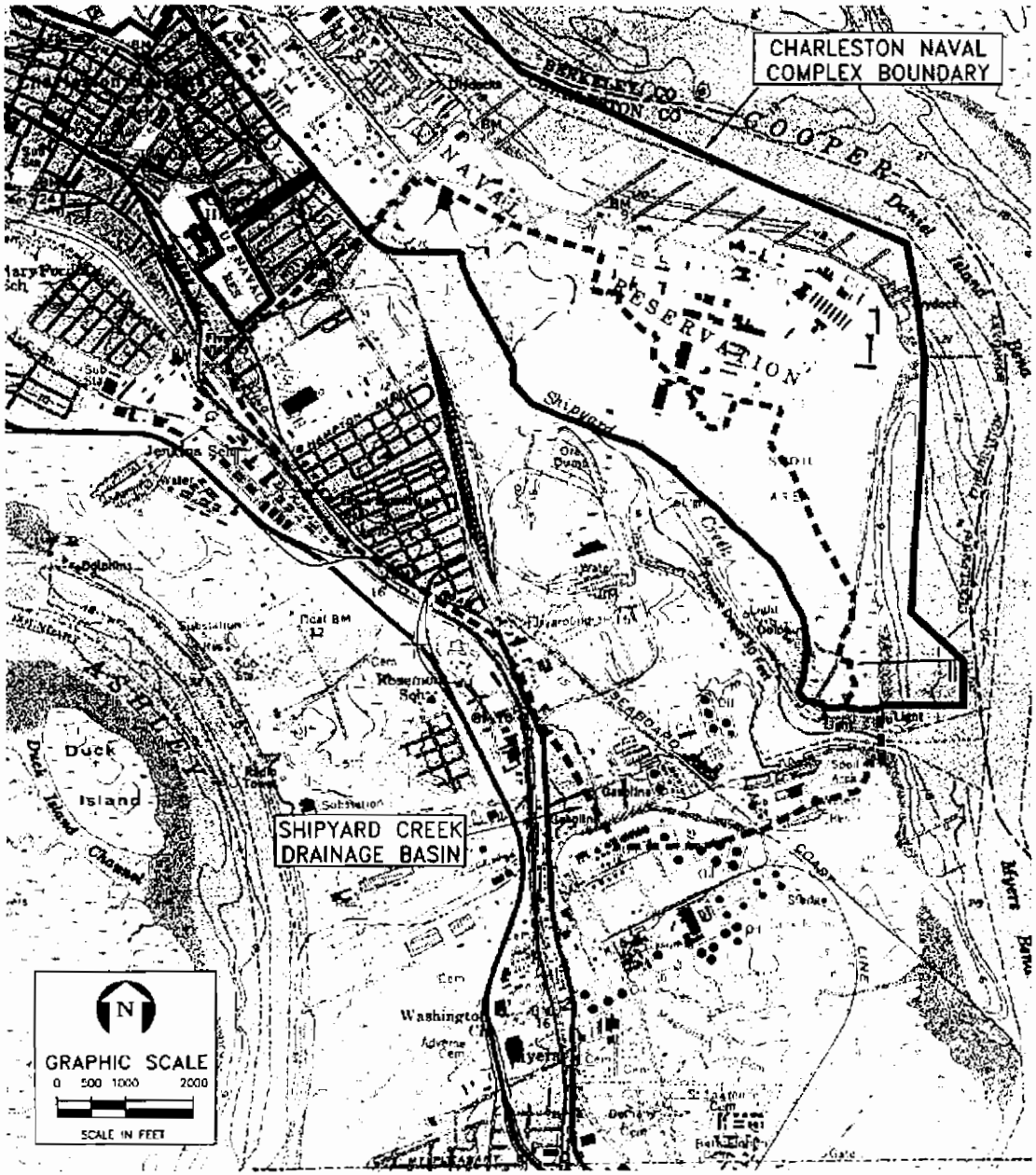
Tidal Flushing and Dilution in Noisette Creek

- Low tide volume = 46 acre-ft
- Tidal prism = 344 acre-ft
- Average tidal flow = 670 cfs
- Peak tidal flow = 1,053 cfs
- 88 percent of creek water can be flushed out in one tidal cycle
- Tidal dilution to CNC runoff is 55 to 1 during an average storm
- Tidal dilution to Noisette Creek runoff is 3.7 to 1 during an average storm
- Noisette Creek runoff/CNC runoff = 14.7
- Noisette Creek hydraulics are dominated by stormwater during severe storms

Shipyard Creek

- Outer turning basin depth = 50 ft @ MLW
- Ship channel and inner turning basin depth = 44 ft @ MLW
- Dredged area = 46 acres
- Open water = 91 acres
- Tidal marsh = 105 acres
- Entrance channel width = 600 ft
- Average tide range = 5.3 ft
- Spring tide range = 6.1 ft
- Average peak current speed at entrance channel = 0.05 ft/sec

Shipyard Creek Drainage Map



Shipyard Creek Drainage Area

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	279	878	1,157
Upland	279	682	961
Marsh	0	105	105
Open water	0	91	91

Source: ECT, 2003.

Shipyard Creek Runoff Summary

	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak runoff (cfs)	—	1,427	1,959	2,328	2,736	3,142	3,627
Runoff volume (acre-ft)	49.3	308.9	427.8	511.3	605.0	699.3	813.0
Runoff from CNC (acre-ft)	5.9	66.5	95.7	116.6	140.2	164.1	193.0

Source: ECT, 2002.

Sediment Loads

- Noisette Creek Basin = 890,000 lb/yr (366 cy/yr)
- Shipyard Creek Basin = 580,000 lb/yr (239 cy/yr)

Tidal Flushing and Dilution in Shipyard Creek

- Tidal prism = 692 acre-ft
- Low tide volume = 2,620 acre-ft
- Average tidal flow = 1,348 cfs
- Peak tidal flow = 2,118 cfs
- Average storm runoff volume = 49.3 acre-ft
- Tidal prism/average storm runoff = 14
- Tidal flushing time (dilute to 10 percent) = 5.2 days
- Shipyard Creek is a low energy area

Conclusion

- Potential contaminants from CNC can travel to a large area in the estuary
- Contaminants found in Cooper River near CNC may come from remote areas
- Large tidal dilution at Cooper River
- Noisette Creek has efficient flushing
- Shipyard Creek is near stagnant and has inefficient flushing

Hydrodynamics and Contaminant Transport in Charleston Harbor Estuary

by: Ivan B. Chou, P.E.

ECT
Environmental Consulting & Technology, Inc.

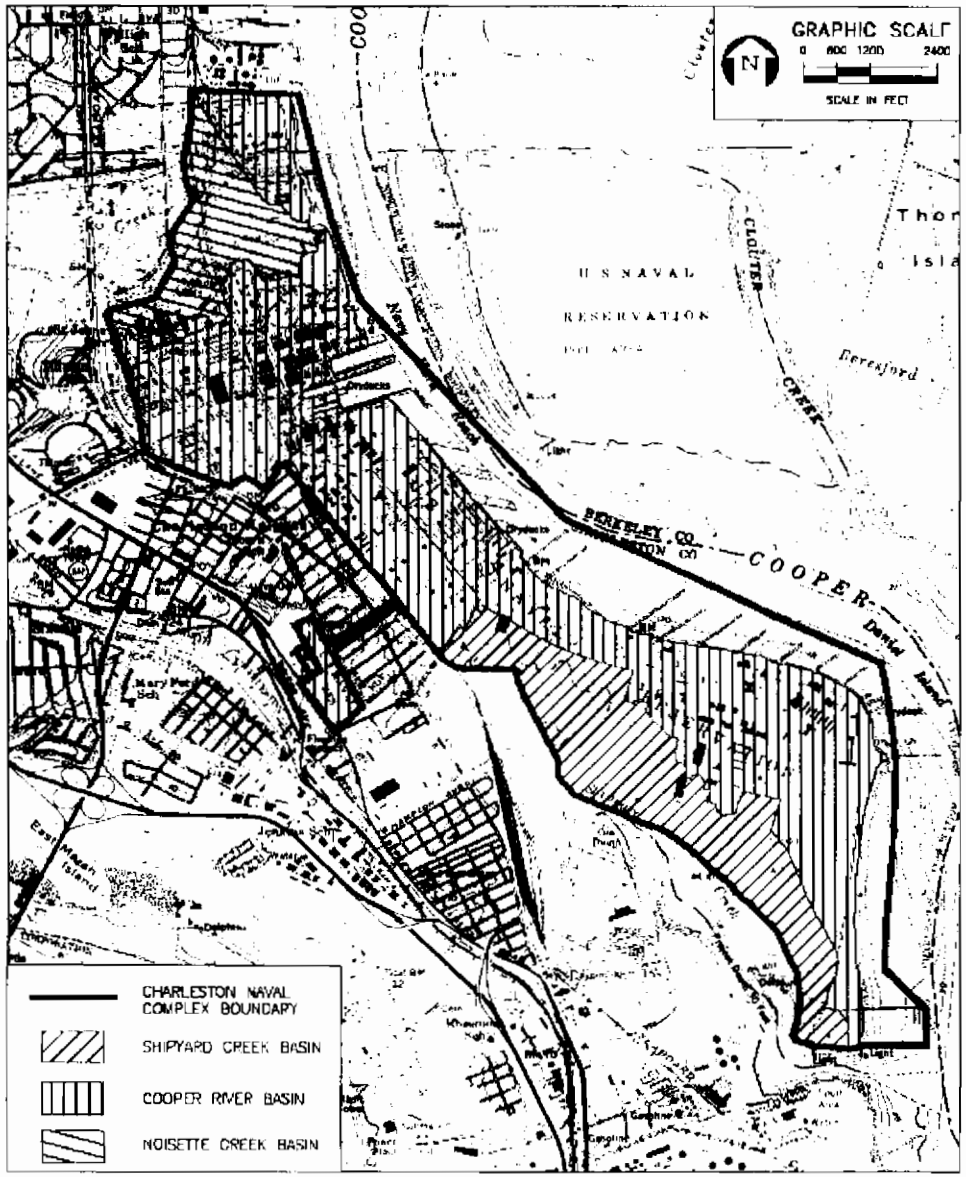
Naval Facilities Engineering Command • Southern Division •

ENSAFE
Environmental and Management Consultants

Purpose

To evaluate potential contaminant migration pathway in the surface water around Charleston Naval Complex and Charleston Harbor Estuary

Charleston Naval Complex



Factors Affecting Estuarine Hydrodynamics

- Tide
- Freshwater inflow
- Bathymetry and boundary geometry
- Wind
- Density stratification

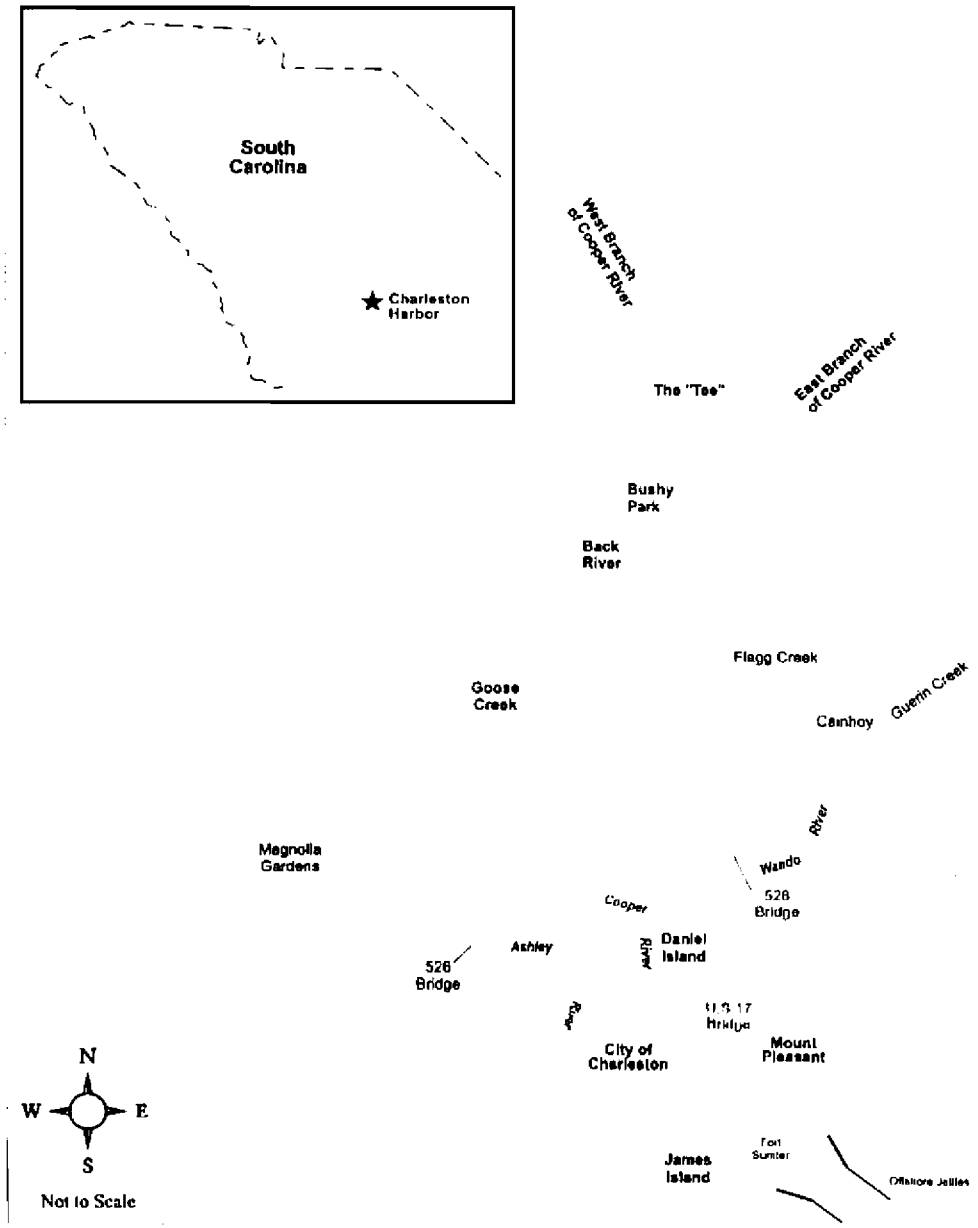
Factors Affecting Pollutant Transport

- Tidal current
- Pollutant source location
- Effluent quantity
- Effluent quality
- Sedimentation/resuspension
- Biochemical processes

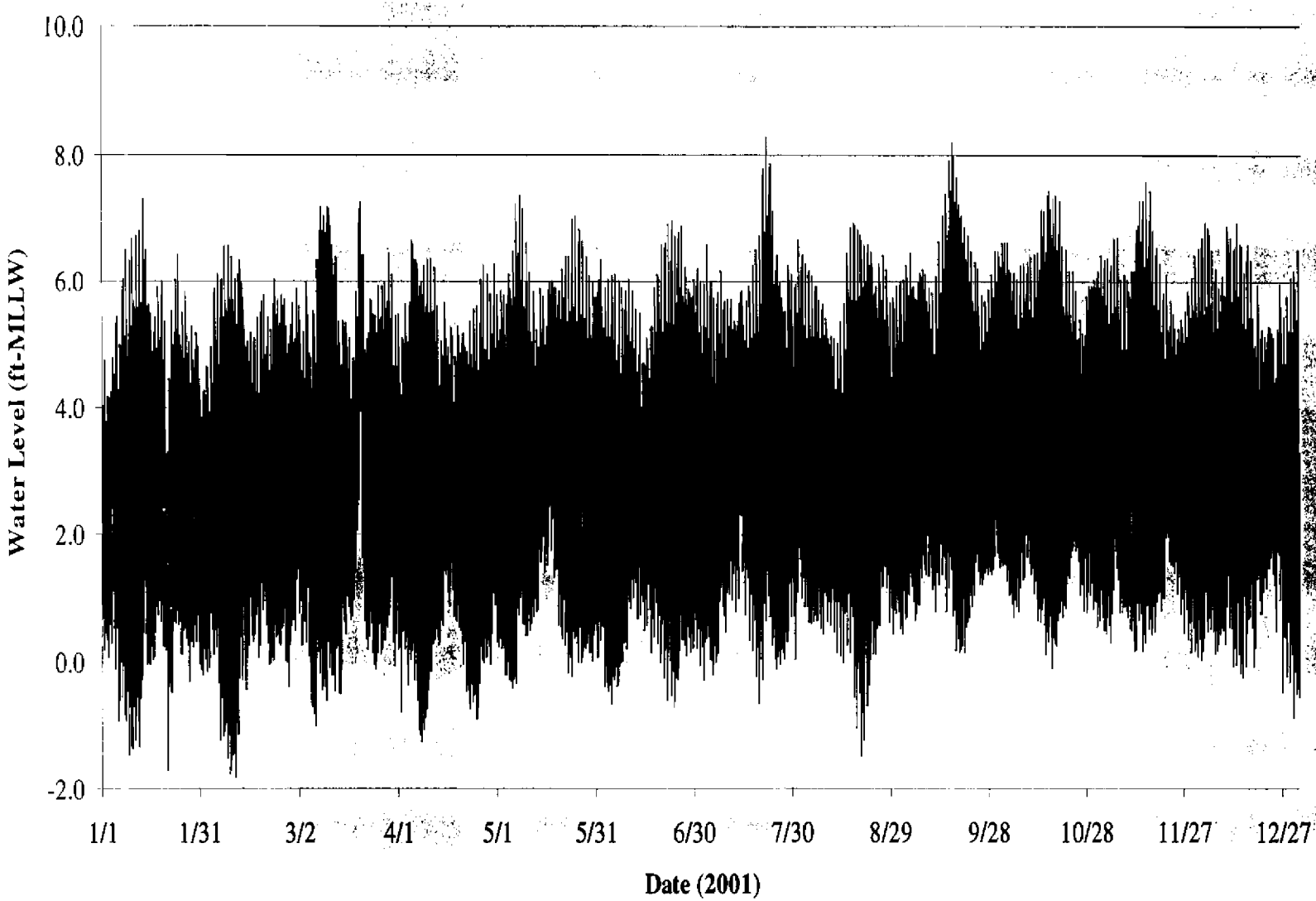
Pollutant Transport Process

- Nearfield processes:
  - Turbulent jet entrainment
  - Turbulent diffusion
  - Buoyant spreading
- Farfield processes:
  - Dispersion
  - Advection

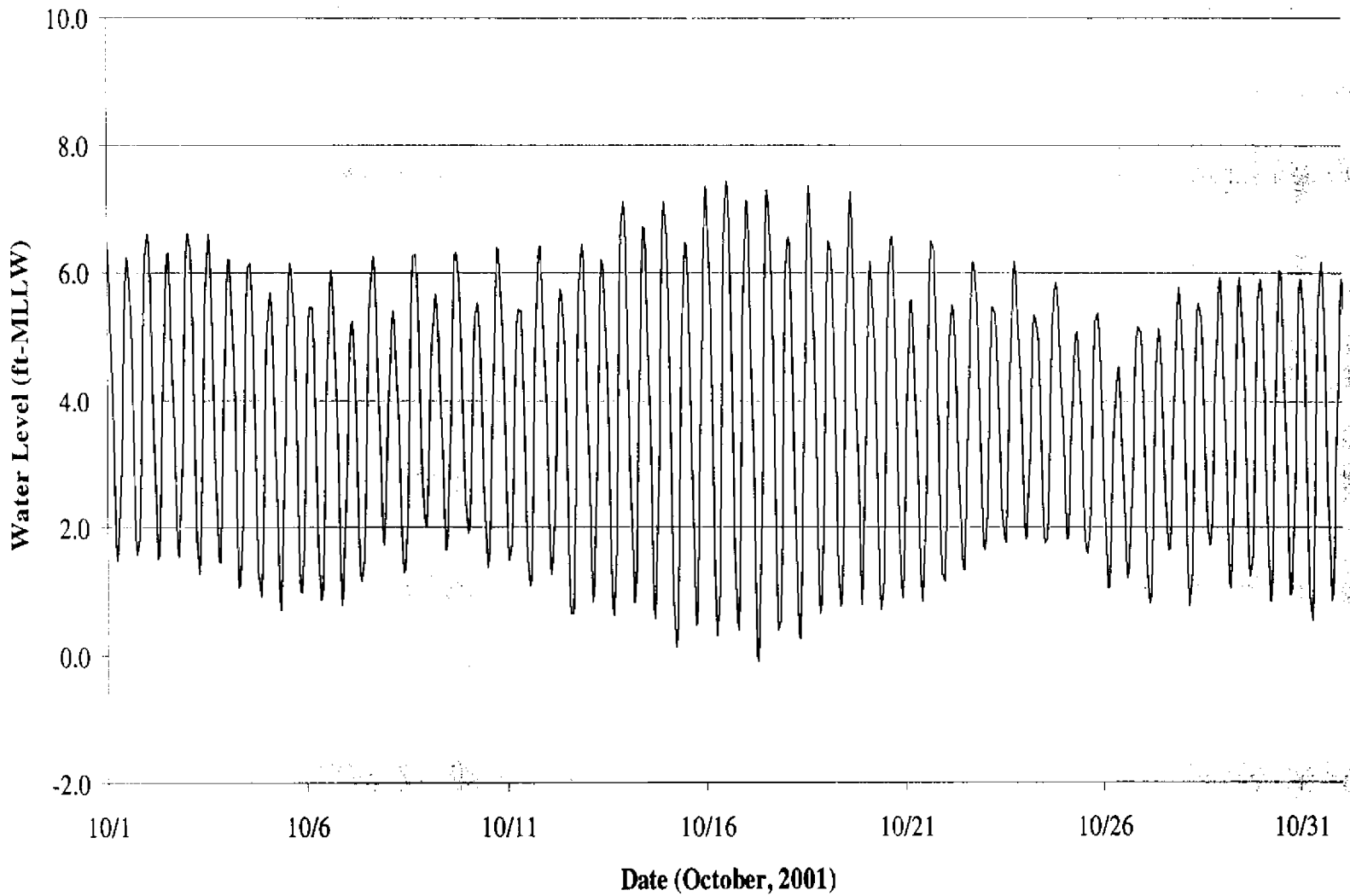
Charleston Harbor Estuary



Tidal Level at Cooper River Entrance (2001)



Tidal Level at Cooper River Entrance (October 2001)



Tidal Ranges and Phases in Charleston Harbor/Cooper River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Charleston (Customhouse Wharf)	5.27	6.11	0.00
Shipyard Creek	5.30	6.10	0.38
Cooper River at Clouter Creek, south entrance	5.40	6.26	0.32
Cooper River at Clouter Creek, north entrance	5.48	6.36	0.55
Cooper River at Snow Point	5.36	6.22	0.75
Cooper River at General Dynamics Pier	4.37	5.07	1.42
Cooper River at Dupon, Dean Hall	3.43	3.98	2.12
Cooper River at Old Rice Mill, West Branch	2.60	3.02	2.93
Cooper River at Pimlico, West Branch	1.70	1.97	3.90

Note: Phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Ranges and Phases in Ashley River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Ashley River at South Ashley Bridge	5.34	6.19	0.12
Ashley River at Duck Island	5.60	6.50	0.28
Ashley River at Cosgrove Bridge	5.62	6.52	0.30
Ashley River at Drayton, Bee's Ferry	5.76	6.68	0.65
Ashley River at Magnolia Gardens	5.79	6.72	0.90
Ashley River at Greggs Landing, Matceba Gardens	6.06	7.03	1.70

Note: The phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Ranges and Phases in Wando River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Wando River at Hobcaw Point	5.76	6.68	0.18
Wando River at Parker Island	5.76	6.68	0.47
Wando River at Cainhoy	6.15	7.13	0.50
Wando River at Big Paradise Island	6.54	7.59	0.87
Wando River at Woodville	6.30	7.30	1.37

Note: The phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Charleston Harbor Entrance, between jetties	1.8	1.8	-0.02
Charleston Harbor off Ft. Sumter	1.7	2.0	0.00
South Channel at Buoy "32"	0.8	1.0	-0.02
South Channel, 0.8 mile ENE of Fort Johnson	0.8	2.6	0.72
South Channel, 0.4 mile NW of Fort Johnson	0.7	1.9	1.17
The Cove, entrance on the Cove Range	1.2	0.9	0.47
Shutes Reach, Buoy "8"	1.3	1.5	0.30
Hog Island Channel	0.8	0.8	-0.65
Folly Reach at Buoy "5"	1.2	1.6	0.03
Folly Reach north of Fort Johnson	1.2	1.1	-0.85
0.6 miles SW of Castle Pinckney	0.7	1.3	-0.35
0.4 miles west of Shutes Folly Island	0.8	2.2	0.88
Customhouse Reach off Customhouse	1.0	1.3	0.82
Customhouse Reach	1.0	1.8	0.77
Horse Reach	1.4	1.9	0.60
Hog Island Reach, Buoy "12"	1.2	1.3	0.22
Drum Island, east of bridge	1.2	2.0	0.50
Town Creek Lower Reach	1.1	2.2	0.57
Town Creek, 0.2 mile above bridge	0.8	2.5	1.10
Drum Island Reach at Buoy"45"	0.6	1.0	0.43
Cooper River, 0.2 mile above Drum Island	1.1	2.4	1.20
Cooper River at Daniel Island Reach, Buoy "48"	1.2	1.3	1.02
Cooper River at Shipyard Creek entrance	0.5	1.5	0.68
Cooper River at Daniel Island Reach	1.3	2.3	1.48
Cooper River at Daniel Island Bend	1.2	2.1	0.92
Cooper River at North Charleston	1.1	1.7	1.43
Cooper River at Filbin Creek Reach	1.2	1.8	1.52
Cooper River at Filbin Creek Reach, Buoy "58"	1.1	1.3	1.30

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

(Continued, Page 2 of 2)

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Cooper River at Ordnance Reach	1.0	1.2	1.58
Cooper River at Yellow House Creek	0.7	1.4	2.10
Cooper River at 1 mile NW of Yellow House Landing	0.7	1.8	2.43
Cooper River at SE of Woods Point	0.8	1.0	1.80
Copper River at Woods Point	0.9	1.4	2.68
Cooper River at 0.5 mile North of Snow Point	1.1	1.4	2.25
Cooper River off Amoco Pier	0.7	0.9	2.15
Cooper River at 0.5 mile below Moreland	1.9	2.0	3.54
Cooper River at 1 mile below Hagan Island	1.3	1.4	3.54
Cooper River at 0.4 mile SW of The "Tee"	1.0	1.7	4.37
Cooper River at The "Tee"	0.9	1.0	3.00
Cooper River at Childsbury, S.A.L. RR Bridge	0.7	1.7	4.72

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Ashley River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Ashley River SW of Battery	1.2	1.8	0.27
Ashley River off Wappoo Creek	1.1	1.2	0.12
Ashley River at highway bridge	1.2	1.1	-0.15
Ashley River at 0.1 mile below SCL railroad bridge	1.0	1.1	-0.10
Ashley River at 1.5 mile above SCL railroad bridge	1.2	1.5	0.37
Ashley River at State Highway 7 bridge	1.0	1.0	0.10
Ashley River at 0.1 mile east of West Marsh Island	0.7	1.0	0.38
Ashley River at Bees Ferry Bridge	1.9	2.3	1.22

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Wando River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Wando River at 0.2 mile NW of Ramley Point	1.3	1.8	-0.23
Wando River at Upper Reach, Turning Basin	1.0	1.2	-0.23
Wando River at Rathall Creek Entrance	1.3	1.7	0.42
Wando River off Nowell Creek, Buoy "19"	0.8	1.0	-0.13
Wando River at 0.2 mile above Horbeck Creek entrance	1.0	0.9	0.47
Wando River at 2.5 miles north of Horbeck Creek	0.8	1.3	0.50

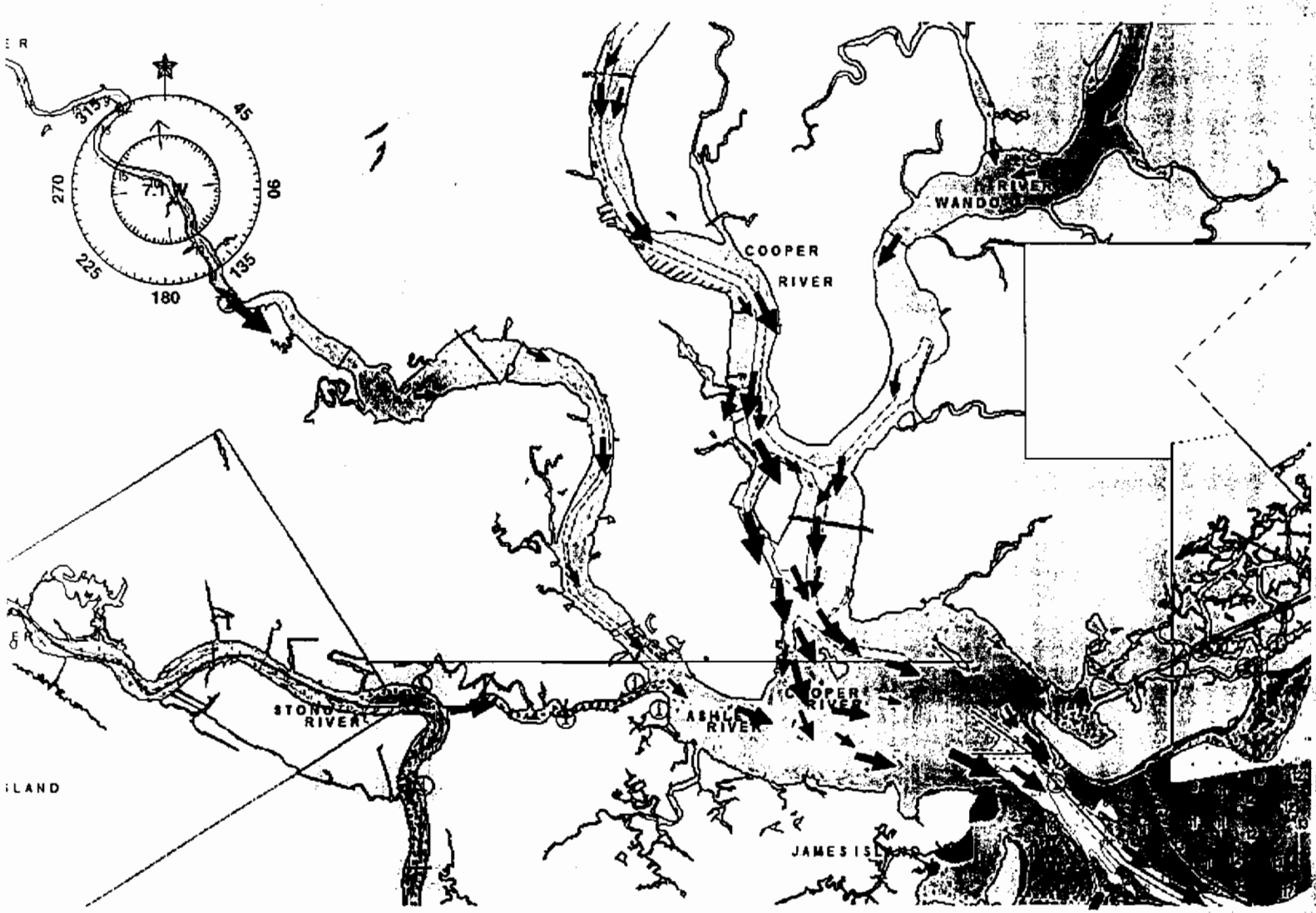
Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

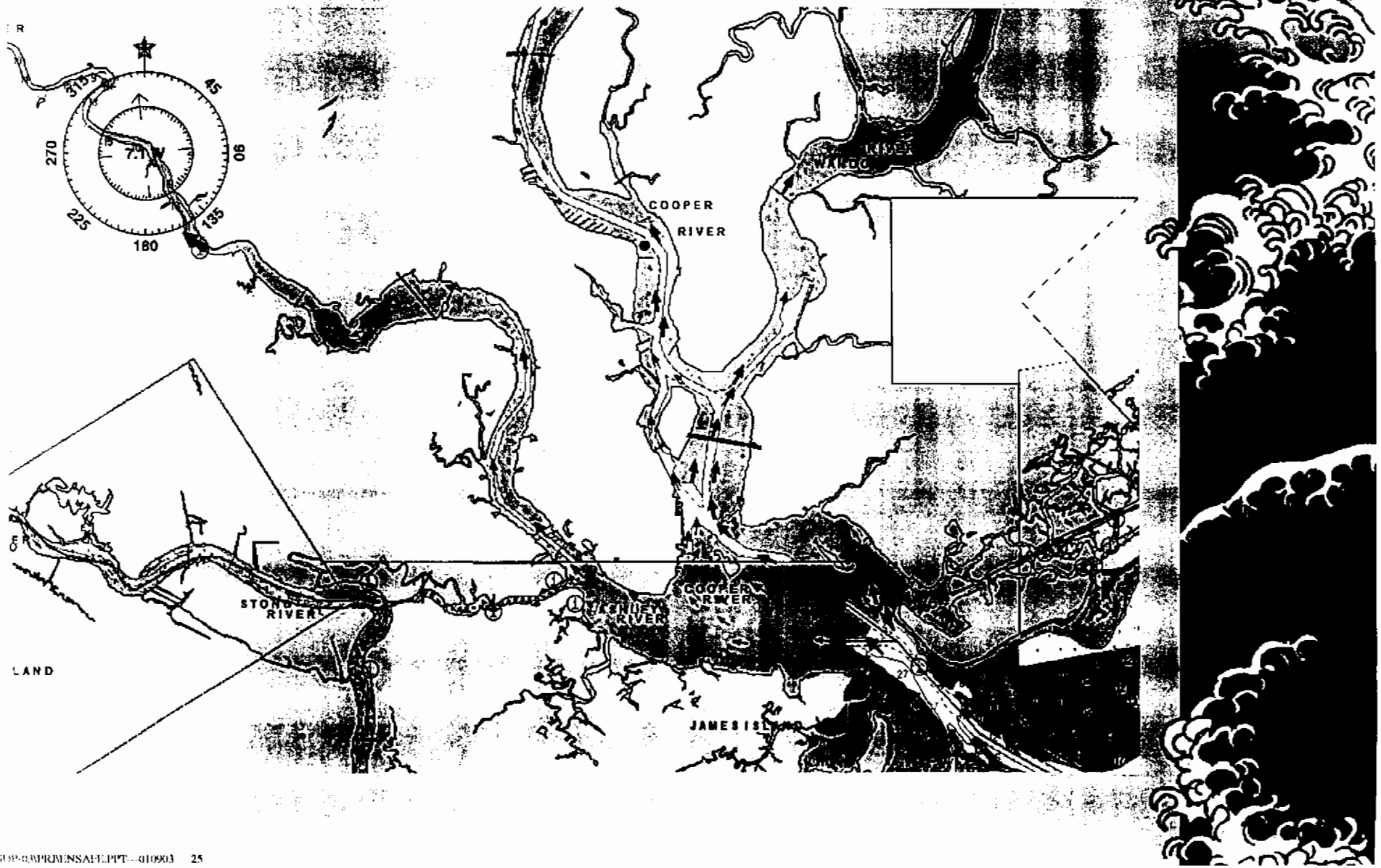
Cooper River Flows

- Average freshwater flow of Cooper River = 4,500 cfs
- Tidal flows (measured in September 1996):
  - Cooper River at Daniel Island = -150,000 to +160,000 cfs
  - Cooper River at Drum Island = -320,000 to +360,000 cfs

Ebb Currents



Flood Currents



Excursion Analysis

- Tidal excursion: the average travel distance of a water particle on the flood tide
- Methodology: Particle tracking by Lagrangian integration
- Results:
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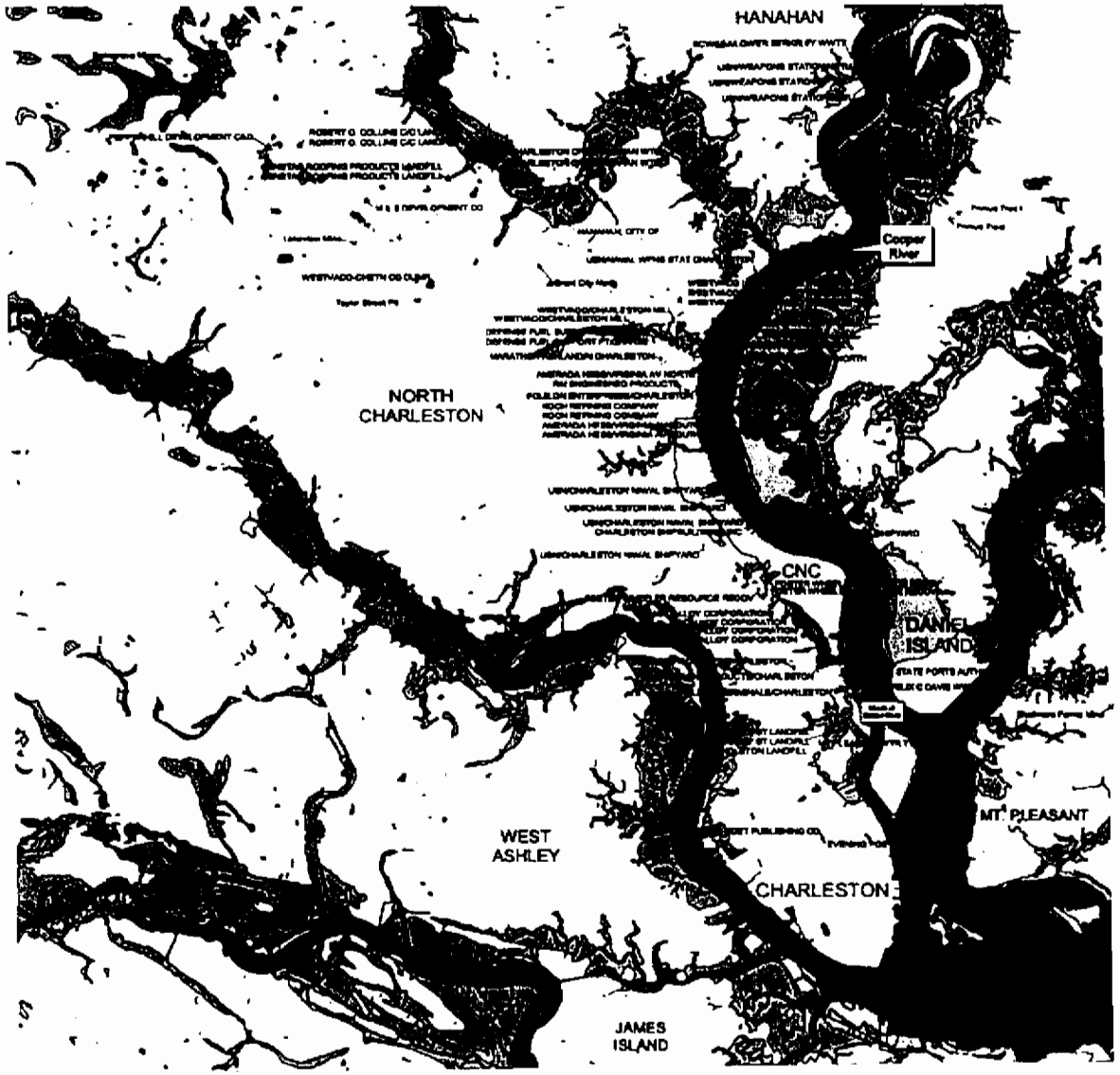
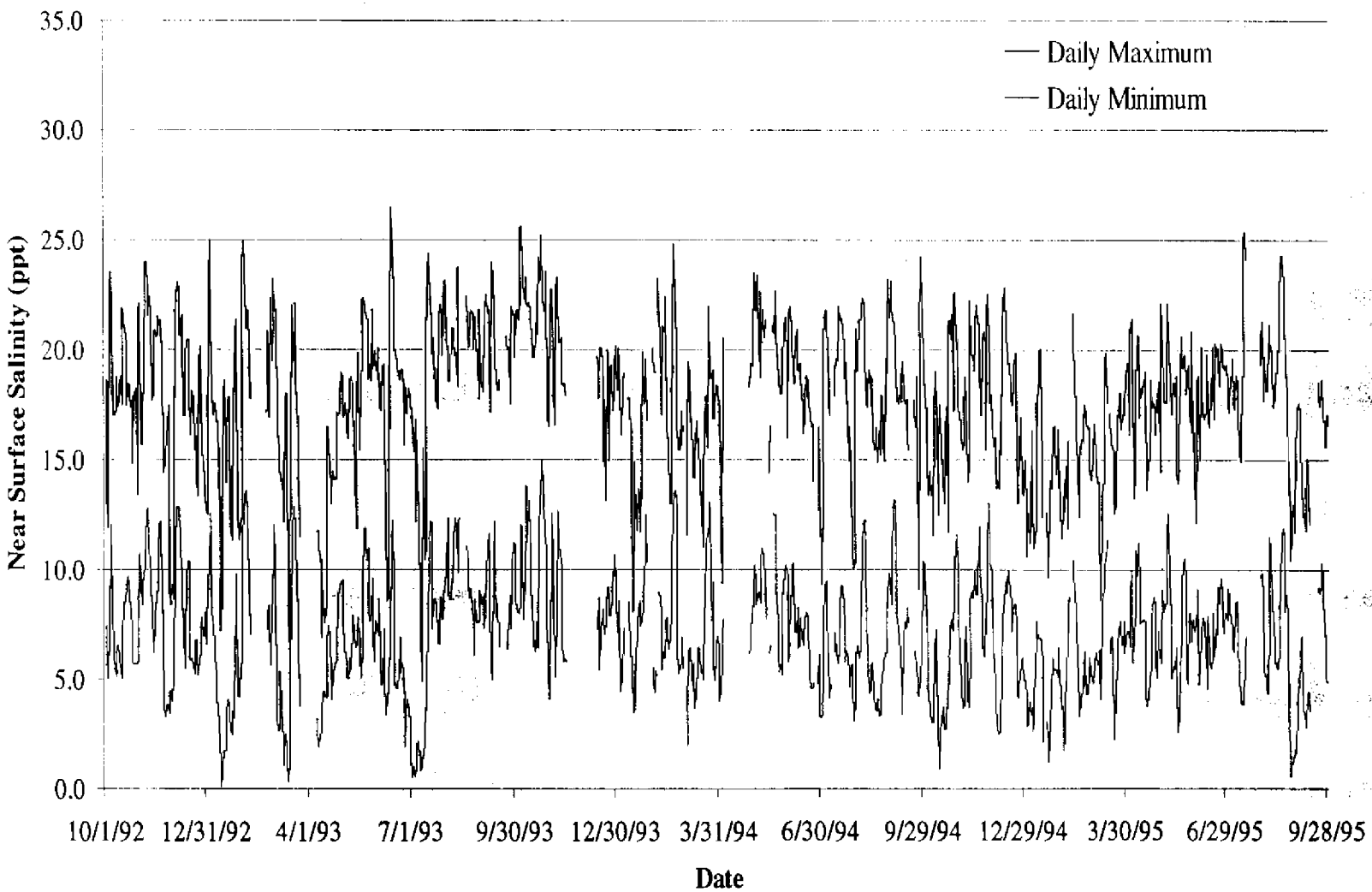


3 0 3 Miles

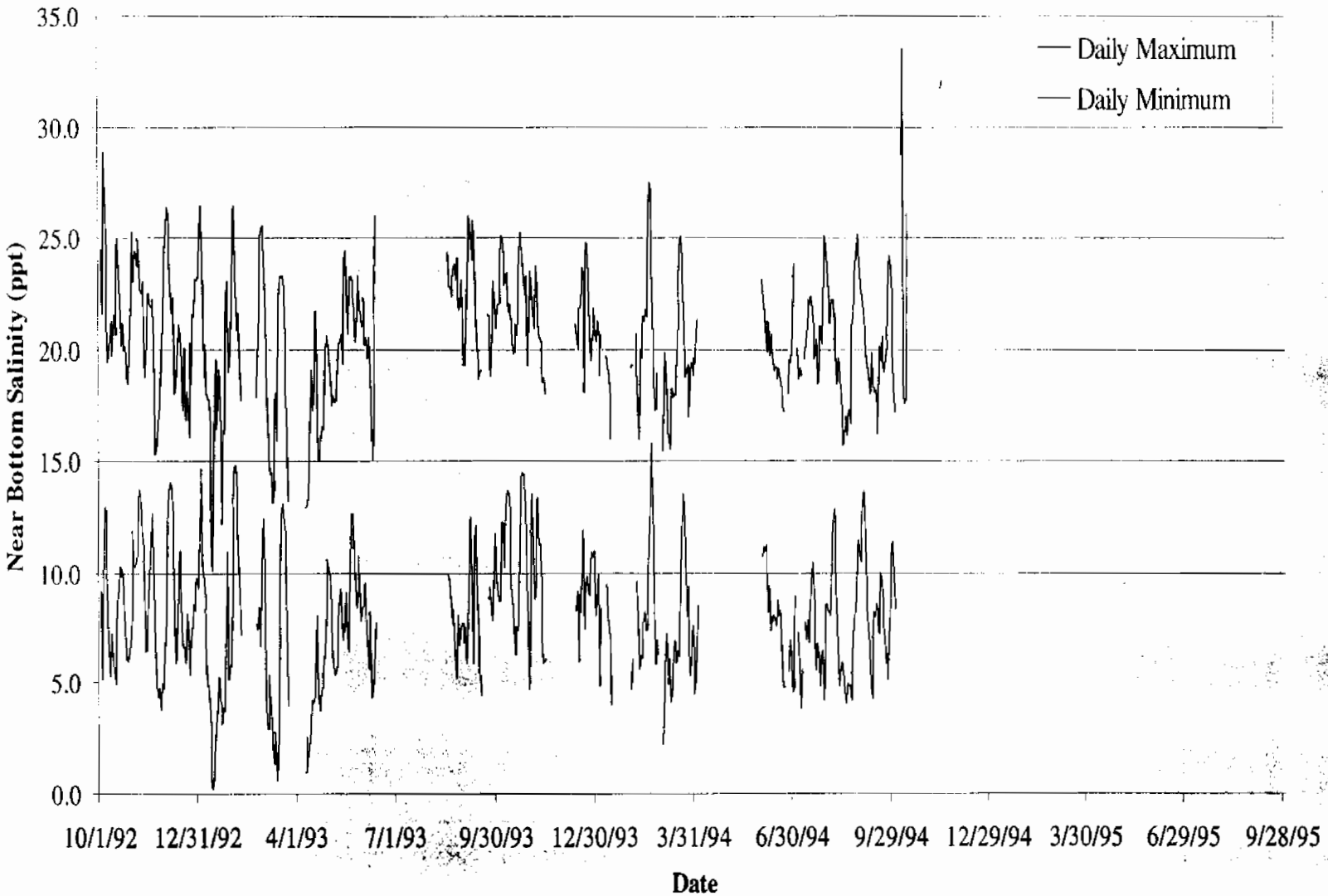
ZONE J
POINT OF ENTRY
EFFLUENT SAMPLING WORK PLAN
CHARLESTON NAVAL COMPLEX
CHARLESTON, SC

The data used to create this map was collected and created by SC DHEC. This information is contained in the Watershed Water Quality Management Strategy Report.

Cooper River Surface Salinity Near Army Depot



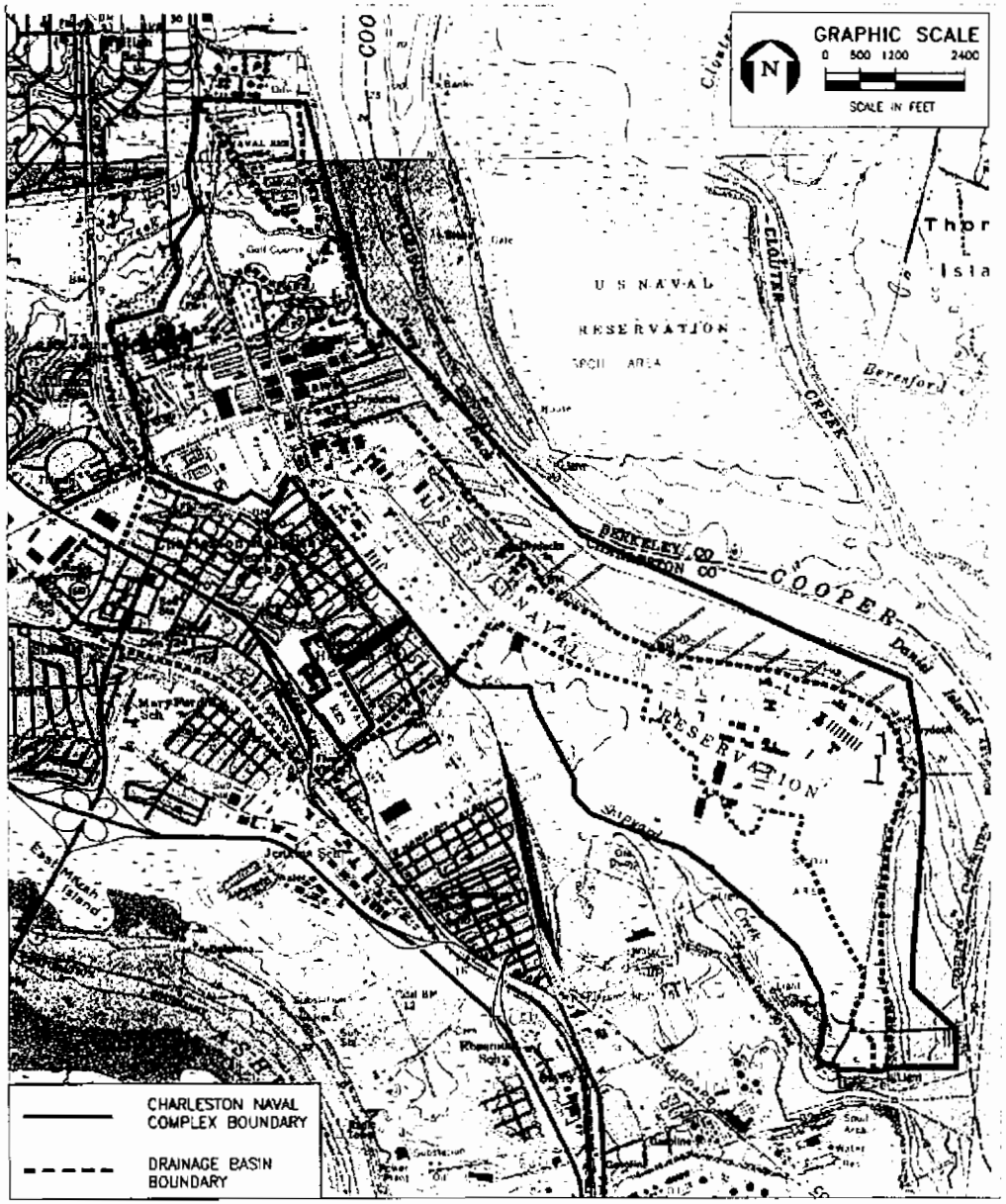
Cooper River Bottom Salinity Near Army Depot



Cooper River Salinity Near CNC

	Surface (ppt)	Bottom (ppt)
Average daily mean	11.3	14.3
Average daily minimum	7.1	8.5
Average daily maximum	17.8	20.6
Minimum	0.1	0.3
Maximum	26.4	33.9

Cooper River Watershed



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- Annual average: 700,000 lb/yr (288 cubic yards per year)
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Cumulative Percent of Mass in Urban Runoff	Average Settling Velocity (ft/hour)	Settling Time in 40 ft of Water (hour)
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Sources: Wanielista and Yousef, 1993.
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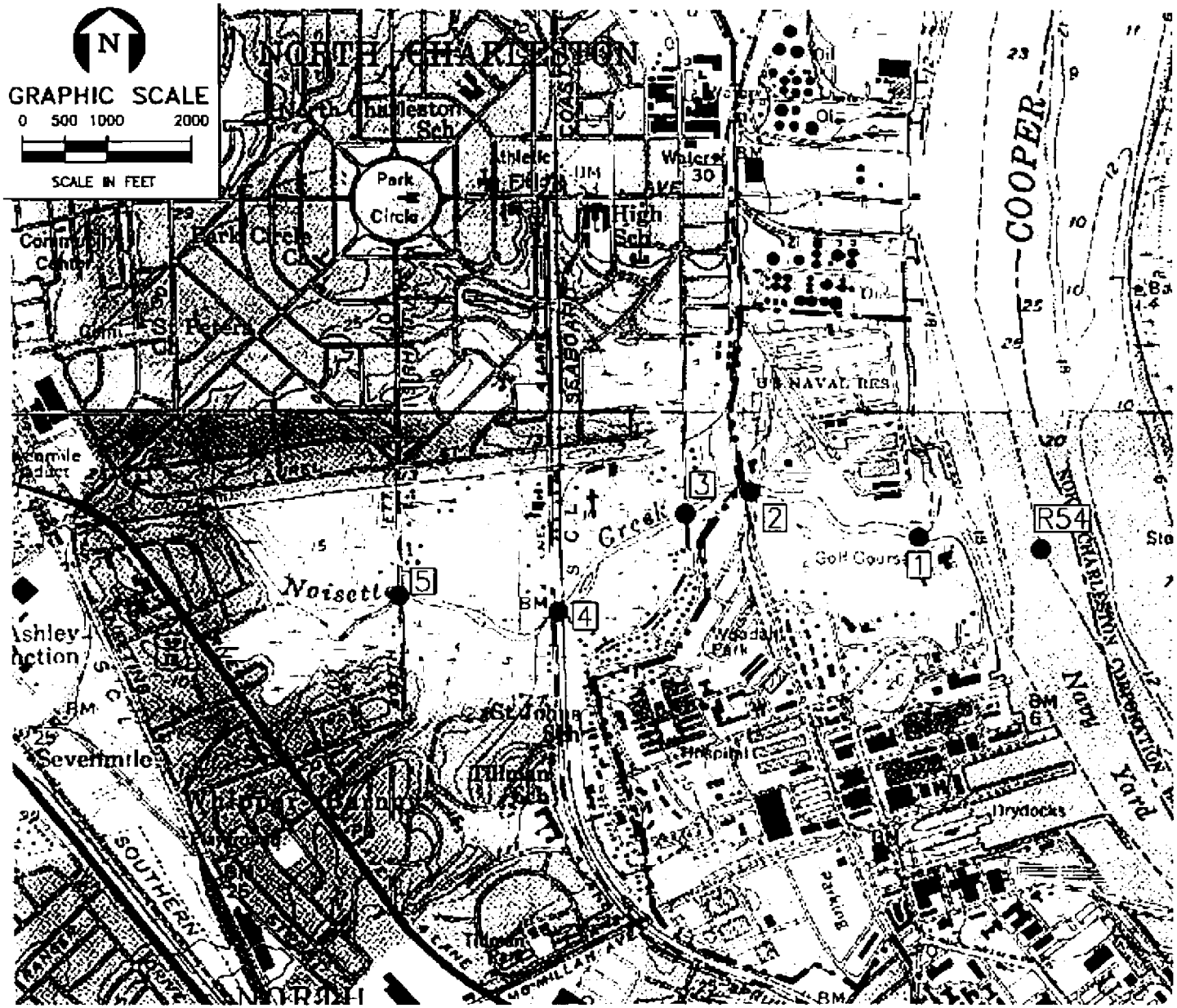
Potential Depositional Areas

- Dry dock area in Zone E
- Shipyard Creek
- Nearshore shallow area in Zone I
- Middle ground
- Shallow area near Crab Bank
- South of Hog Island and Mount Pleasant
- Near Morris Island

Monitoring Station Locations



Noisette Creek Bathymetry

Station	Width (ft)	Depth at Low Tide (ft)
1	—	4
2	108	5
3	112	2.5
4	92	<1
5	51	<1

Source: ECT, 2003.

Noisette Creek Salinity Data (December 6 & 7, 2000)

Station	Low Tide* (ppt)	High Tide* (ppt)
1	14.3	15.9
2	12.7	15.2
3	11.9	13.8
4	11.1	13.5
5	9.8	13.6
Cooper River	17.7	22.4

*Vertical average salinity.

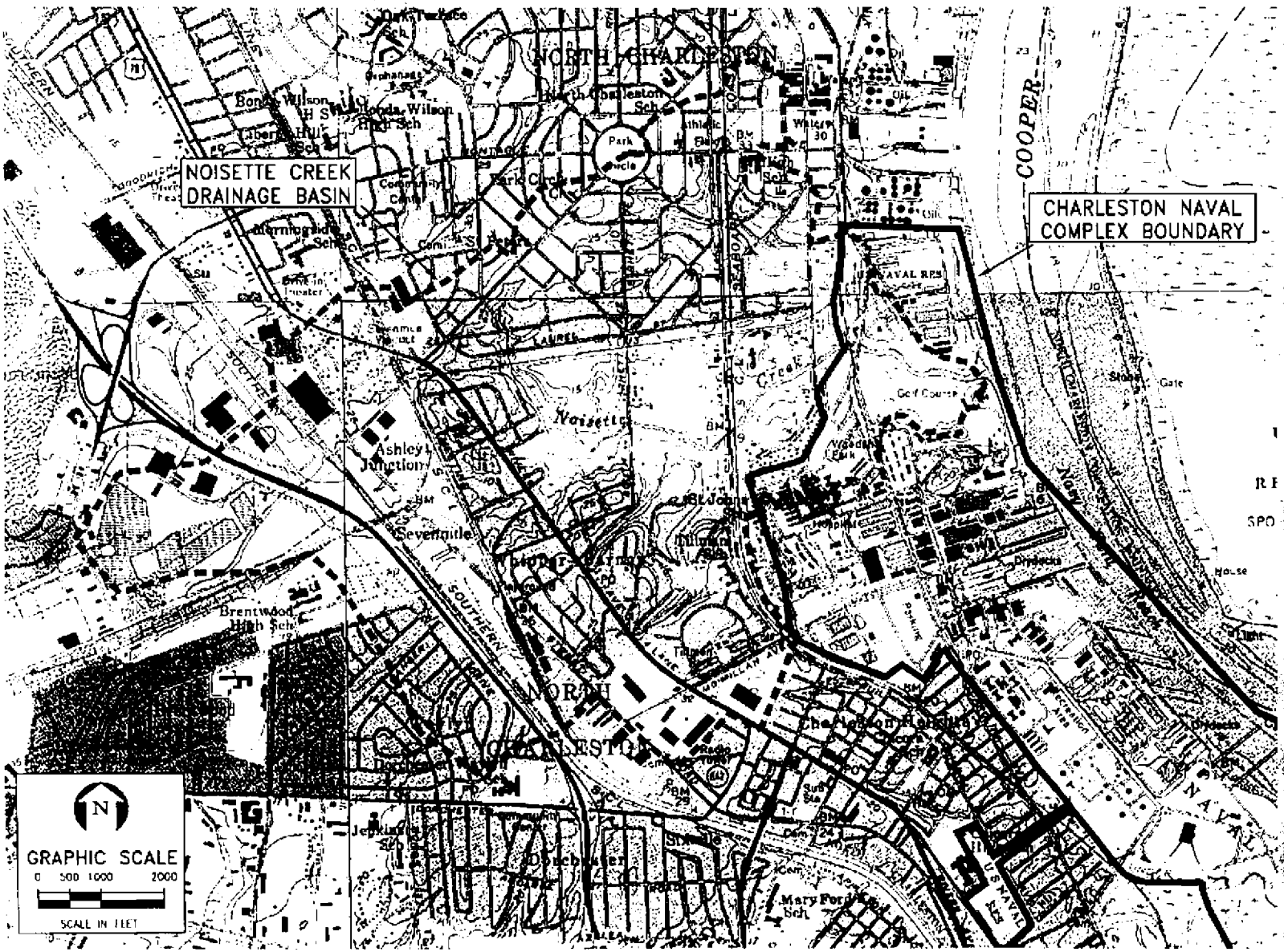
Source: ECT, 2003.

Noisette Creek Current Velocity

Station	Peak Current Speed Flood (fps)	Peak Current Speed Ebb (fps)
1	0.83	0.82
2	0.49	0.98
3	0.48	0.65
4	0.72	1.12
5	0.59	0.30

Source: ECT, 2003.

Noisette Creek Drainage Map



Noisette Creek Drainage Basin

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	123	1,624	1,747
Upland	118	1,481	1,599
Open water at low tide	5	9	14
Tidal marsh	0	134	134

Source: ECT, 2003.

Noisette Creek
Runoff Summary

	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak runoff (cfs)	—	2,380	3,179	3,720	4,333	4,936	5,659
Runoff volume (acre-ft)	92.8	523.2	707.3	835.7	979.1	1,123.0	1,296.0
Runoff from CNC (acre-ft)	6.3	35.3	47.7	56.4	66.1	75.8	87.5

Source: ECT, 2002.

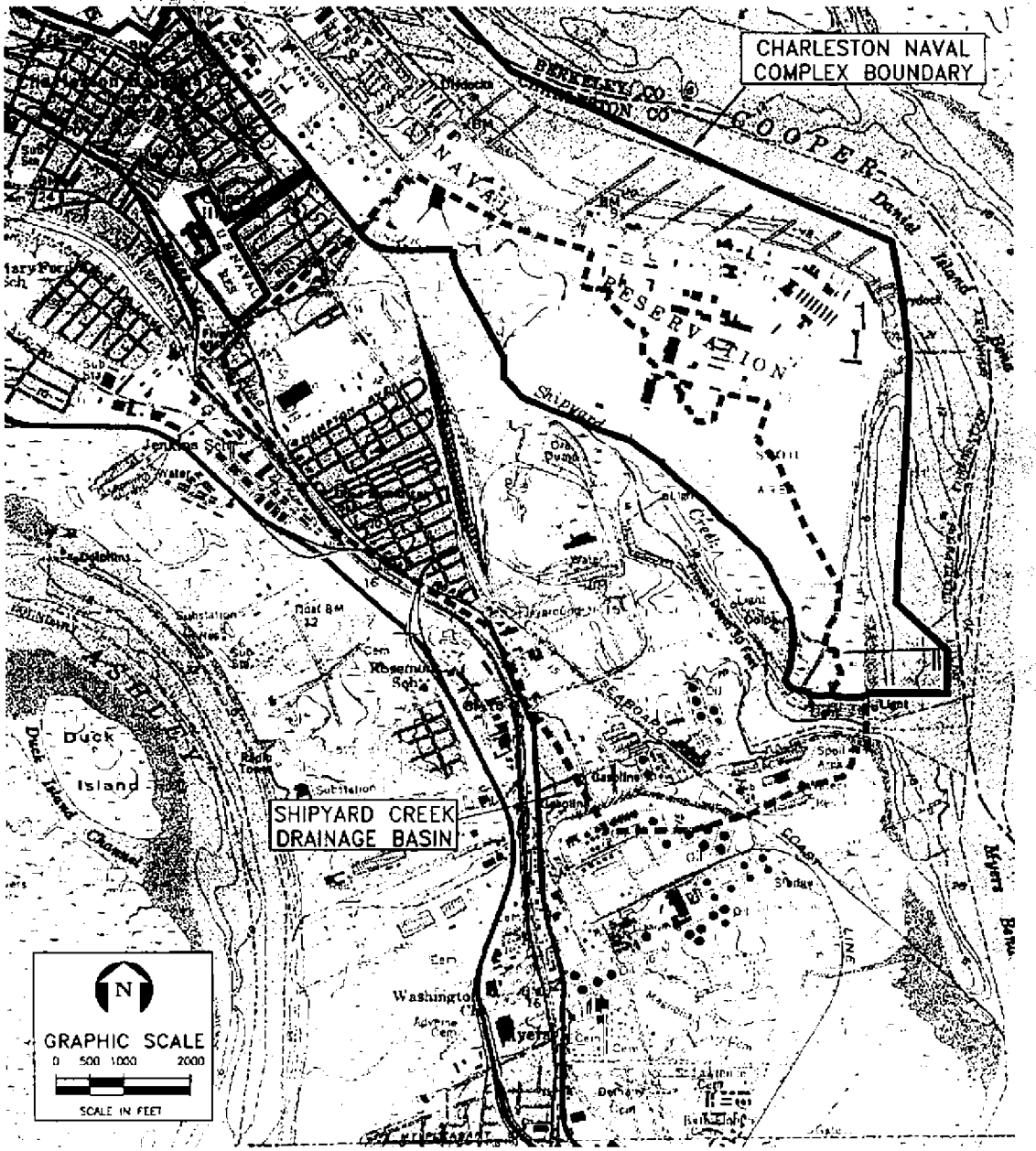
Tidal Flushing and Dilution in Noisette Creek

- Low tide volume = 46 acre-ft
- Tidal prism = 344 acre-ft
- Average tidal flow = 670 cfs
- Peak tidal flow = 1,053 cfs
- 88 percent of creek water can be flushed out in one tidal cycle
- Tidal dilution to CNC runoff is 55 to 1 during an average storm
- Tidal dilution to Noisette Creek runoff is 3.7 to 1 during an average storm
- Noisette Creek runoff/CNC runoff = 14.7
- Noisette Creek hydraulics are dominated by stormwater during severe storms

Shipyard Creek

- Outer turning basin depth = 50 ft @ MLW
- Ship channel and inner turning basin depth = 44 ft @ MLW
- Dredged area = 46 acres
- Open water = 91 acres
- Tidal marsh = 105 acres
- Entrance channel width = 600 ft
- Average tide range = 5.3 ft
- Spring tide range = 6.1 ft
- Average peak current speed at entrance channel = 0.05 ft/sec

Shipyard Creek Drainage Map



Shipyard Creek Drainage Area

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	279	878	1,157
Upland	279	682	961
Marsh	0	105	105
Open water	0	91	91

Source: ECT, 2003.

Shipyard Creek Runoff Summary

	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak runoff (cfs)	—	1,427	1,959	2,328	2,736	3,142	3,627
Runoff volume (acre-ft)	49.3	308.9	427.8	511.3	605.0	699.3	813.0
Runoff from CNC (acre-ft)	5.9	66.5	95.7	116.6	140.2	164.1	193.0

Source: ECT, 2002.

Sediment Loads

- Noisette Creek Basin = 890,000 lb/yr (366 cy/yr)
- Shipyard Creek Basin = 580,000 lb/yr (239 cy/yr)

Tidal Flushing and Dilution in Shipyard Creek

- Tidal prism = 692 acre-ft
- Low tide volume = 2,620 acre-ft
- Average tidal flow = 1,348 cfs
- Peak tidal flow = 2,118 cfs
- Average storm runoff volume = 49.3 acre-ft
- Tidal prism/average storm runoff = 14
- Tidal flushing time (dilute to 10 percent) = 5.2 days
- Shipyard Creek is a low energy area

Conclusion

- Potential contaminants from CNC can travel to a large area in the estuary
- Contaminants found in Cooper River near CNC may come from remote areas
- Large tidal dilution at Cooper River
- Noisette Creek has efficient flushing
- Shipyard Creek is near stagnant and has inefficient flushing

Hydrodynamics and Contaminant Transport in Charleston Harbor Estuary

by: Ivan B. Chou, P.E.

ECT
Environmental Consulting & Technology, Inc.

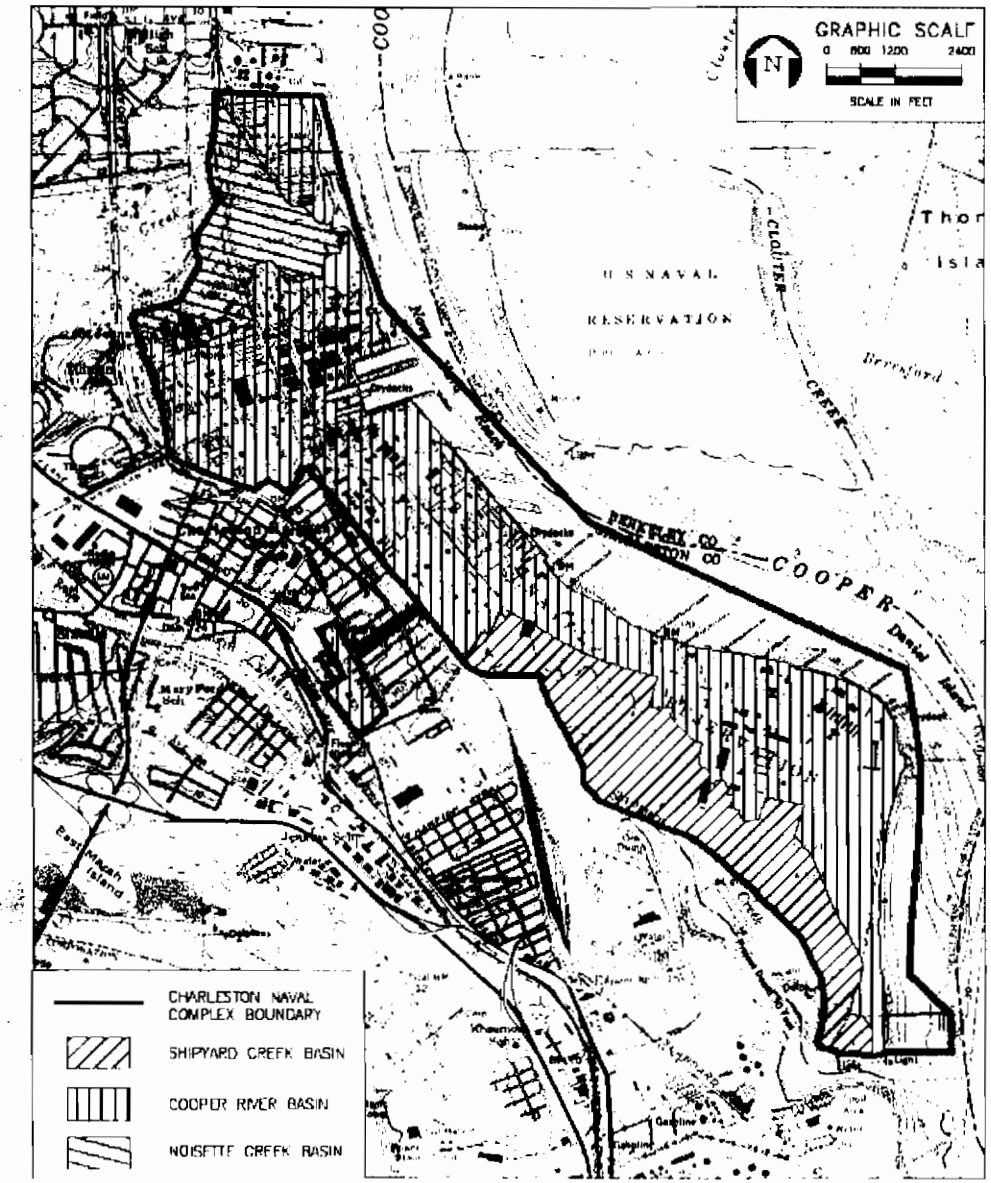
Naval Facilities Engineering Command • Southern Division •

ENSAFE
ENVIRONMENTAL AND MANAGEMENT CONSULTANTS

Purpose

To evaluate potential contaminant migration pathway in the surface water around Charleston Naval Complex and Charleston Harbor Estuary

Charleston Naval Complex



Factors Affecting Estuarine Hydrodynamics

- Tide
- Freshwater inflow
- Bathymetry and boundary geometry
- Wind
- Density stratification

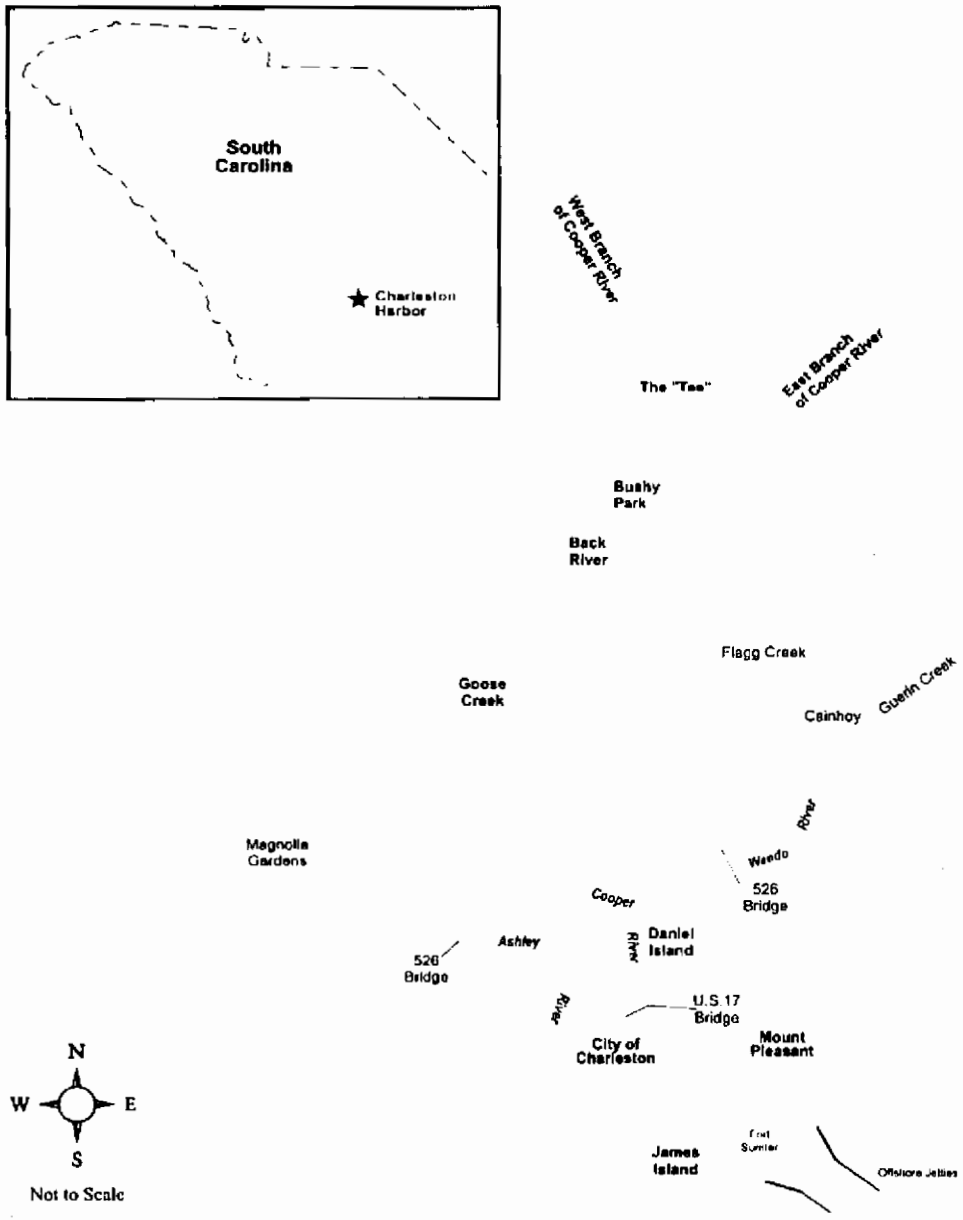
Factors Affecting Pollutant Transport

- Tidal current
- Pollutant source location
- Effluent quantity
- Effluent quality
- Sedimentation/resuspension
- Biochemical processes

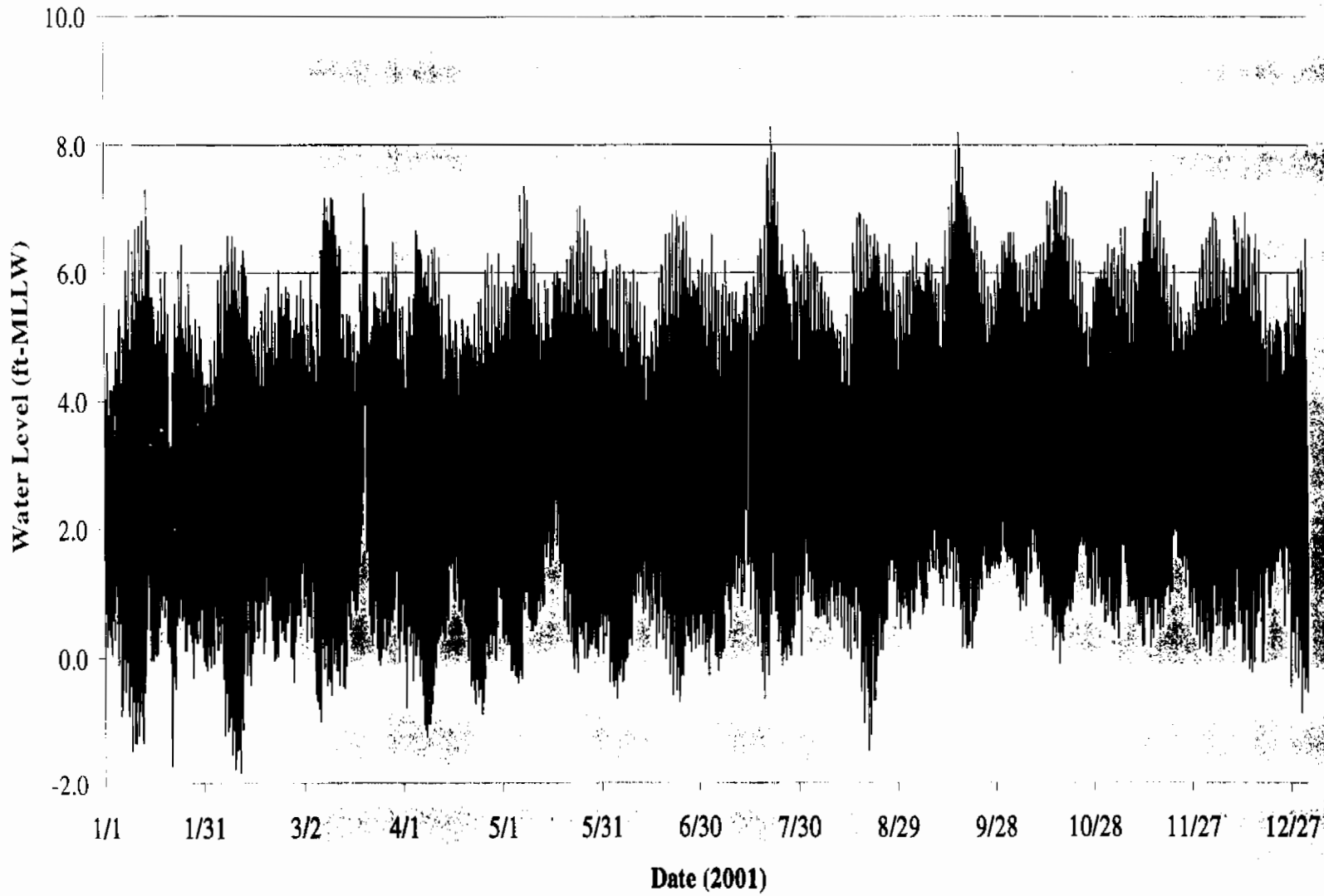
Pollutant Transport Process

- Nearfield processes:
  - Turbulent jet entrainment
  - Turbulent diffusion
  - Buoyant spreading
- Farfield processes:
  - Dispersion
  - Advection

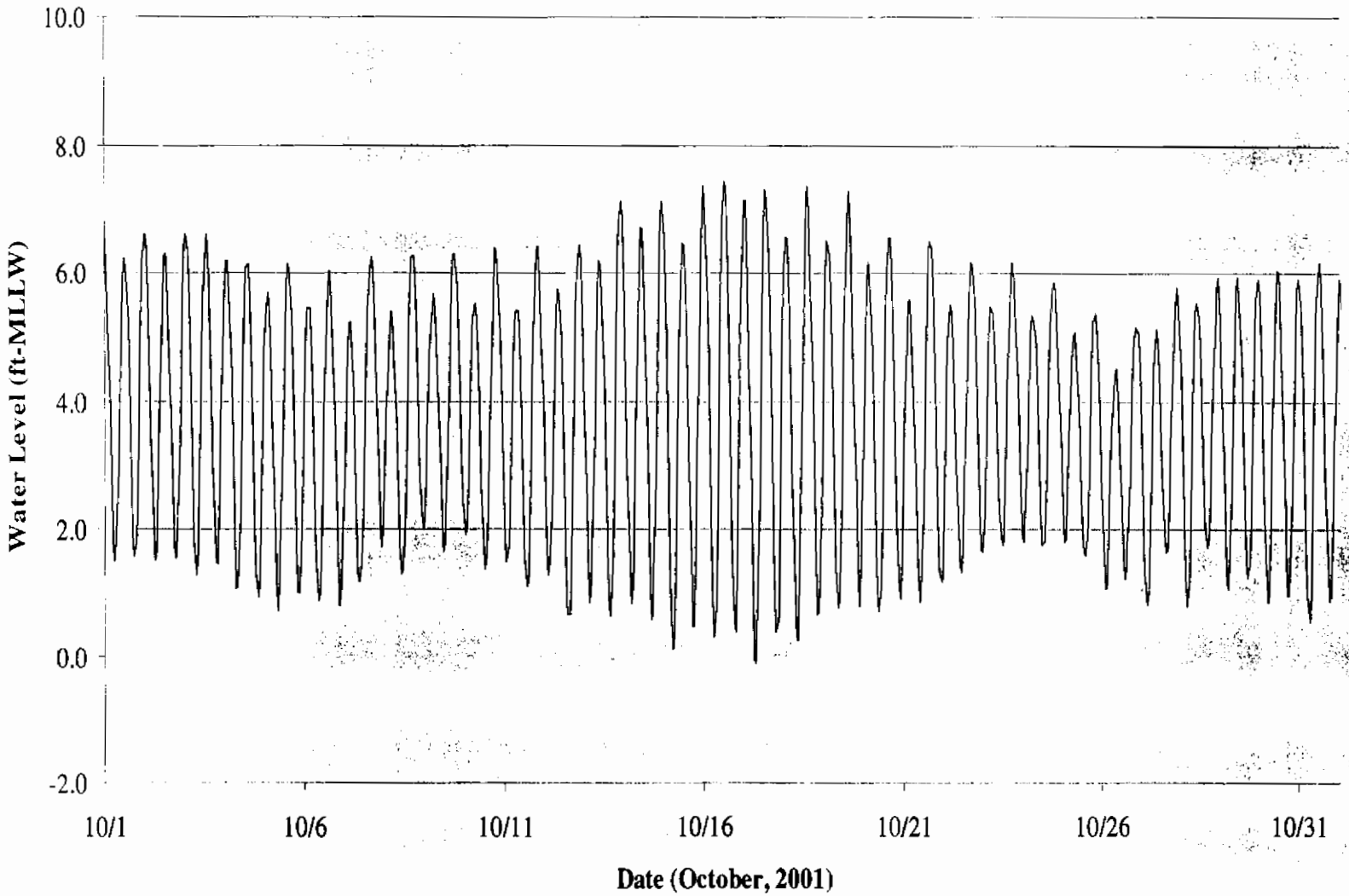
Charleston Harbor Estuary



Tidal Level at Cooper River Entrance (2001)



Tidal Level at Cooper River Entrance (October 2001)



Tidal Ranges and Phases in Charleston Harbor/Cooper River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Charleston (Customhouse Wharf)	5.27	6.11	0.00
Shipyard Creek	5.30	6.10	0.33
Cooper River at Clouter Creek, south entrance	5.40	6.26	0.32
Cooper River at Clouter Creek, north entrance	5.48	6.36	0.55
Cooper River at Snow Point	5.36	6.22	0.75
Cooper River at General Dynamics Pier	4.37	5.07	1.42
Cooper River at Dupon, Dean Hall	3.43	3.98	2.12
Cooper River at Old Rice Mill, West Branch	2.60	3.02	2.93
Cooper River at Pimlico, West Branch	1.70	1.97	3.90

Note: Phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Ranges and Phases in Ashley River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Ashley River at South Ashley Bridge	5.34	6.19	0.12
Ashley River at Duck Island	5.60	6.50	0.28
Ashley River at Cosgrove Bridge	5.62	6.52	0.30
Ashley River at Drayton, Bee's Ferry	5.76	6.68	0.65
Ashley River at Magnolia Gardens	5.79	6.72	0.90
Ashley River at Greggs Landing, Matceba Gardens	6.06	7.03	1.70

Note: The phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Ranges and Phases in Wando River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Wando River at Hobcaw Point	5.76	6.68	0.18
Wando River at Parker Island	5.76	6.68	0.47
Wando River at Cainhoy	6.15	7.13	0.50
Wando River at Big Paradise Island	6.54	7.59	0.87
Wando River at Woodville	6.30	7.30	1.37

Note: The phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Charleston Harbor Entrance, between jetties	1.8	1.8	-0.02
Charleston Harbor off Ft. Sumter	1.7	2.0	0.00
South Channel at Buoy "32"	0.8	1.0	-0.02
South Channel, 0.8 mile ENE of Fort Johnson	0.8	2.6	0.72
South Channel, 0.4 mile NW of Fort Johnson	0.7	1.9	1.17
The Cove, entrance on the Cove Range	1.2	0.9	0.47
Shutes Reach, Buoy "8"	1.3	1.5	0.30
Hog Island Channel	0.8	0.8	-0.65
Folly Reach at Buoy "5"	1.2	1.6	0.03
Folly Reach north of Fort Johnson	1.2	1.1	-0.85
0.6 miles SW of Castle Pinckney	0.7	1.3	-0.35
0.4 miles west of Shutes Folly Island	0.8	2.2	0.88
Customhouse Reach off Customhouse	1.0	1.3	0.82
Customhouse Reach	1.0	1.8	0.77
Horse Reach	1.4	1.9	0.60
Hog Island Reach, Buoy "12"	1.2	1.3	0.22
Drum Island, east of bridge	1.2	2.0	0.50
Town Creek Lower Reach	1.1	2.2	0.57
Town Creek, 0.2 mile above bridge	0.8	2.5	1.10
Drum Island Reach at Buoy"45"	0.6	1.0	0.43
Cooper River, 0.2 mile above Drum Island	1.1	2.4	1.20
Cooper River at Daniel Island Reach, Buoy "48"	1.2	1.3	1.02
Cooper River at Shipyard Creek entrance	0.5	1.5	0.68
Cooper River at Daniel Island Reach	1.3	2.3	1.48
Cooper River at Daniel Island Bend	1.2	2.1	0.92
Cooper River at North Charleston	1.1	1.7	1.43
Cooper River at Filbin Creek Reach	1.2	1.8	1.52
Cooper River at Filbin Creek Reach, Buoy "58"	1.1	1.3	1.30

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

(Continued, Page 2 of 2)

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Cooper River at Ordnance Reach	1.0	1.2	1.58
Cooper River at Yellow House Creek	0.7	1.4	2.10
Cooper River at 1 mile NW of Yellow House Landing	0.7	1.8	2.43
Cooper River at SE of Woods Point	0.8	1.0	1.80
Copper River at Woods Point	0.9	1.4	2.68
Cooper River at 0.5 mile North of Snow Point	1.1	1.4	2.25
Cooper River off Amoco Pier	0.7	0.9	2.15
Cooper River at 0.5 mile below Moreland	1.9	2.0	3.54
Cooper River at 1 mile below Hagan Island	1.3	1.4	3.54
Cooper River at 0.4 mile SW of The "Tee"	1.0	1.7	4.37
Cooper River at The "Tee"	0.9	1.0	3.00
Cooper River at Childsbury, S.A.L. RR Bridge	0.7	1.7	4.72

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Ashley River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Ashley River SW of Battery	1.2	1.8	0.27
Ashley River off Wappoo Creek	1.1	1.2	0.12
Ashley River at highway bridge	1.2	1.1	-0.15
Ashley River at 0.1 mile below SCL railroad bridge	1.0	1.1	-0.10
Ashley River at 1.5 mile above SCL railroad bridge	1.2	1.5	0.37
Ashley River at State Highway 7 bridge	1.0	1.0	0.10
Ashley River at 0.1 mile east of West Marsh Island	0.7	1.0	0.38
Ashley River at Bees Ferry Bridge	1.9	2.3	1.22

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Wando River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Wando River at 0.2 mile NW of Ramley Point	1.3	1.8	-0.23
Wando River at Upper Reach, Turning Basin	1.0	1.2	-0.23
Wando River at Rathall Creek Entrance	1.3	1.7	0.42
Wando River off Nowell Creek, Buoy "19"	0.8	1.0	-0.13
Wando River at 0.2 mile above Horbeck Creek entrance	1.0	0.9	0.47
Wando River at 2.5 miles north of Horbeck Creek	0.8	1.3	0.50

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

Cooper River Flows

- Average freshwater flow of Cooper River = 4,500 cfs
- Tidal flows (measured in September 1996):
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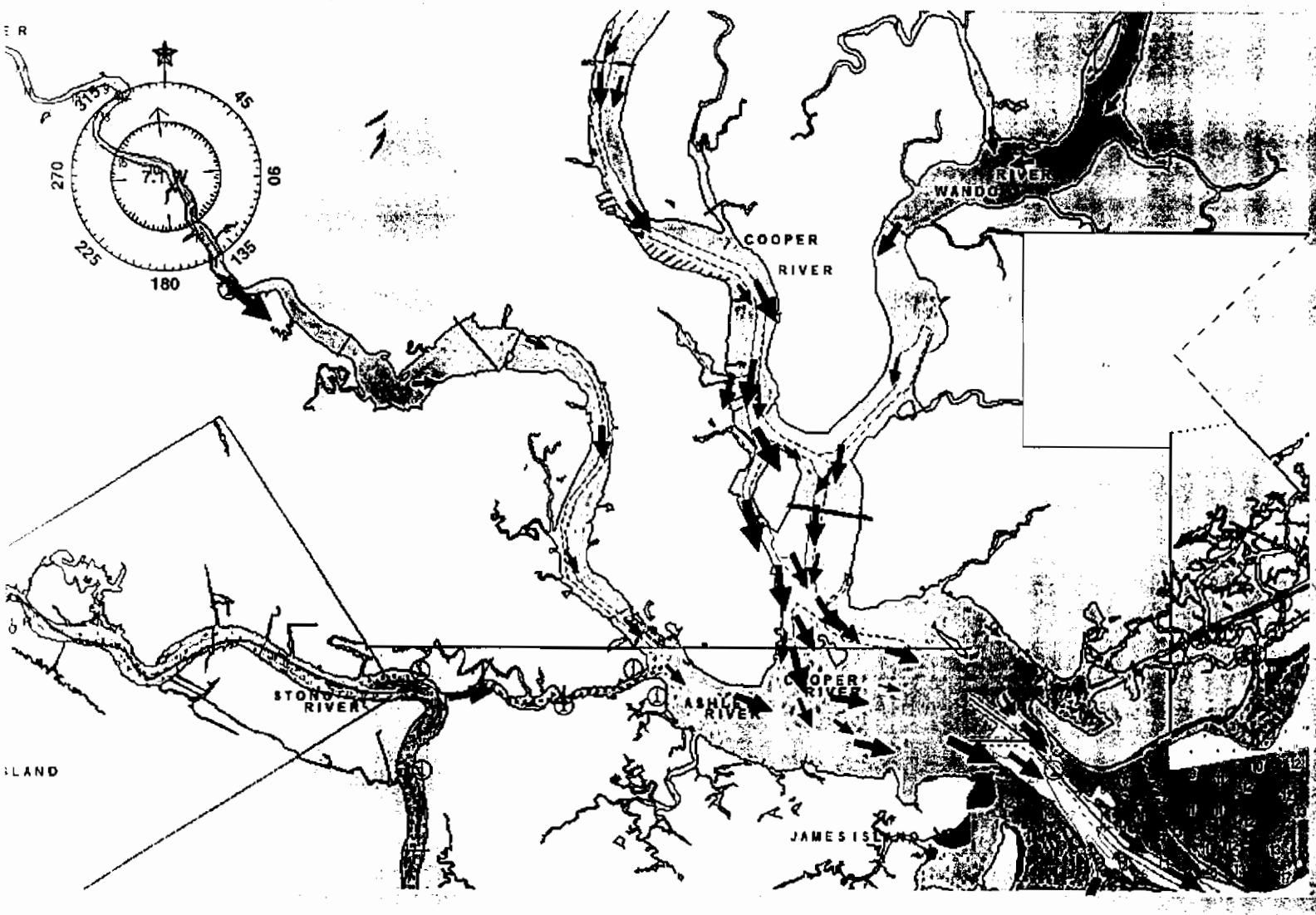
  - Cooper River at Drum Island = -320,000 to +360,000 cfs

Ebb Currents



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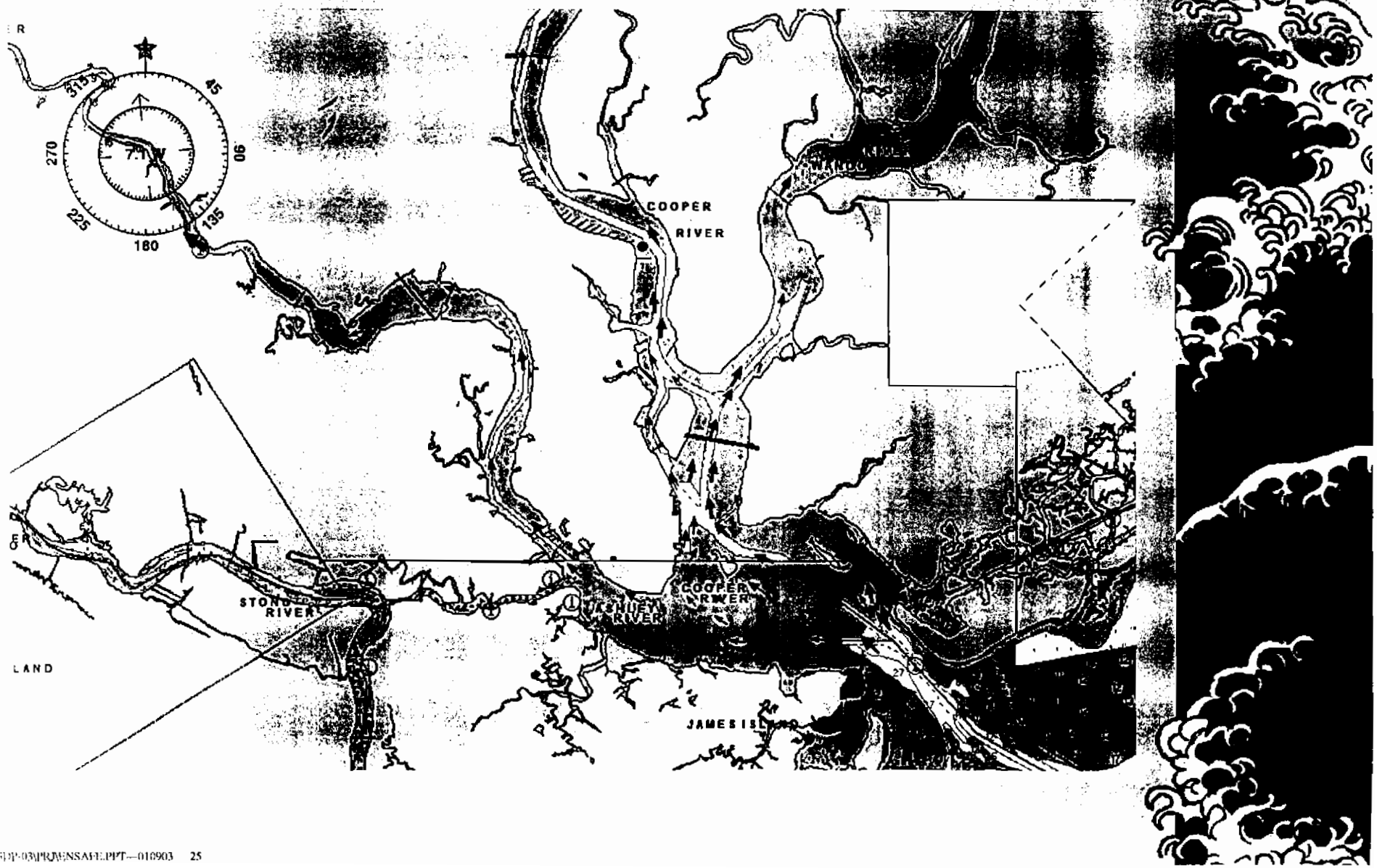

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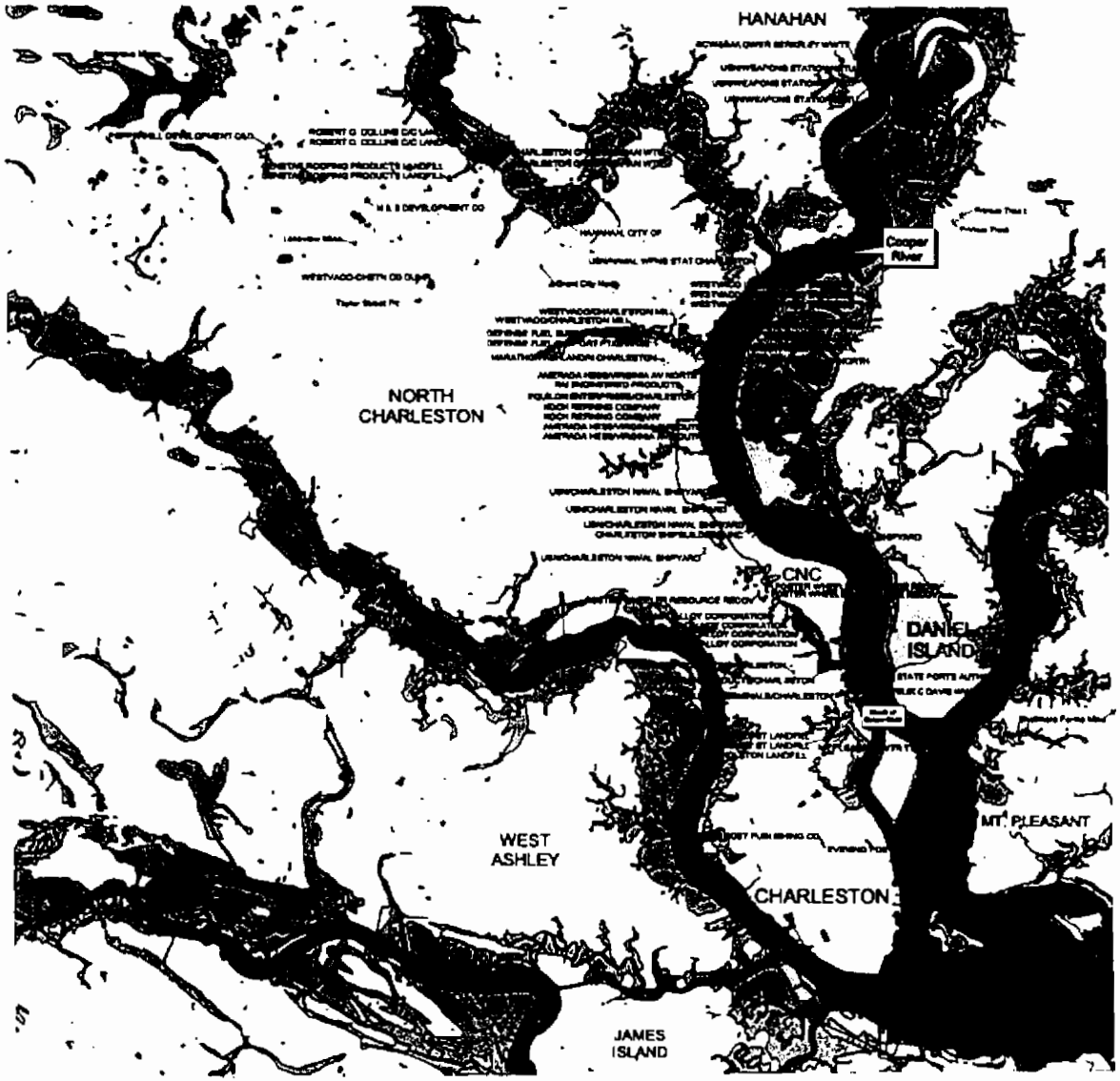

3 0 3 Miles

ZONE J
POINT OF ENTRY
EFFLUENT SAMPLING WORK PLAN
CHARLESTON NAVAL COMPLEX
CHARLESTON, SC

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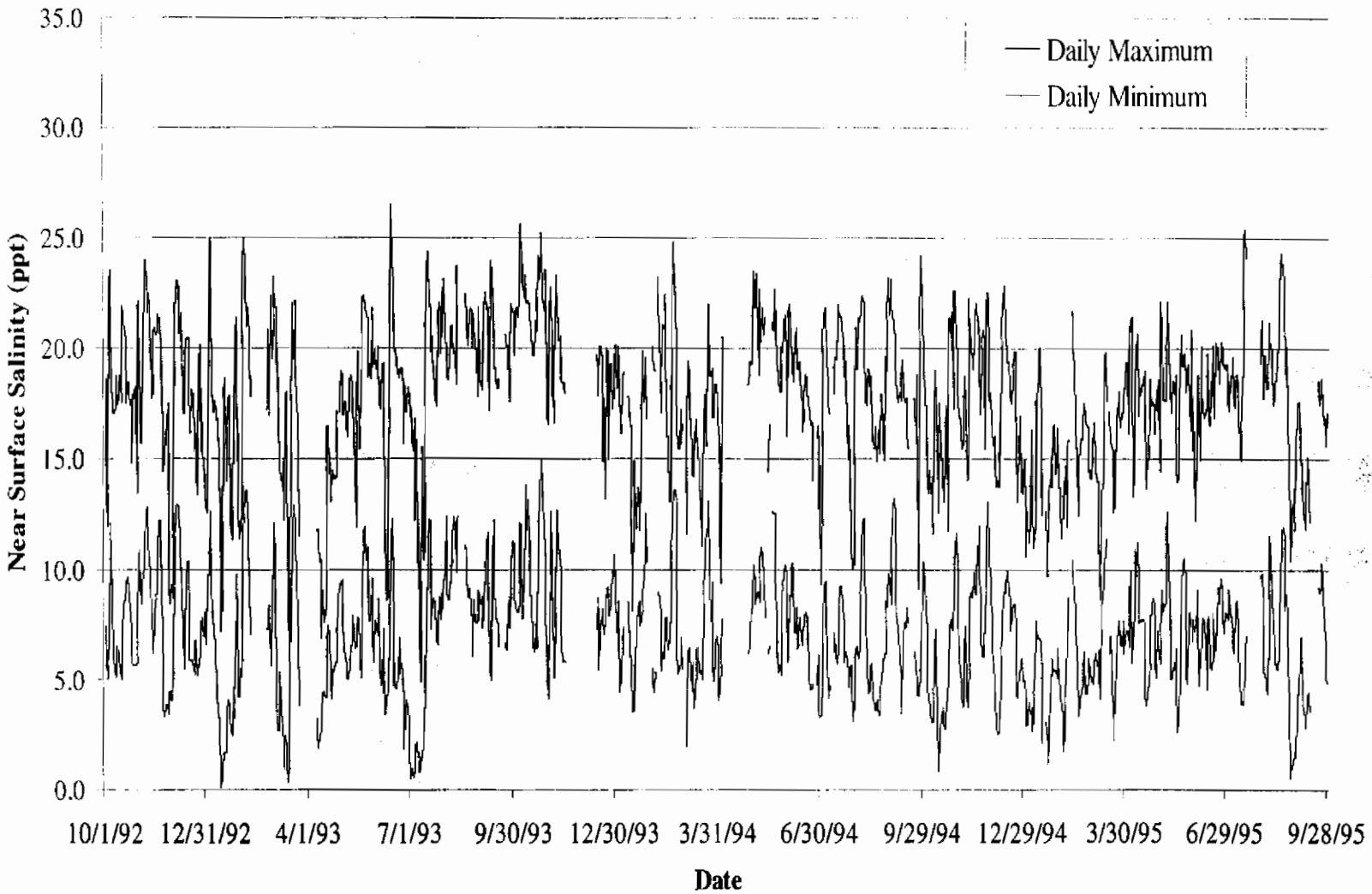

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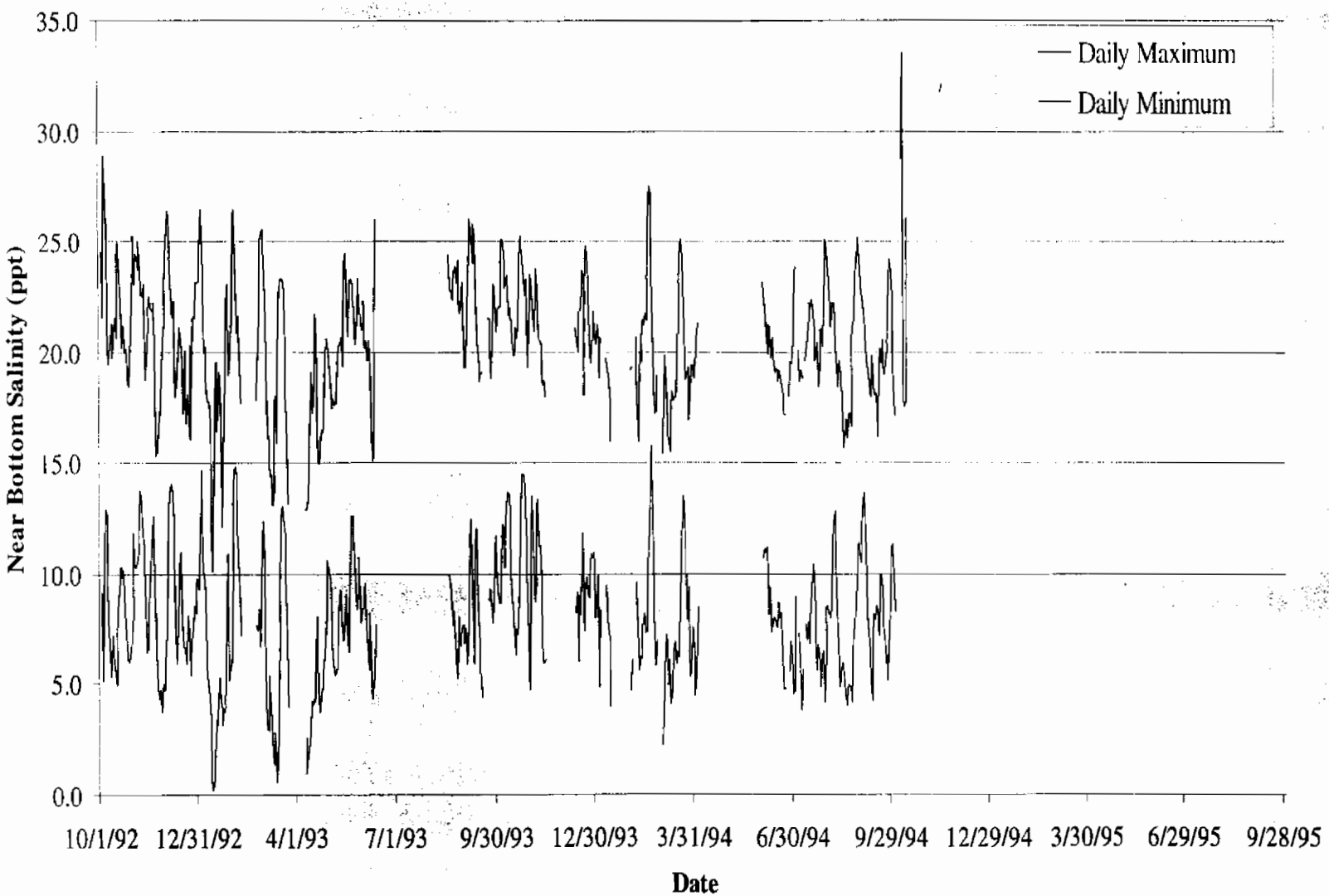

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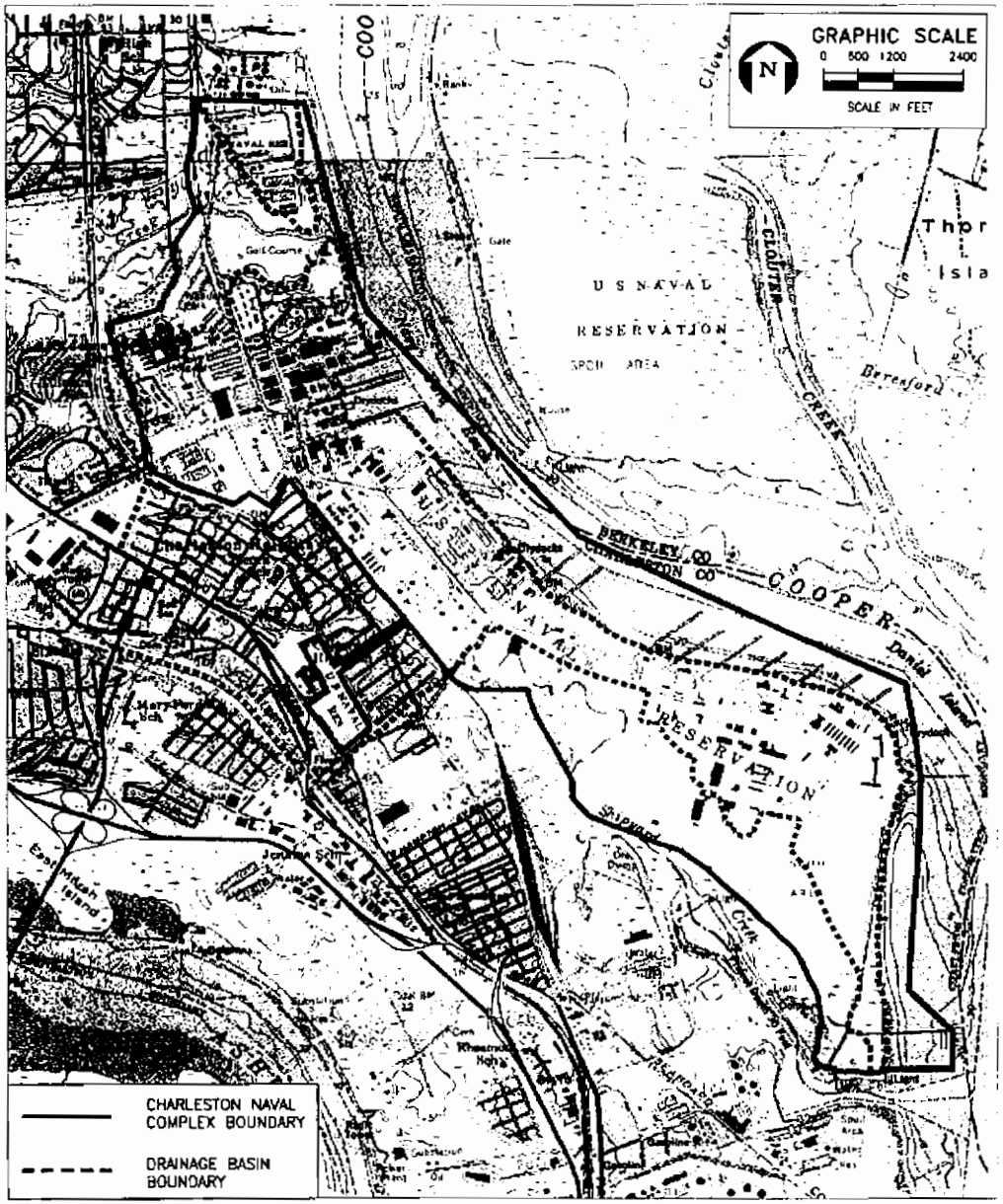

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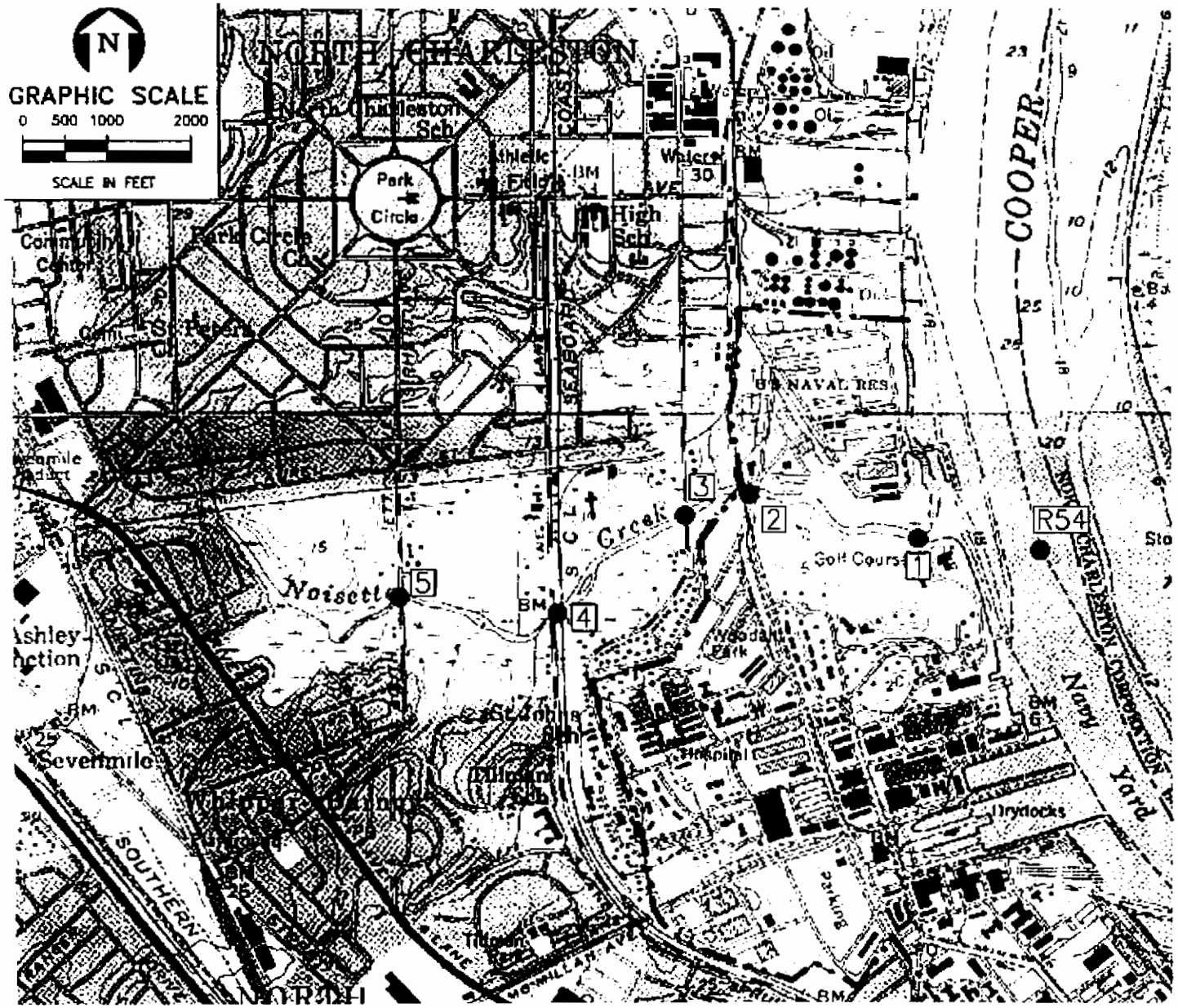
- Shipyard Creek
- Nearshore shallow area in Zone I
- Middle ground
- Shallow area near Crab Bank
- South of Hog Island and Mount Pleasant
- Near Morris Island

Monitoring Station Locations



Noisette Creek Bathymetry

Station	Width (ft)	Depth at Low Tide (ft)
1	—	4
2	108	5
3	112	2.5
4	92	<1
5	51	<1

Source: ECT, 2003.

Noisette Creek Salinity Data (December 6 & 7, 2000)

Station	Low Tide* (ppt)	High Tide* (ppt)
1	14.3	15.9
2	12.7	15.2
3	11.9	13.8
4	11.1	13.5
5	9.8	13.6
Cooper River	17.7	22.4

*Vertical average salinity.

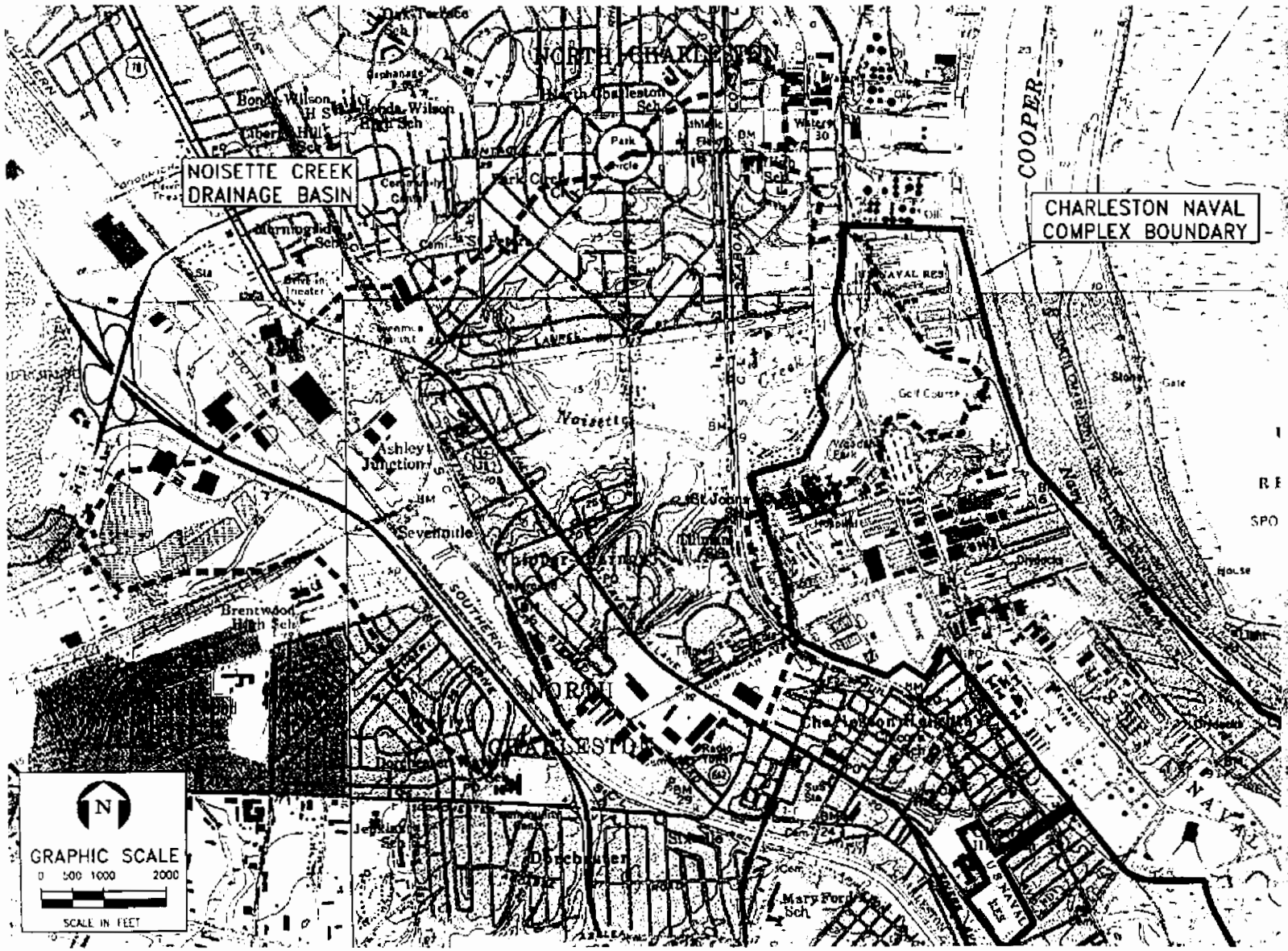
Source: ECT, 2003.

Noisette Creek Current Velocity

Station	Peak Current Speed Flood (fps)	Peak Current Speed Ebb (fps)
1	0.83	0.82
2	0.49	0.98
3	0.48	0.65
4	0.72	1.12
5	0.59	0.30

Source: ECT, 2003.

Noisette Creek Drainage Map



Noisette Creek Drainage Basin

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	123	1,624	1,747
Upland	118	1,481	1,599
Open water at low tide	5	9	14
Tidal marsh	0	134	134

Source: ECT, 2003.

Noisette Creek Runoff Summary

	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak runoff (cfs)	—	2,380	3,179	3,720	4,333	4,936	5,659
Runoff volume (acre-ft)	92.8	523.2	707.3	835.7	979.1	1,123.0	1,296.0
Runoff from CNC (acre-ft)	6.3	35.3	47.7	56.4	66.1	75.8	87.5

Source: ECT, 2002.

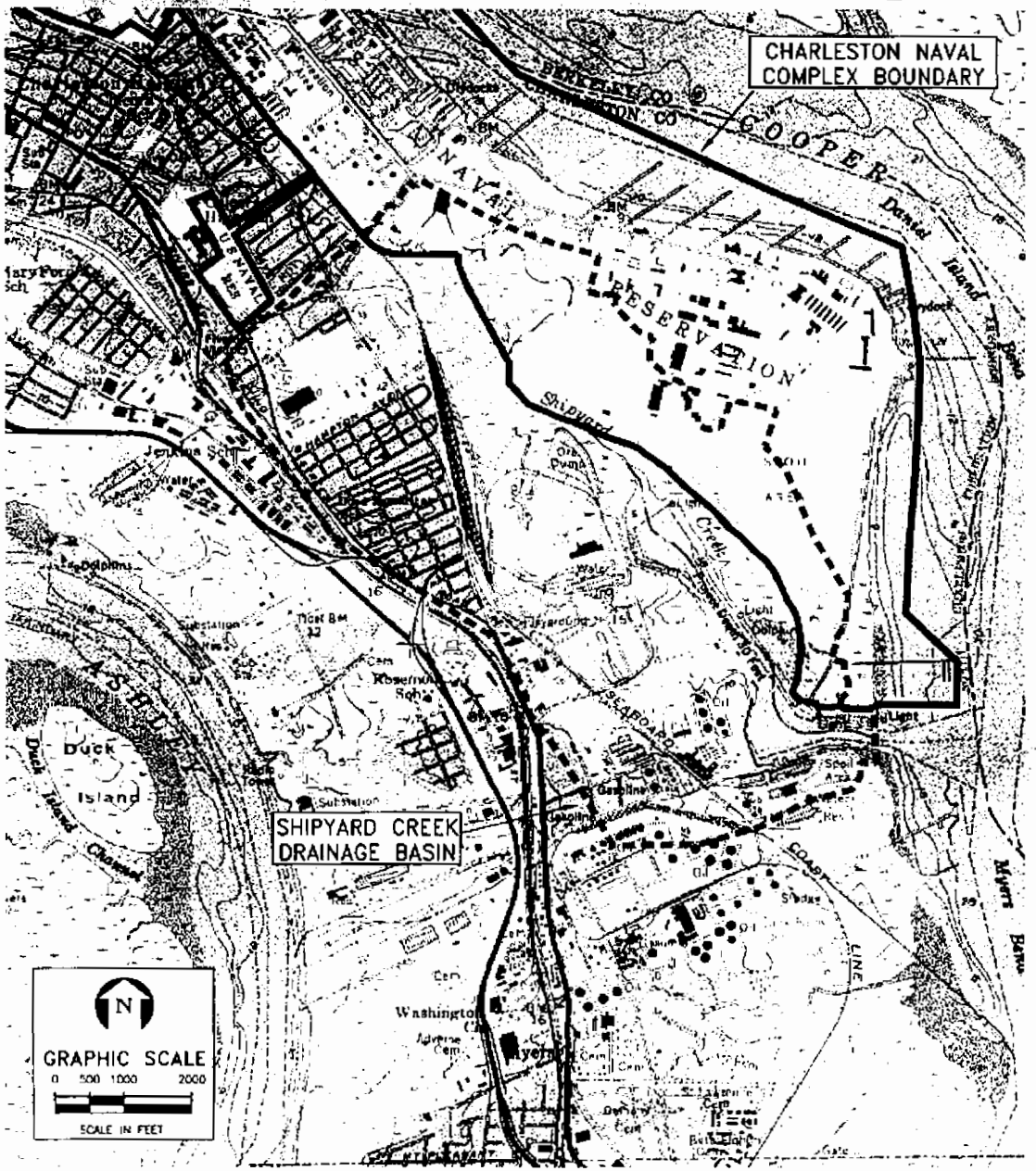
Tidal Flushing and Dilution in Noisette Creek

- Low tide volume = 46 acre-ft
- Tidal prism = 344 acre-ft
- Average tidal flow = 670 cfs
- Peak tidal flow = 1,053 cfs
- 88 percent of creek water can be flushed out in one tidal cycle
- Tidal dilution to CNC runoff is 55 to 1 during an average storm
- Tidal dilution to Noisette Creek runoff is 3.7 to 1 during an average storm
- Noisette Creek runoff/CNC runoff = 14.7
- Noisette Creek hydraulics are dominated by stormwater during severe storms

Shipyard Creek

- Outer turning basin depth = 50 ft @ MLW
- Ship channel and inner turning basin depth = 44 ft @ MLW
- Dredged area = 46 acres
- Open water = 91 acres
- Tidal marsh = 105 acres
- Entrance channel width = 600 ft
- Average tide range = 5.3 ft
- Spring tide range = 6.1 ft
- Average peak current speed at entrance channel = 0.05 ft/sec

Shipyard Creek Drainage Map



Shipyard Creek Drainage Area

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	279	878	1,157
Upland	279	682	961
Marsh	0	105	105
Open water	0	91	91

Source: ECT, 2003.

Shipyard Creek Runoff Summary

	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak runoff (cfs)	—	1,427	1,959	2,328	2,736	3,142	3,627
Runoff volume (acre-ft)	49.3	308.9	427.8	511.3	605.0	699.3	813.0
Runoff from CNC (acre-ft)	5.9	66.5	95.7	116.6	140.2	164.1	193.0

Source: ECT, 2002.

Sediment Loads

- Noisette Creek Basin = 890,000 lb/yr (366 cy/yr)
- Shipyard Creek Basin = 580,000 lb/yr (239 cy/yr)

Tidal Flushing and Dilution in Shipyard Creek

- Tidal prism = 692 acre-ft
- Low tide volume = 2,620 acre-ft
- Average tidal flow = 1,348 cfs
- Peak tidal flow = 2,118 cfs
- Average storm runoff volume = 49.3 acre-ft
- Tidal prism/average storm runoff = 14
- Tidal flushing time (dilute to 10 percent) = 5.2 days
- Shipyard Creek is a low energy area

Conclusion

- Potential contaminants from CNC can travel to a large area in the estuary
- Contaminants found in Cooper River near CNC may come from remote areas
- Large tidal dilution at Cooper River
- Noisette Creek has efficient flushing
- Shipyard Creek is near stagnant and has inefficient flushing

Hydrodynamics and Contaminant Transport in Charleston Harbor Estuary

by: Ivan B. Chou, P.E.

ECT
Environmental Consulting & Technology, Inc.

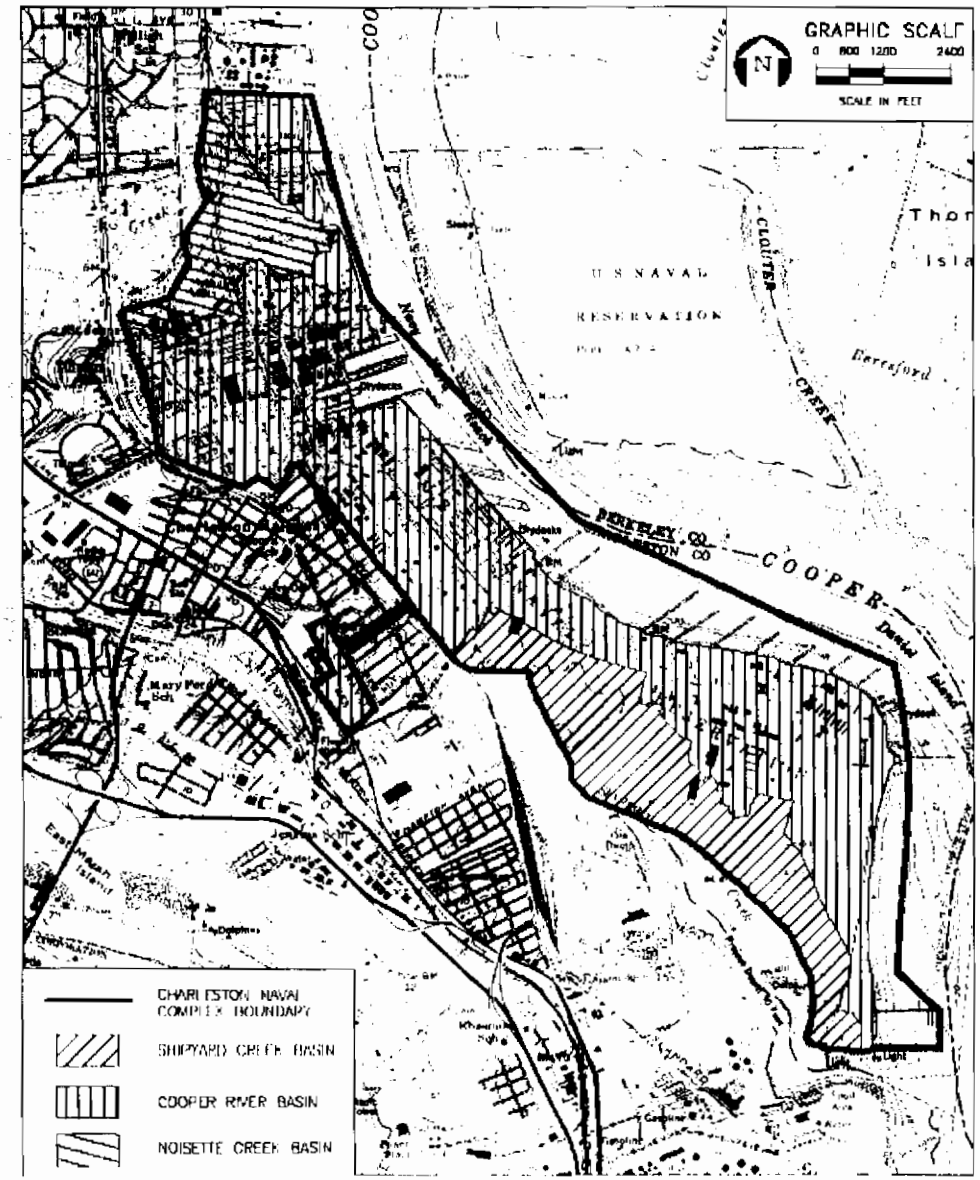
Naval Facilities Engineering Command
Southern Division

ENSAFE
Environmental and Management Consultants

Purpose

To evaluate potential contaminant migration pathway in the surface water around Charleston Naval Complex and Charleston Harbor Estuary

Charleston Naval Complex



Factors Affecting Estuarine Hydrodynamics

- Tide
- Freshwater inflow
- Bathymetry and boundary geometry
- Wind
- Density stratification

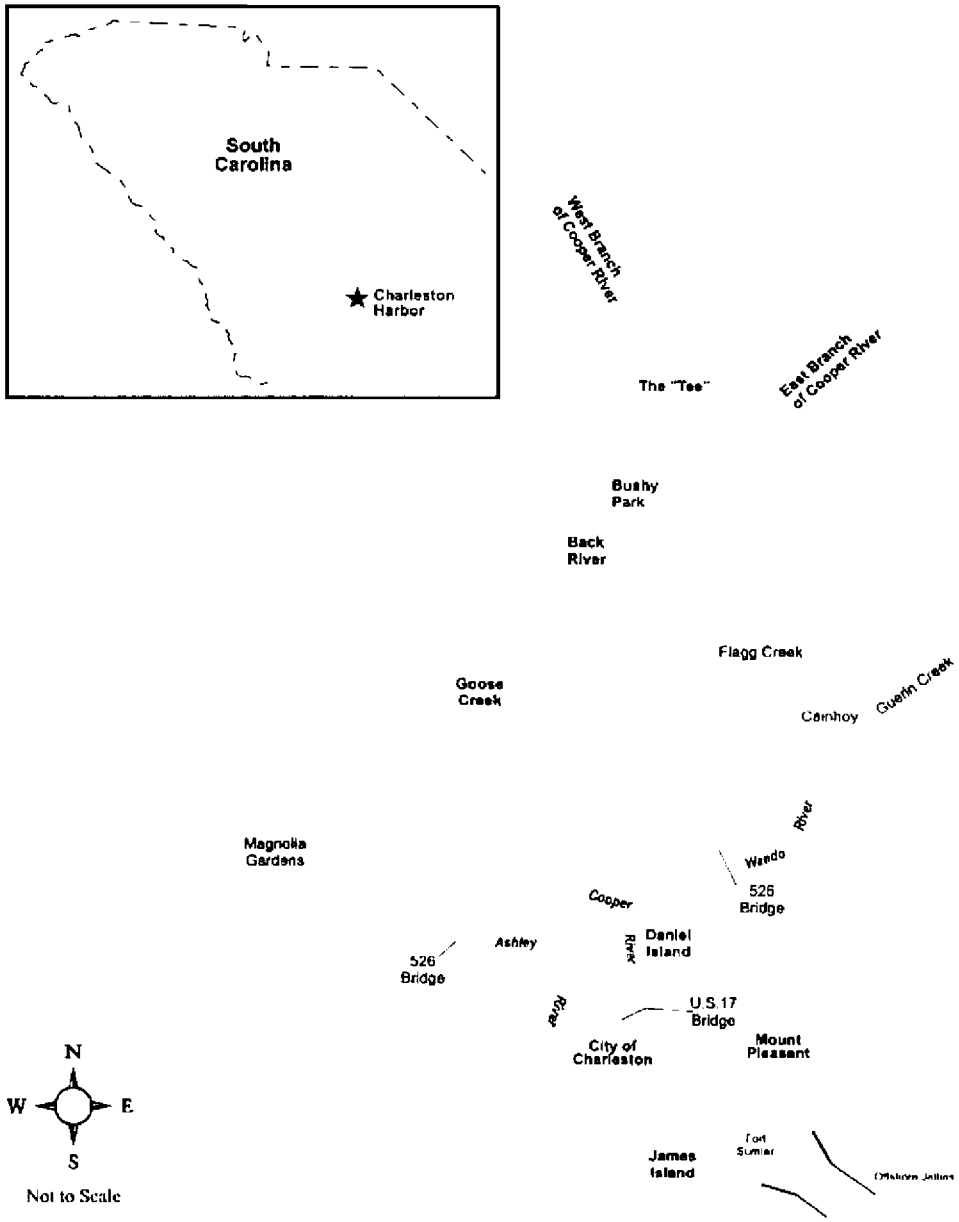
Factors Affecting Pollutant Transport

- Tidal current
- Pollutant source location
- Effluent quantity
- Effluent quality
- Sedimentation/resuspension
- Biochemical processes

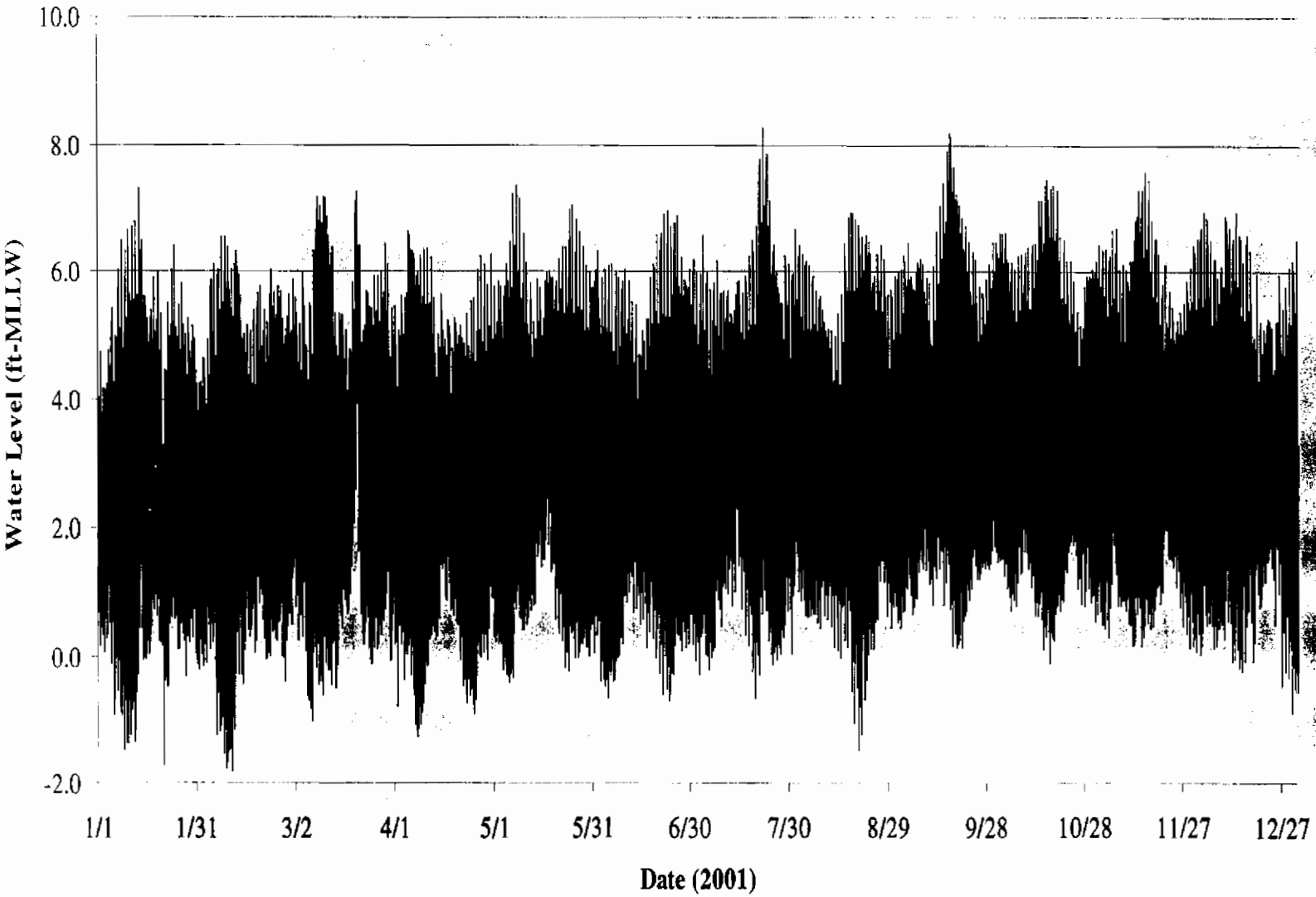
Pollutant Transport Process

- Nearfield processes:
  - Turbulent jet entrainment
  - Turbulent diffusion
  - Buoyant spreading
- Farfield processes:
  - Dispersion
  - Advection

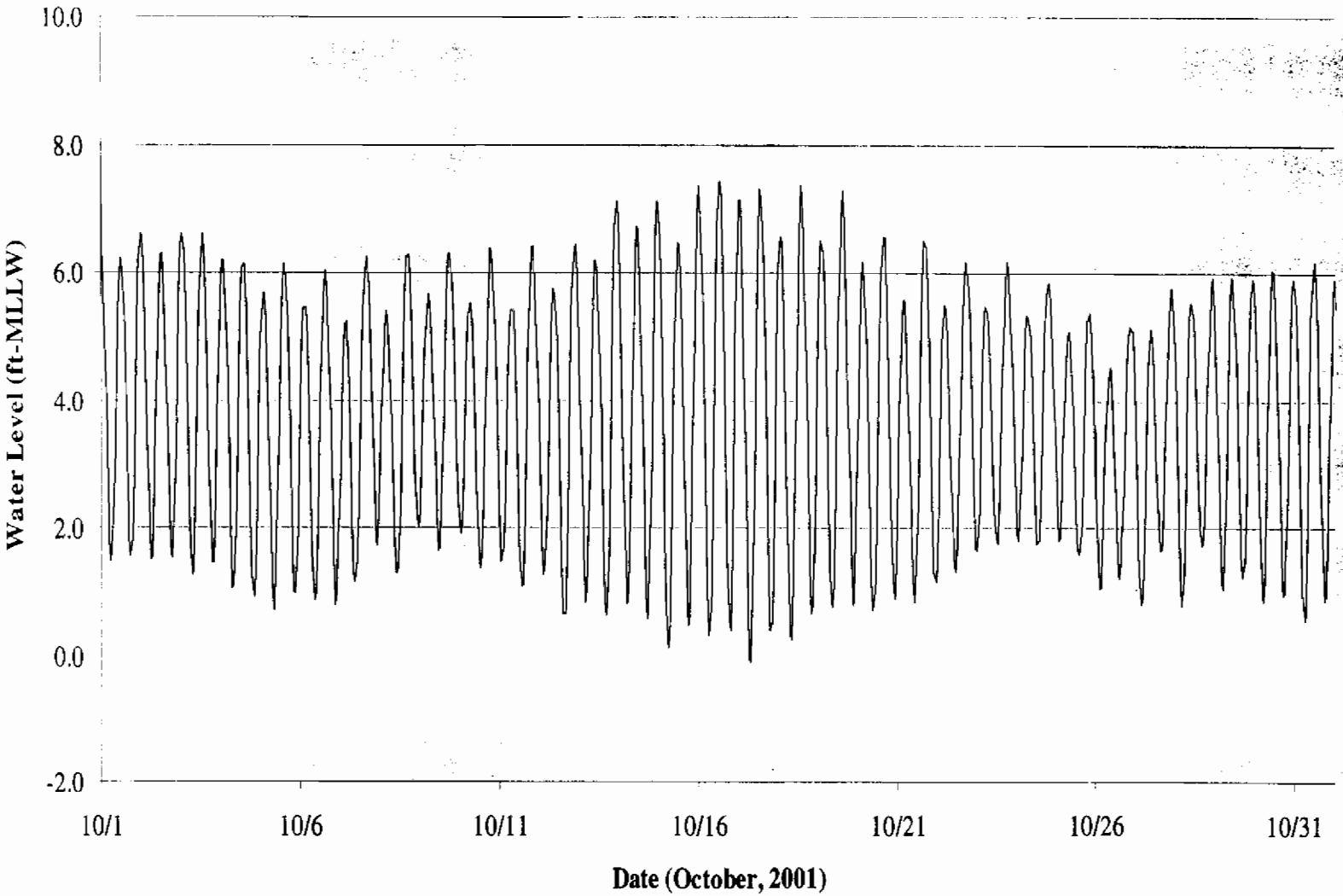
Charleston Harbor Estuary



Tidal Level at Cooper River Entrance (2001)



Tidal Level at Cooper River Entrance (October 2001)



Tidal Ranges and Phases in Charleston Harbor/Cooper River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Charleston (Customhouse Wharf)	5.27	6.11	0.00
Shipyard Creek	5.30	6.10	0.33
Cooper River at Clouter Creek, south entrance	5.40	6.26	0.32
Cooper River at Clouter Creek, north entrance	5.48	6.36	0.55
Cooper River at Snow Point	5.36	6.22	0.75
Cooper River at General Dynamics Pier	4.37	5.07	1.42
Cooper River at Dupon, Dean Hall	3.43	3.98	2.12
Cooper River at Old Rice Mill, West Branch	2.60	3.02	2.93
Cooper River at Pimlico, West Branch	1.70	1.97	3.90

Note: Phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Ranges and Phases in Ashley River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Ashley River at South Ashley Bridge	5.34	6.19	0.12
Ashley River at Duck Island	5.60	6.50	0.28
Ashley River at Cosgrove Bridge	5.62	6.52	0.30
Ashley River at Drayton, Bee's Ferry	5.76	6.68	0.65
Ashley River at Magnolia Gardens	5.79	6.72	0.90
Ashley River at Greggs Landing, Matceba Gardens	6.06	7.03	1.70

Note: The phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Ranges and Phases in Wando River

Station	Mean Tide Range (ft)	Spring Tide Range (ft)	Phase Lag (hours)
Fort Sumter	5.09	5.90	-0.02
Wando River at Hobcaw Point	5.76	6.68	0.18
Wando River at Parker Island	5.76	6.68	0.47
Wando River at Cainhoy	6.15	7.13	0.50
Wando River at Big Paradise Island	6.54	7.59	0.87
Wando River at Woodville	6.30	7.30	1.37

Note: The phase lag is relative to the tide phase at Customhouse.

Source: NOAA, 2002a.

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Charleston Harbor Entrance, between jetties	1.8	1.8	-0.02
Charleston Harbor off Ft. Sumter	1.7	2.0	0.00
South Channel at Buoy "32"	0.8	1.0	-0.02
South Channel, 0.8 mile ENE of Fort Johnson	0.8	2.6	0.72
South Channel, 0.4 mile NW of Fort Johnson	0.7	1.9	1.17
The Cove, entrance on the Cove Range	1.2	0.9	0.47
Shutes Reach, Buoy "8"	1.3	1.5	0.30
Hog Island Channel	0.8	0.8	-0.65
Folly Reach at Buoy "5"	1.2	1.6	0.03
Folly Reach north of Fort Johnson	1.2	1.1	-0.85
0.6 miles SW of Castle Pinckney	0.7	1.3	-0.35
0.4 miles west of Shutes Folly Island	0.8	2.2	0.88
Customhouse Reach off Customhouse	1.0	1.3	0.82
Customhouse Reach	1.0	1.8	0.77
Horse Reach	1.4	1.9	0.60
Hog Island Reach, Buoy "12"	1.2	1.3	0.22
Drum Island, east of bridge	1.2	2.0	0.50
Town Creek Lower Reach	1.1	2.2	0.57
Town Creek, 0.2 mile above bridge	0.8	2.5	1.10
Drum Island Reach at Buoy"45"	0.6	1.0	0.43
Cooper River, 0.2 mile above Drum Island	1.1	2.4	1.20
Cooper River at Daniel Island Reach, Buoy "48"	1.2	1.3	1.02
Cooper River at Shipyard Creek entrance	0.5	1.5	0.68
Cooper River at Daniel Island Reach	1.3	2.3	1.48
Cooper River at Daniel Island Bend	1.2	2.1	0.92
Cooper River at North Charleston	1.1	1.7	1.43
Cooper River at Filbin Creek Reach	1.2	1.8	1.52
Cooper River at Filbin Creek Reach, Buoy "58"	1.1	1.3	1.30

Tidal Current Velocities and Phases in Charleston Harbor/Cooper River

(Continued, Page 2 of 2)

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Cooper River at Ordnance Reach	1.0	1.2	1.58
Cooper River at Yellow House Creek	0.7	1.4	2.10
Cooper River at 1 mile NW of Yellow House Landing	0.7	1.8	2.43
Cooper River at SE of Woods Point	0.8	1.0	1.80
Copper River at Woods Point	0.9	1.4	2.68
Cooper River at 0.5 mile North of Snow Point	1.1	1.4	2.25
Cooper River off Amoco Pier	0.7	0.9	2.15
Cooper River at 0.5 mile below Moreland	1.9	2.0	3.54
Cooper River at 1 mile below Hagan Island	1.3	1.4	3.54
Cooper River at 0.4 mile SW of The "Tee"	1.0	1.7	4.37
Cooper River at The "Tee"	0.9	1.0	3.00
Cooper River at Childsbury, S.A.L. RR Bridge	0.7	1.7	4.72

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Ashley River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Ashley River SW of Battery	1.2	1.8	0.27
Ashley River off Wappoo Creek	1.1	1.2	0.12
Ashley River at highway bridge	1.2	1.1	-0.15
Ashley River at 0.1 mile below SCL railroad bridge	1.0	1.1	-0.10
Ashley River at 1.5 mile above SCL railroad bridge	1.2	1.5	0.37
Ashley River at State Highway 7 bridge	1.0	1.0	0.10
Ashley River at 0.1 mile east of West Marsh Island	0.7	1.0	0.38
Ashley River at Bees Ferry Bridge	1.9	2.3	1.22

Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter

Source: NOAA, 2002b.

Tidal Current Velocities and Phases in Wando River

Station	Average Peak Flood Velocity (knots)	Average Peak Ebb Velocity (knots)	Phase Lag at Low Slack (hours)
Wando River at 0.2 mile NW of Ramley Point	1.3	1.8	-0.23
Wando River at Upper Reach, Turning Basin	1.0	1.2	-0.23
Wando River at Rathall Creek Entrance	1.3	1.7	0.42
Wando River off Nowell Creek, Buoy "19"	0.8	1.0	-0.13
Wando River at 0.2 mile above Horbeck Creek entrance	1.0	0.9	0.47
Wando River at 2.5 miles north of Horbeck Creek	0.8	1.3	0.50

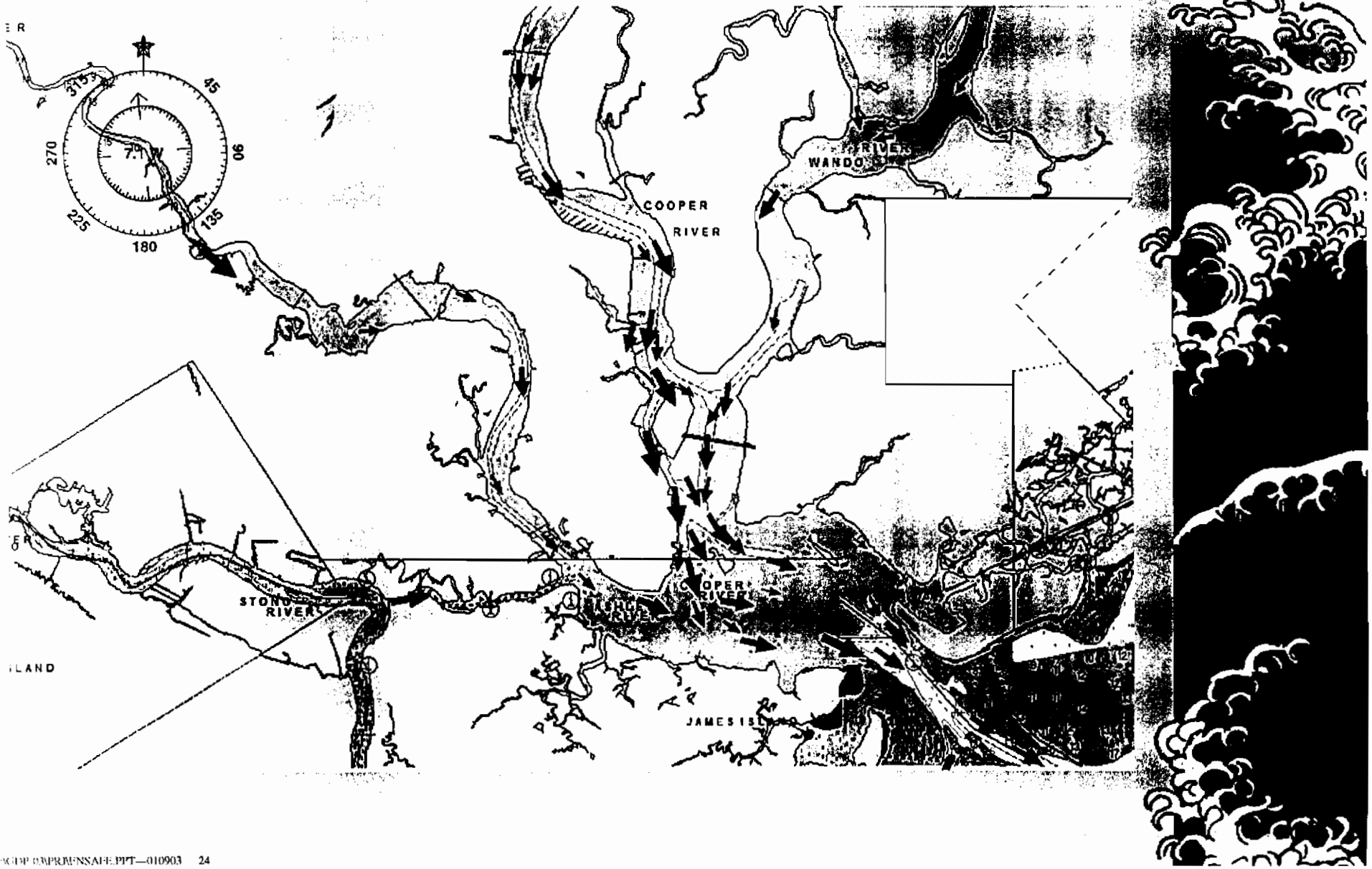
Note: Phase lag is relative to the phase at Charleston Harbor off Fort Sumter.

Source: NOAA, 2002b.

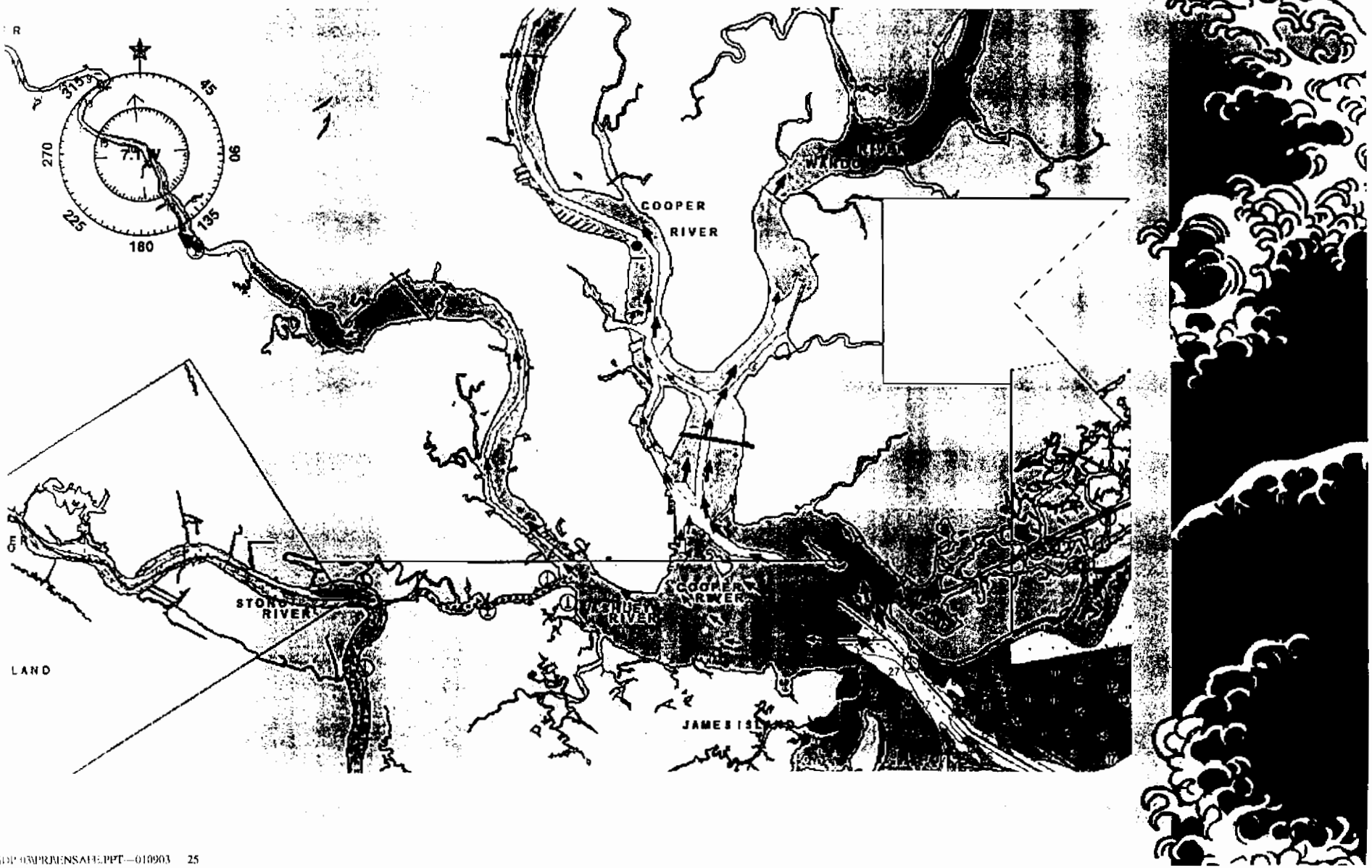
Cooper River Flows

- Average freshwater flow of Cooper River = 4,500 cfs
- Tidal flows (measured in September 1996):
  - Cooper River at Daniel Island = -150,000 to +160,000 cfs
  - Cooper River at Drum Island = -320,000 to +360,000 cfs

Ebb Currents



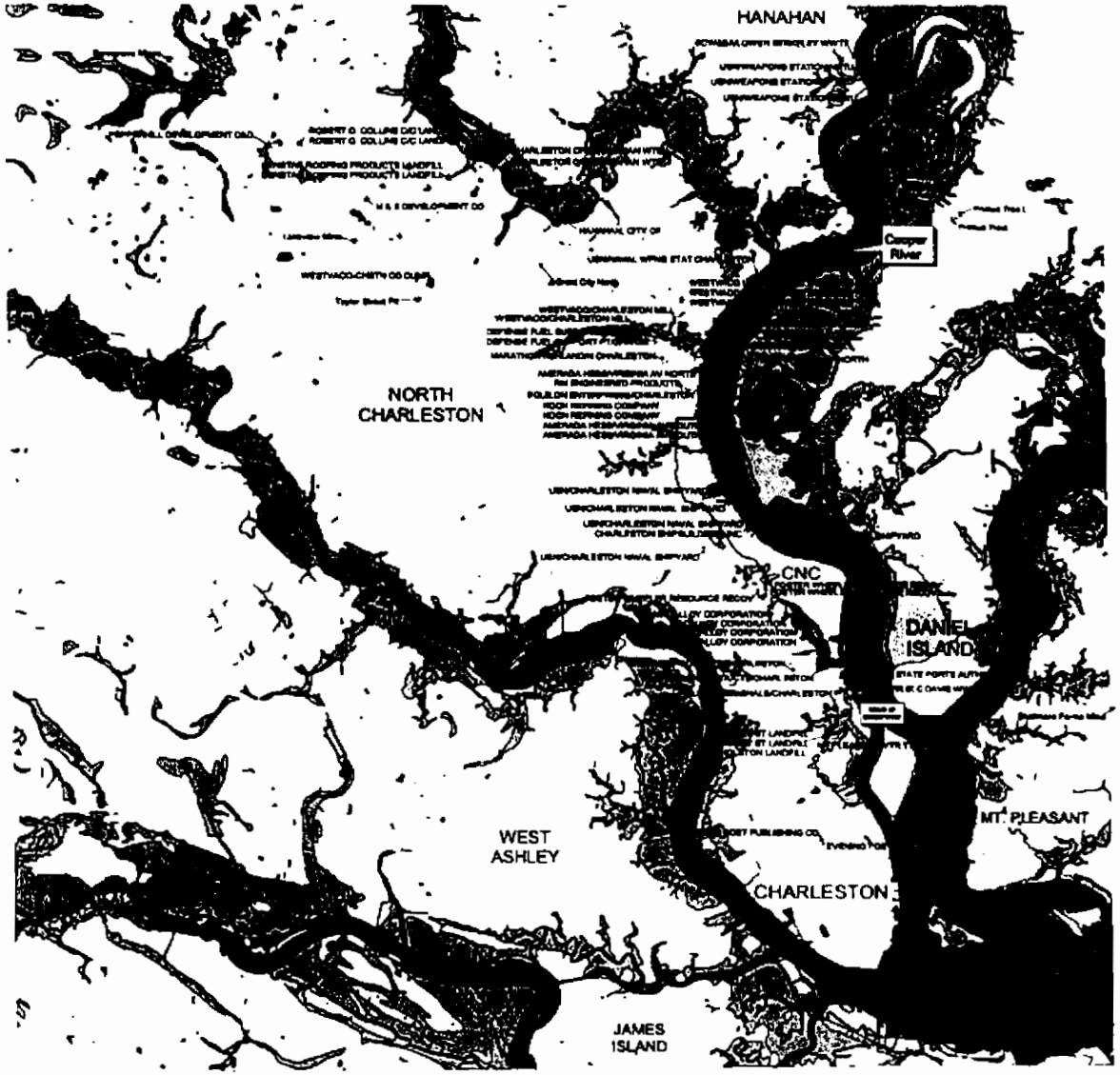
Flood Currents



Excursion Analysis

- Tidal excursion: the average travel distance of a water particle on the flood tide
- Methodology: Particle tracking by Lagrangian integration
- Results:
  - Cooper River = 4.3 miles north of CNC northern boundary
  - Ashley River = 3.5 miles upstream of river entrance
  - Wando River = 5.6 miles upstream of river entrance

Tidal Excursion Limits

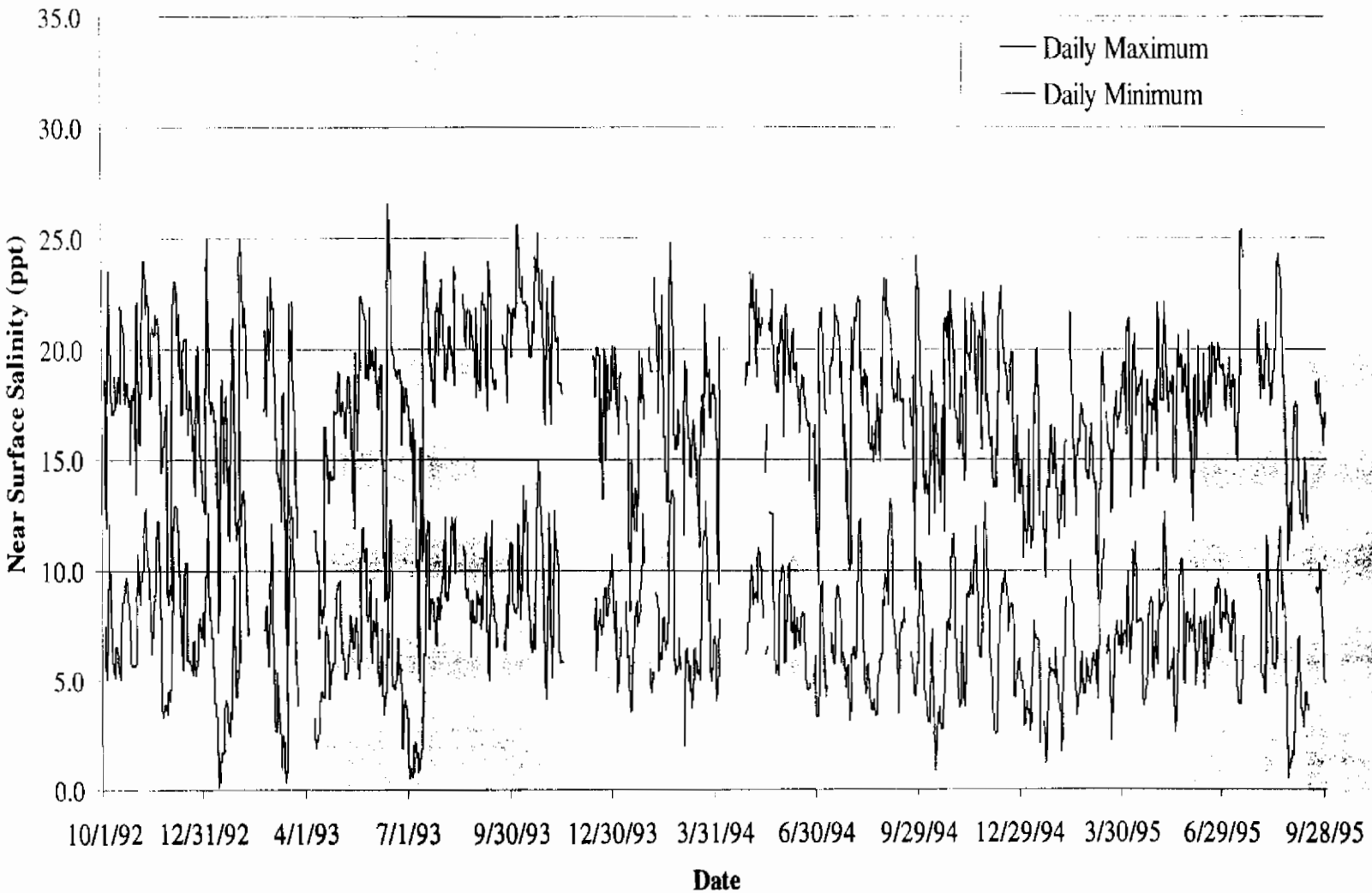


3 0 3 Miles

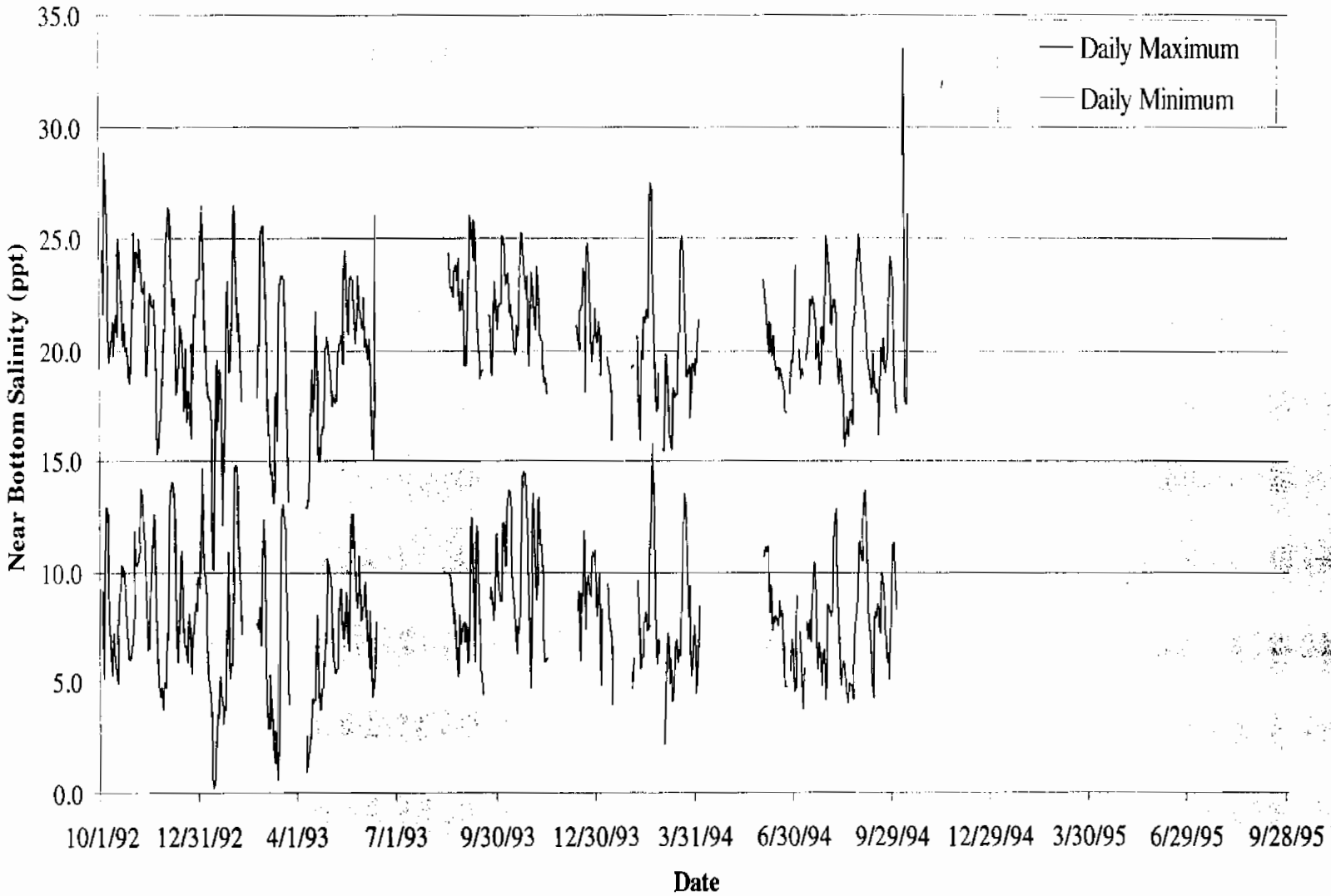
ZONE J
POINT OF ENTRY
EFFLUENT SAMPLING WORK PLAN
CHARLESTON NAVAL COMPLEX
CHARLESTON, SC

The data used to create this map was collected and created by SC DHEC. This information is contained in the Watershed Water Quality Management Strategy Report.

Cooper River Surface Salinity Near Army Depot



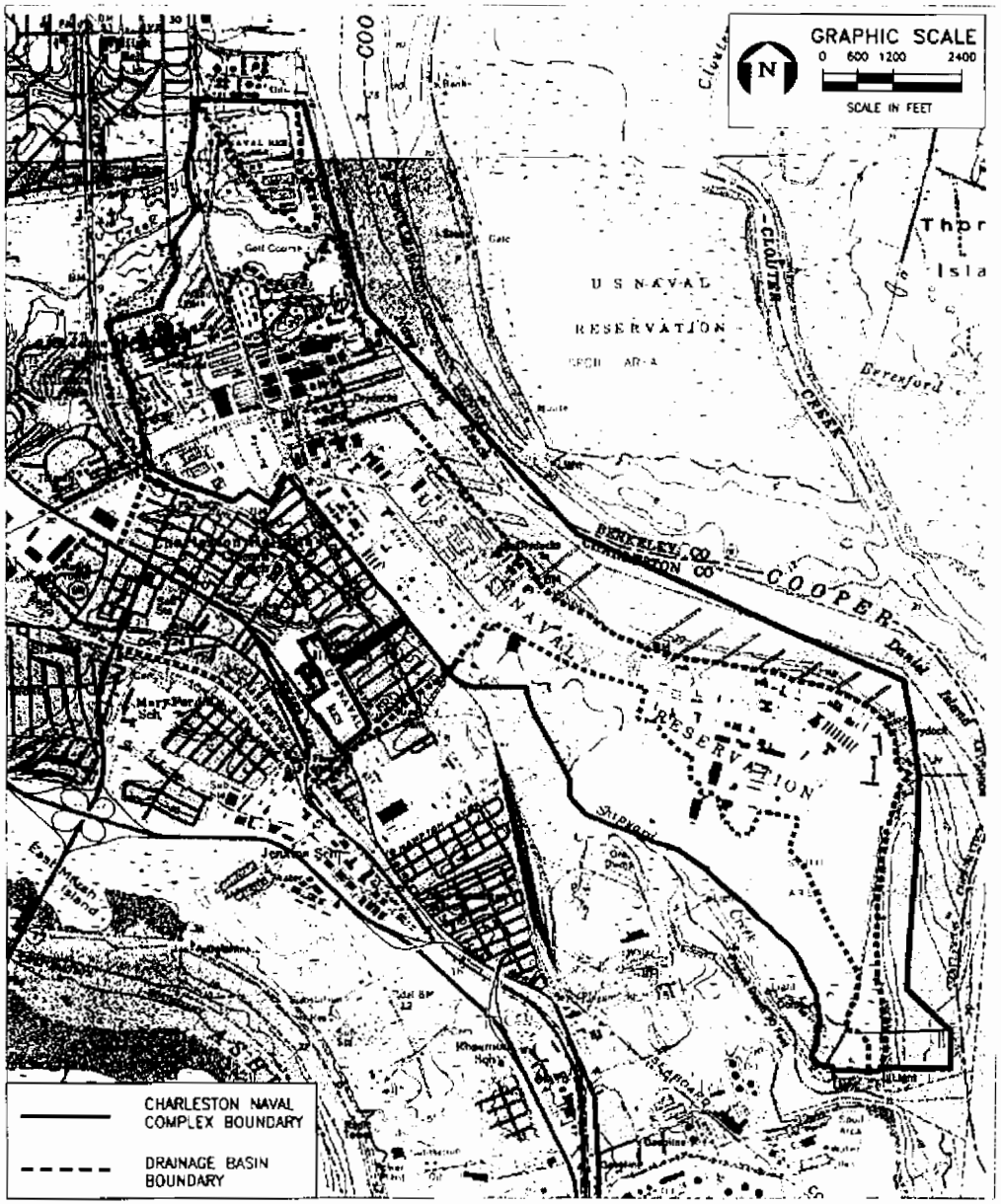
Cooper River Bottom Salinity Near Army Depot



Cooper River Salinity Near CNC

	Surface (ppt)	Bottom (ppt)
Average daily mean	11.3	14.3
Average daily minimum	7.1	8.5
Average daily maximum	17.8	20.6
Minimum	0.1	0.3
Maximum	26.4	33.9

Cooper River Watershed



Areas Draining to Cooper River

	Onsite (acres)	Offsite (acres)	Total (acres)
Total drainage area	886	440	1,326
Upland	849	433	1,282
Tidal marsh and wetland	37	7	44

Summary of Surface Runoff to Cooper River Along the CNC Shoreline

	Mean Event	Return Period (Years)					
		2	5	10	25	50	100
Rainfall (inches)	0.75	4.6	5.9	6.8	7.8	8.8	10
Peak Runoff Rate (cfs)	—	1,939	2,607	3,065	3,568	4,077	4,685
Total Runoff Volume (acre-ft)	53.0	385.8	524.7	621.8	730.3	839.1	970.2
Runoff from CNC (acre-ft)	34.9	265.4	358.8	424.0	496.7	589.6	657.4

Source: ECT, 2002.

Sediment Loads from Cooper River Basin

- Annual average: 700,000 lb/yr (288 cubic yards per year)
- Wet season = 280,000 lb/yr (115 cubic yards per year)

Percentage of Particle Mass in Stormwater as Related to Average Settling Velocity

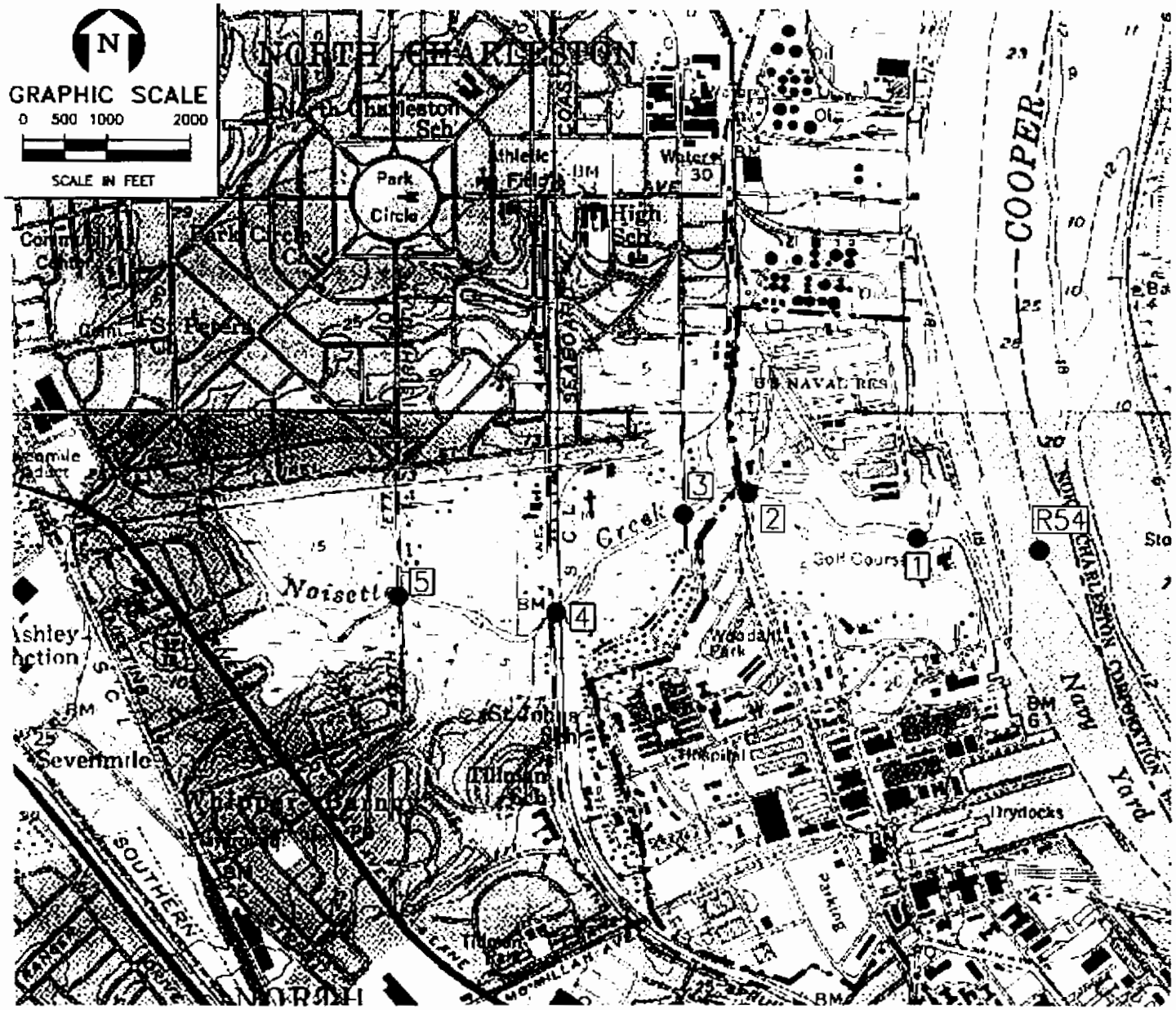
Cumulative Percent of Mass in Urban Runoff	Average Settling Velocity (ft/hour)	Settling Time in 40 ft of Water (hour)
0 to 20	0.03	1,670
20 to 40	0.33	152
40 to 60	1.5	27
60 to 80	7	5.7
80 to 100	70	0.6

Sources: Wanielista and Yousef, 1993.
EPA, 1983.
ECT, 2002.

Potential Depositional Areas

- Dry dock area in Zone E
- Shipyard Creek
- Nearshore shallow area in Zone I
- Middle ground
- Shallow area near Crab Bank
- South of Hog Island and Mount Pleasant
- Near Morris Island

Monitoring Station Locations



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Station	Low Tide* (ppt)	High Tide* (ppt)
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Cooper River	17.7	22.4

*Vertical average salinity.

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Station	Peak Current Speed Flood (fps)	Peak Current Speed Ebb (fps)
1	0.83	0.82
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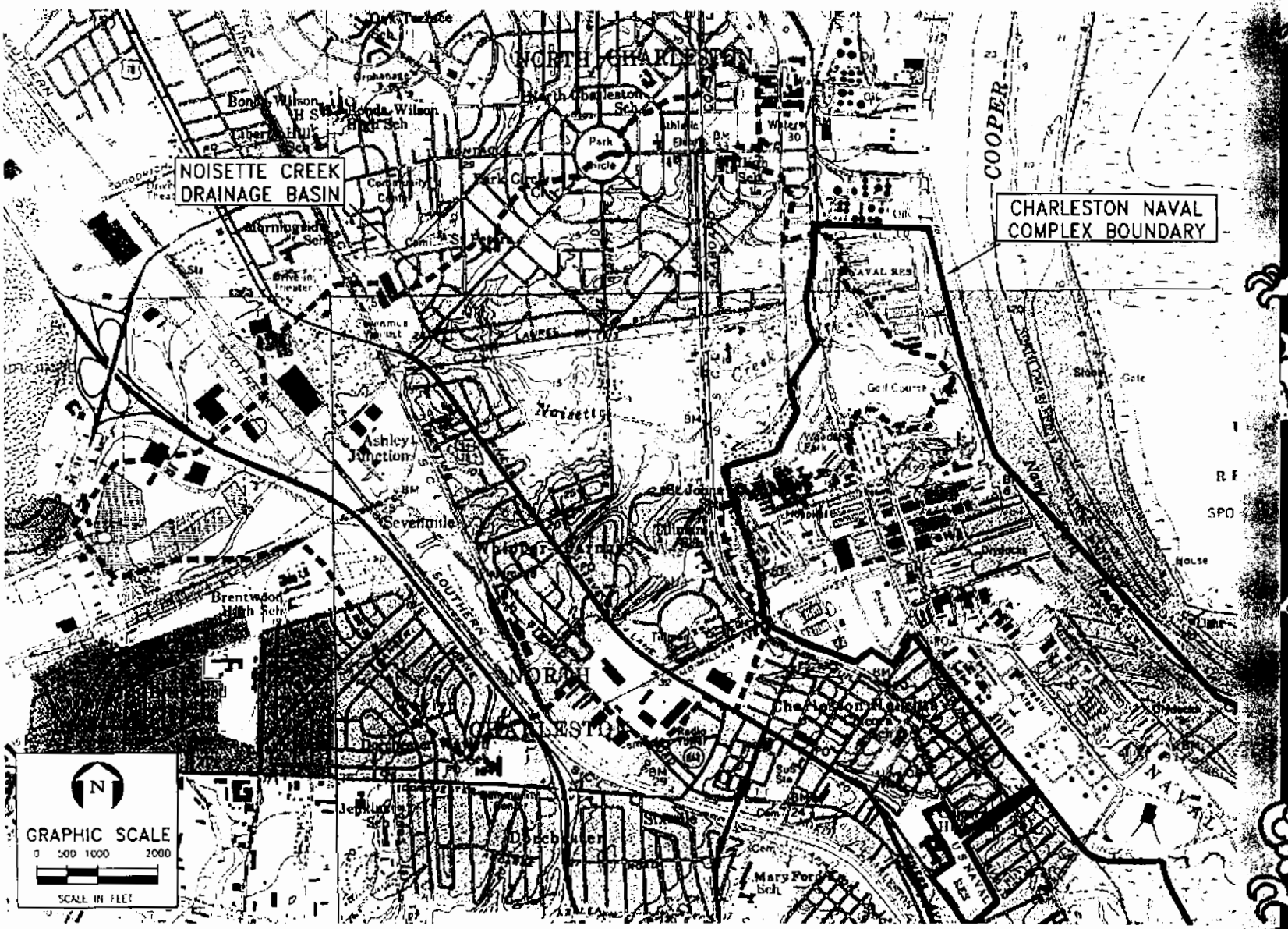
Source: ECT, 2003.

Noisette Creek Drainage Map



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Upland	118	1,481	1,599
Open water at low tide	5	9	14
Tidal marsh	0	134	134

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	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
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Peak runoff (cfs)	—	2,380	3,179	3,720	4,333	4,936	5,659
Runoff volume (acre-ft)	92.8	523.2	707.3	835.7	979.1	1,123.0	1,296.0
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- Low tide volume = 46 acre-ft
- Tidal prism = 344 acre-ft
- Average tidal flow = 670 cfs
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- 88 percent of creek water can be flushed out in one tidal cycle
- Tidal dilution to CNC runoff is 55 to 1 during an average storm
- Tidal dilution to Noisette Creek runoff is 3.7 to 1 during an average storm
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- Noisette Creek hydraulics are dominated by stormwater during severe storms

Shipyard Creek

- Outer turning basin depth = 50 ft @ MLW
- Ship channel and inner turning basin depth = 44 ft @ MLW
- Dredged area = 46 acres
- Open water = 91 acres
- Tidal marsh = 105 acres
- Entrance channel width = 600 ft
- Average tide range = 5.3 ft
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- Average peak current speed at entrance channel = 0.05 ft/sec

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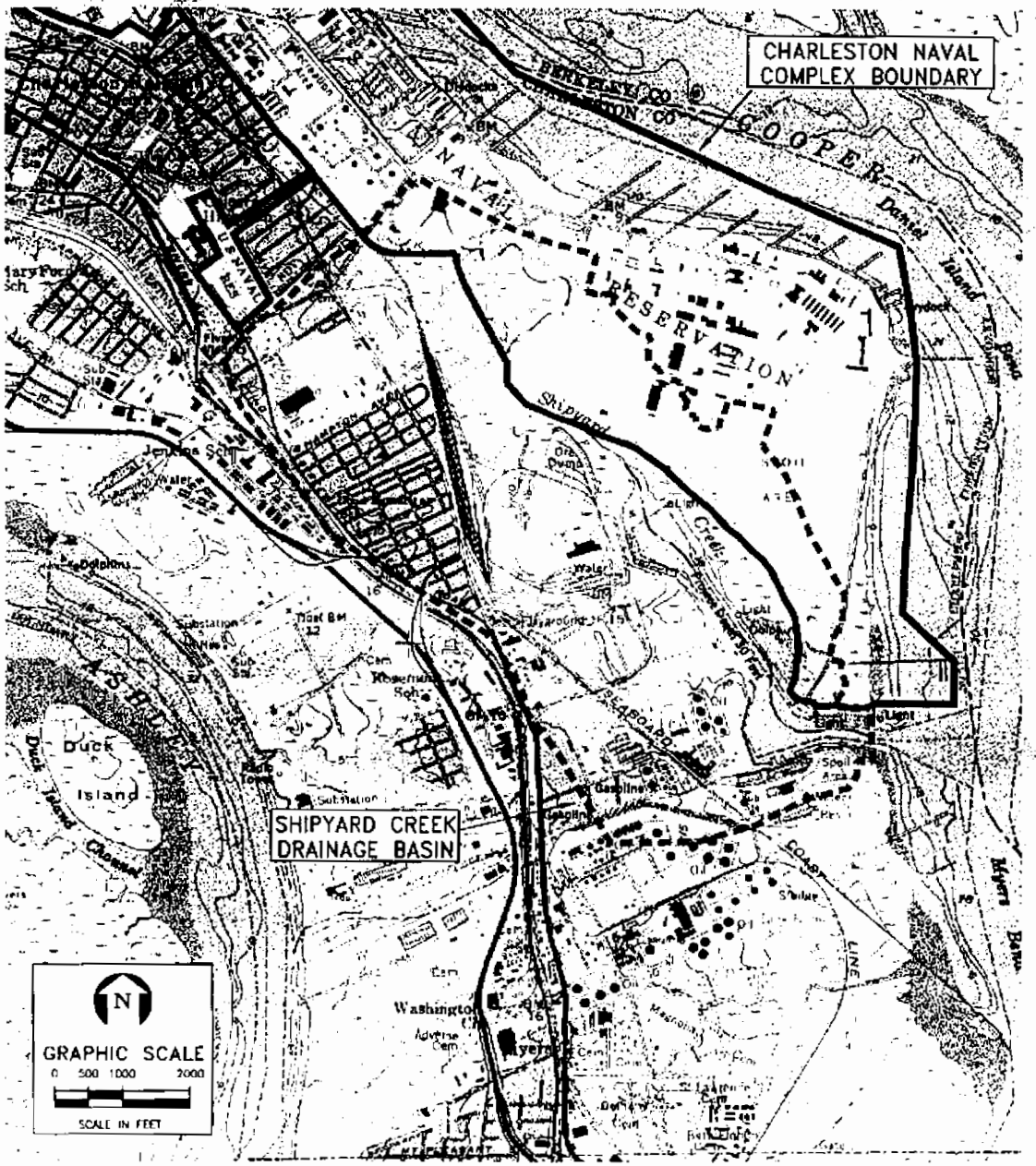

Shipyard Creek Drainage Area

	Onsite (acres)	Offsite (acres)	Total (acres)
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Upland	279	682	961
Marsh	0	105	105
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	Mean Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
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Peak runoff (cfs)	—	1,427	1,959	2,328	2,736	3,142	3,627
Runoff volume (acre-ft)	49.3	308.9	427.8	511.3	605.0	699.3	813.0
Runoff from CNC (acre-ft)	5.9	66.5	95.7	116.6	140.2	164.1	193.0

Source: ECT, 2002.

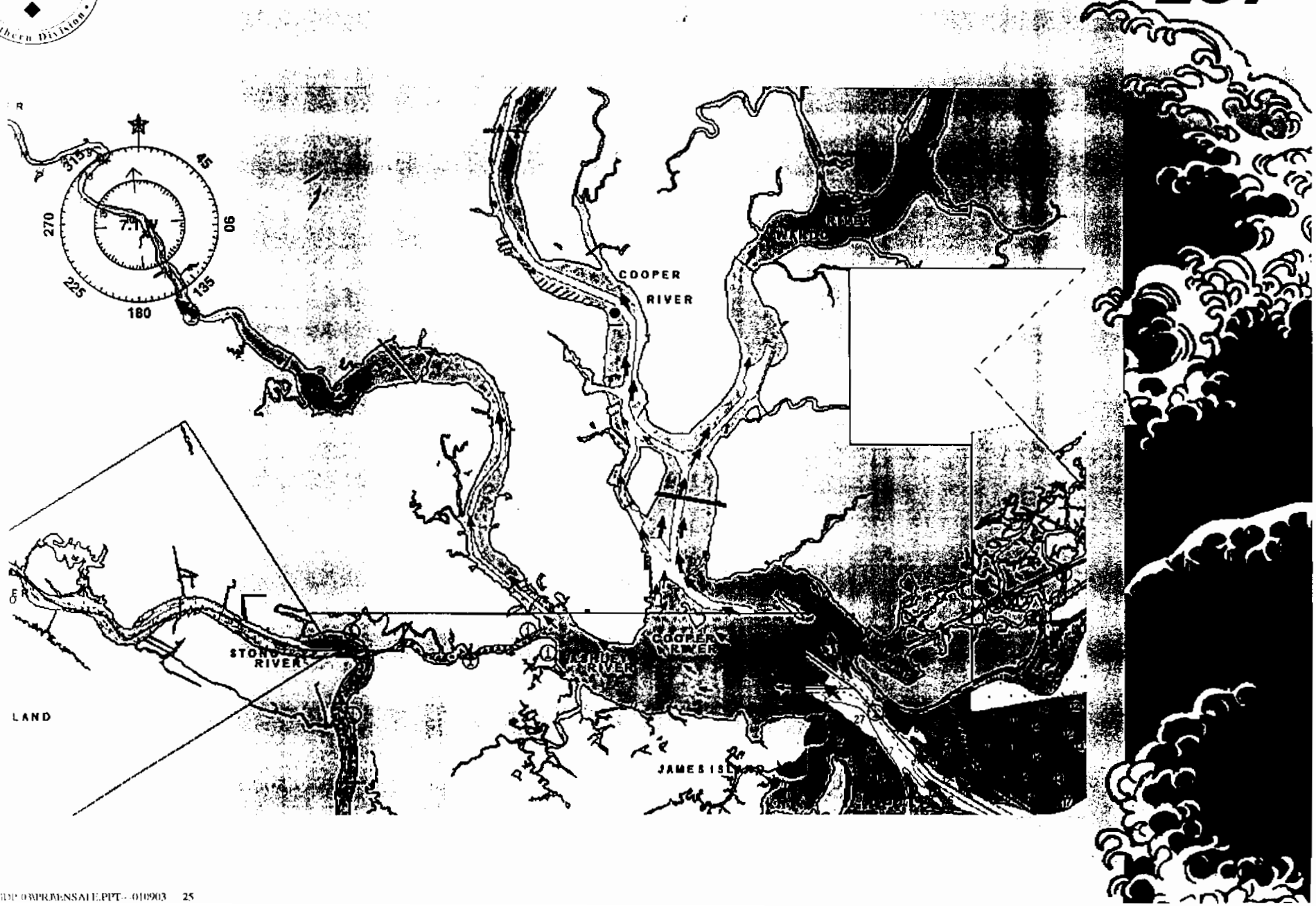
Sediment Loads

- Noisette Creek Basin = 890,000 lb/yr (366 cy/yr)
- Shipyard Creek Basin = 580,000 lb/yr (239 cy/yr)

Tidal Flushing and Dilution in Shipyard Creek

- Tidal prism = 692 acre-ft
- Low tide volume = 2,620 acre-ft
- Average tidal flow = 1,348 cfs
- Peak tidal flow = 2,118 cfs
- Average storm runoff volume = 49.3 acre-ft
- Tidal prism/average storm runoff = 14
- Tidal flushing time (dilute to 10 percent) = 5.2 days
- Shipyard Creek is a low energy area

Conclusion

- Potential contaminants from CNC can travel to a large area in the estuary
- Contaminants found in Cooper River near CNC may come from remote areas
- Large tidal dilution at Cooper River
- Noisette Creek has efficient flushing
- Shipyard Creek is near stagnant and has inefficient flushing

Flood Currents