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LOWER ST. JOHNS RIVER BASIN RECONNAISSANCE

HYDRODYNAMICS AND SALINITY OF SURFACE WATER

by

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Palatka, Florida

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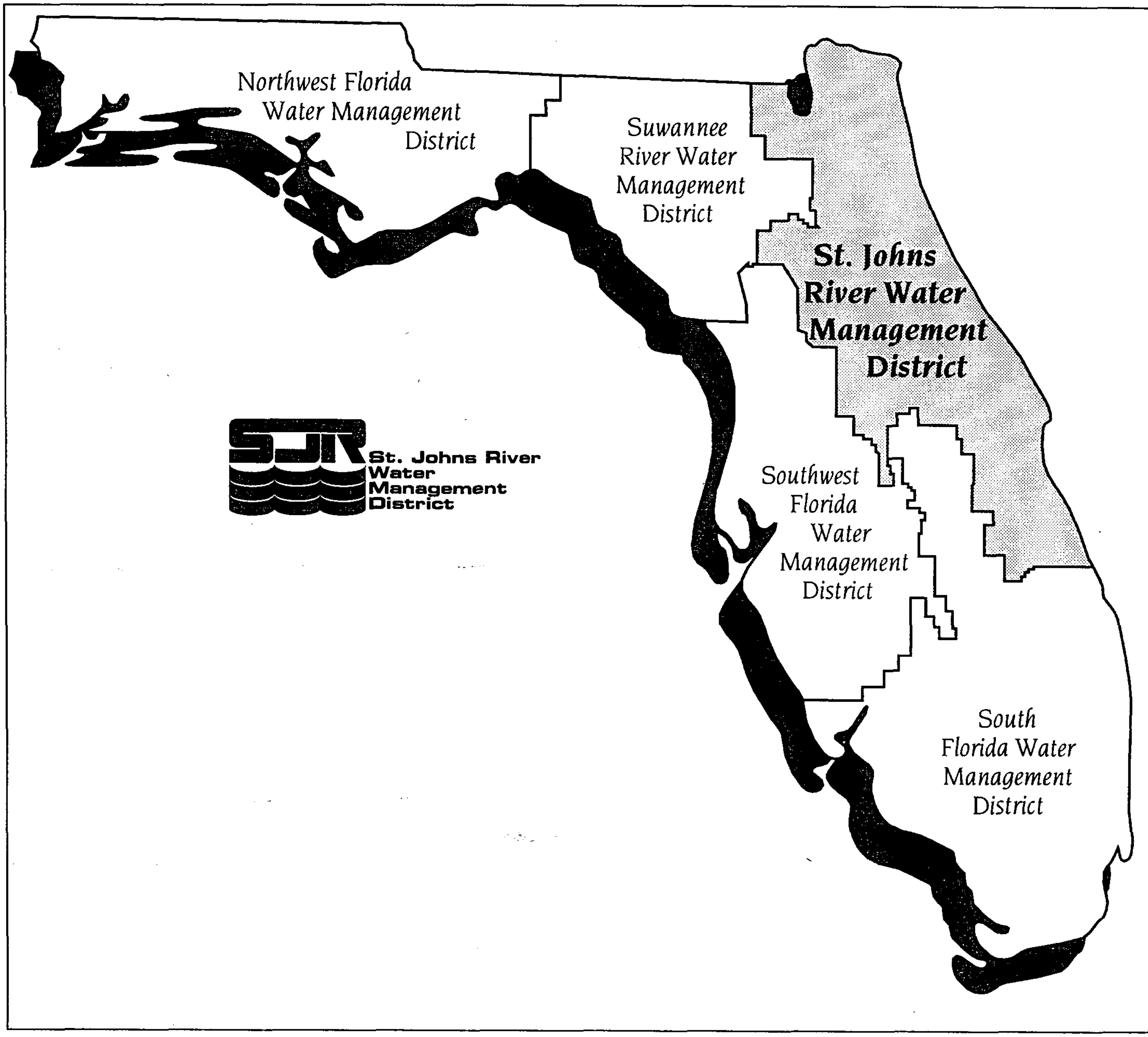

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CONTENTS

List of Figures xiii

List of Tables xix

List of Abbreviations and Acronyms xxv

Conversion Table xxix

ABSTRACT 1

INTRODUCTION 5
- Terminology 11
- Reports Reviewed 11
- General Description of the River 12
- Reconnaissance of the River 12
- Relative Size of the River 13
- Physical Dimensions of the River 13
- Salinity Classification 15
- Stratification Classification 16
- Flow Ratios 18
- Estuarine Zones 18
- Estimates of Drainage Area 18
- Long-Term Mean Non-Tidal Flow 19
- River Miles 20
- Detailed Description of the River 21
  - Maintained Navigation Channel 29
  - Segmentation of the River 30
  - Bottom Topography 31
  - Other Hydrographic Surveys and Maps 33
- Climatology and Hydrology 33
- Tributary Discharge and Sediment Loadings 36
- Summary of River Location, Description, and Drainage Area 37

WATER SURFACE ELEVATION 39
- Water Surface Datums 39

Water Level Geodetic Network 39
Datums and Benchmarks 39
Water Levels 40
Water Level Data 41
Mean Sea Level 41
Long-Term Changes in Mean Sea Level 42
Historical Water Level Measurements 43
Present Water Level Measurements 44
Monthly Mean Sea Level 51
Atmospheric Pressure Effect on Water Level 51
Wind Considerations 51
Wind Effect on Water Level 51
Wind Measurements 52
Historical Analyses of Wind Effects 55
Other Periodic Wind Analyses 57
Flooding 57
Summary of Water Levels 62

TIDES 65
Basic Characteristics of the Tide 66
Tributary Tidal Extent 68
Tidal Currents 69
Measurements of Tide 69
Historical Tidal Measurements 69
Reference and Subordinate NOS Stations 69
Tide and Depth Datums 70
NOS Tidal Stations 70
Tidal Data Collection 71
Tidal Statistics 77
Mean Sea Level 77
Mean Tide Level 77
Statistics for Mayport Tides 78
Monthly Variation in Tide 78
Relationships between MSL, MTL, MLW, and MLLW at Mayport 79
Tidal Analysis 80
Tidal Harmonics 80
Period of Data Collection for Analysis 82
Tidal Constituents 83

NOS Analysis of Tidal Characteristics Prior to 1992 84
Diurnal Inequality 86
Flood and Ebb Dominance and the Shallow Water Constituents 89
Tidal Predictions 89
Tidal Elevation Frequency Distributions and Probability · 90
Predictions from the Tide Tables 92
Spatial Variation in the LSJR Tide 93
Tide near the River Entrance 93
Tide at Main Street Bridge 94
Tide Upstream in the River 96
NOS 1992 Tidal Analyses and Statistics 98
Statistical Update on Mayport Tides 99
Harmonic Analyses 102
Comparisons of Predicted and Observed Tidal Elevations 105
Tidal Datum Relationships 105
Long-Term Sea Level Variation 106
Variation in Tidal Characteristics 107
Comparisons of Tidal Ranges and Times of Occurrence 108
Summary of Tides in the LSJR 111

WATER STORAGE 113
Water Balance in the River 113
Storage Volumes 113
Tidal Prism 116
Ground Water Exchange 116
Summary of Storage 117

RIVER FLOW 119
Introduction 119
Historical Observations 121
Flow Measurements 123
Velocity Data 123
Data for Flow Calculations 125
Historical Calculations of Flow 137
Historical Discharge Estimates 140
Recent USGS Total Flow Data 140

Drainage Areas 142
Discharge/Drainage Area Relationship 142
Historical Relationship of Drainage Area to Freshwater Inflow 142
Revised Relationship of Discharge-to-Drainage Area . . . 144
Flow at the Upstream Boundary of the Basin 145
Flow at Jacksonville versus Flow at Palatka 146
Tidal Flow 146
Tidal Wave 147
Flood- and Ebb-Dominance Effect on Flow 150
Tidal Current 152
Other Effects on Flow 152
Wind Component of Flow 152
Wind Effect on Flow in the St. Johns River 153
Coriolis Acceleration 154
Summary of River Flow 154

FLOW STATISTICS 157
Total Flow 157
Change in Elevation and Velocity at De Land 157
Estimated Total Flow at the Upstream Boundary of the Basin 157
Total Flow over the Period of Record 158
Peak Flows 158
Extremes of Flow in the Main Stem 158
Historical Annual Means of Total Flow 158
Total Flow/Tidal Range Relationship 159
Flow/Velocity Relationship 160
Derived Annual Total Flow 160
Derived Monthly Total Flow 165
Derived Daily Total Flow 169
Tidal Flow 169
Upstream and Downstream Flows 169
Historical Annual Tidal Flows 170
Annual Tidal Flow 170
Average Tidal Flow 171
Tidal Volume 171
Long-Term Extremes in Tidal Flow 171
Non-Tidal Flow 173

Seasonal Non-Tidal Flow 173
Monthly Non-Tidal Flow 173
Daily Non-Tidal Flow 175
Wind-Induced Flow 175
Flow Distribution and Frequency 175
Cumulative Flow Frequency 177
Duration of Flow 178
Design Flow for Water Quality Modeling 178
Duration of Reversed Flow 183
Recent Flow Frequency Analysis 183
Summary of Flow Statistics 184

RIVER SALINITY 187
Classification Based on Salinity 187
Segmentation Based on Salinity 188
Chlorides, Salinity, and Other Salts 190
Salinity at the Ocean Entrance 191
Zone of Transition 192
Chlorinity and Flow 193
Stratified Flow 194
Mixing 195
Flushing Rate 196
Overmixing and the Control Section 196
Influence of Salinity on Pollution 197
Recent Observations on Salinity 197
Summary of Salinity 198

HYDRODYNAMIC AND WATER QUALITY MODELS 201
Spatial and Temporal Scales 202
Statistical Models 203
Physical Models 204
Numerical Models 206
Model Selection 207
Eulerian versus Lagrangian Flow 209
Numerical Modeling Projects 209
Frederic R. Harris, Inc. Modeling 209
Edge (Clemson) Model 210
Connell (Hydroscience) Model 213
HydroQual Model 215

Atlantis Scientific Model 217
Water Resources Engineers (Stanley Consultants)
Model 218
FDER Pollutant Impact Models 221
Seminole Power Plant Site Model Study 223
Bailard/Jenkins Model 223
FEMA Hurricane Surge Model 224
Divoky and Bhat Black Creek Storm Surge Study 224
Camp Dresser and McKee Hydrologic and Water Quality
Models 225
NOAA Screening Assessment Model 226
Summary of Modeling the LSJR 227

SUMMARY 229
Scope of the Report 229
Description of the River 230
Reports Reviewed 233
Data Collection on the River 233
Modeling of the River 233

RECOMMENDATIONS 235
Tides 235
Tributary Inflows 236
River Flows 236
Salinity 237
Ground Water Interchanges 237
Sediment Transport 238
Long-Term Modeling 238
Applications of Models 239

GLOSSARY 241

REFERENCES 249

APPENDIX A: RIVER MILES 261

APPENDIX B: HYDROGRAPHIC SURVEYS 275

APPENDIX C: WIND STATISTICS 279

APPENDIX D: TIDE STATIONS AND TIDAL CHARACTERISTICS 283

APPENDIX E: MAINSTEM FLOW 329

APPENDIX F: WATER QUALITY SURVEYS 351

APPENDIX G: MODEL GEOMETRY 357

FIGURES

1 Major hydrologic units of the St. Johns River Water Management District 6

2 Lower St. Johns River surface water basin 7

3 Lower St. Johns River surface water tributary basins 9

3.1a Location map, by river mile, for significant locations on the St. Johns River between the river mouth and Julington Creek 22

3.1b Location map, by river mile, for significant locations on the St. Johns River between Julington Creek and Deep Creek 23

3.1c Location map, by river mile, for significant locations on the St. Johns River between a location north of Rice Creek and Georgetown 24

3.1d Location map, by river mile, for significant locations on the St. Johns River from Lake George to De Land 25

3.2 Mean widths (*A*), mean depths (*B*), and mean volumes (*C*) over the lower 120 miles of the St. Johns River 26

3.3 Areas in the St. Johns River covered by Coast and Geodetic Survey hydrographic survey data 34

3.4 Monthly means and high and low net flows at Main Street Bridge, 1972–92 36

3.5 Annual mean sea level at Mayport, 1929–92 42

3.6a Locations of USGS water level stations between the mouth of the St. Johns River and Julington Creek 47

3.6b Locations of USGS water level stations between Julington Creek and Deep Creek 48

3.6c Locations of USGS water level stations between a location north of Rice Creek and Georgetown 49

3.6d Locations of USGS water level stations from Lake George to De Land 50

3.7 Locations of long-term wind recording stations 54

3.8 Wind rose, Naval Air Station, Jacksonville, Florida, 1973–77 58

3.9 Seasonal wind frequency, Naval Air Station, Jacksonville, Florida, 1973–77 59

3.10a Locations of NOS tide stations between the mouth of the St. Johns River and Julington Creek 72

3.10b Locations of NOS tide stations between Julington Creek and Deep Creek 73

3.10c Locations of NOS tide stations between a location north of Rice Creek and Georgetown 74

3.10d Locations of NOS tide stations from Lake George to De Land 75

3.11 Detailed map of locations of NOS tide stations in the vicinity of the St. Johns River inlet to Jacksonville 76

3.12 Monthly mean sea level at Mayport 79

3.13 Comparison of monthly mean sea level and range for data at Mayport 80

3.14 Relationships among MSL, MTL, MLW, and MLLW at Mayport 81

3.15 Cumulative frequency density for tide parameters at Mayport 91

3.16 Variations in elapsed time following high or low water . . . 93

3.17 Monthly mean range of predicted tide versus distance from the river entrance 97

3.18 Tides and extreme water surface elevations from river entrance to Lake George 98

3.19 Updated variations in mean tide level (*A*) and mean and diurnal tide ranges (*B*) 100

3.20 Amplitudes of the six largest tidal constituents at locations from Mayport to Welaka 103

3.21 Ratios of the overtides M_4 and M_6 to the principal lunar constituent M_2 104

3.22 Comparison of variation in ordinary mean tidal range from four sources (*A*), high-water time interval from three sources (*B*), and low-water time interval from three sources (*C*) . . . 109

3.23a Average monthly volume storage rate of the main stem and rainfall minus evapotranspiration 114

3.23b Corresponding average annual variation in mean sea level (MSL) from average MSL for the period 1930–48 115

3.24 Range of tide and vertical-mean speed of current 124

3.25a Locations of stations used for flow calculations between the mouth of the St. Johns River and Julington Creek 126

3.25b Locations of stations used for flow calculations between Julington Creek and Deep Creek 127

3.25c Locations of stations used for flow calculations between a location north of Rice Creek and Georgetown 128

3.25d Locations of stations used for flow calculations between Lake George and De Land 129

3.26 Locations of gages installed in the vicinity of Main Street Bridge for measurements related to the calculation of flow 134

3.27 Relative locations of major tributaries and flow gaging stations in the flow gaging network of the St. Johns River 138

3.28 Hydrographs of monthly mean flow volumes, average monthly mean flow volumes, and net volumes at Jacksonville and the predicted tidal range at Mayport 139

3.29 Discharge-to-drainage area relationship for flows in the Lower St. Johns River Basin (LSJRB) 144

3.30 Lag of strength of flood and ebb current (*A*), lag of high and low water levels (*B*), and lag of slack before ebb and flood (*C*) 149

3.31 Annual mean and range of monthly mean flows at De Land (*A*), the upstream boundary of the LSJRB (*B*), Palatka (*C*), and Jacksonville (*D*) 161

3.32 Monthly mean and extreme daily total flows at De Land (*A*), calculated daily total flow for the upstream boundary of the LSJRB (*B*), monthly mean and extreme daily total flow at Palatka (*C*), and monthly mean and extreme daily total flow at Jacksonville (*D*) 166

3.33 Annual exceedence for flows at De Land (*A*), for partial flows at the upstream boundary of the LSJRB (*B*), flows at Palatka (*C*), and flows at Jacksonville (*D*) 179

3.34 Approximate longitudinal variation in daily maximum chloride concentration that will be exceeded 7% and 50% of the days in a year 193

3.35 Nodal network for the Edge (Clemson) and WRE (Stanley Consultants) link-node models 211

3.36 Network for the Connell one-dimensional segmented model 214

3.37 Comparison of mean widths (*A*), mean depths (*B*), and mean volumes (C) of the lower 100 miles of the St. Johns River as used in numerical models of the river 216

A1 Atlantic Intracoastal Waterway between Norfolk, Virginia, and the St. Johns River, Florida 263

A2 Jacksonville Harbor, Florida 265

A3 St. Johns River, Florida, Jacksonville to Lake Harney 267

A4 Diagram of USGS 7½-minute quandrangle map sheets lying between 30°30′00″ North and 30°07′30″ North 269

A5 Diagram of USGS 7½-minute quandrangle map sheets lying between 30°07′30″ North and 29°45′00″ North 270

A6 Diagram of USGS 7½-minute quandrangle map sheets lying between 29°45′00″ North and 29°22′30″ North 271

A7 Diagram of USGS 7½-minute quandrangle map sheets lying between 29°22′30″ North and 29°00′00″ North 272

TABLES

3.1 Comparison of principal statistics of the St. Johns River with those of some major rivers 14

3.2 The NEI classifications of the St. Johns River 17

3.3 Summary of Coast and Geodetic Survey hydrographic surveys of the lower St. Johns River 32

3.4 Bathymetric surveys used in USGS/NOS 1:100,000-scale metric topographic-bathymetric map of the Jacksonville, Florida, area 35

3.5 Periods of record for reliable data and locations of water level stations on or near the main stem from De Land to the river mouth 45

3.6 Availability of daily wind data and monthly and annual summaries of wind data in the Lower St. Johns River Basin (LSJRB) 53

3.7 Wind characteristics and effects on the LSJRB 56

3.8 Flood stages recorded at tide gages, 1944–64 60

3.9 Peak water levels in the St. Johns River, Mayport to Palatka 61

3.10 Published extremes of measured water levels on or near the main stem of the St. Johns River 62

3.11 Mean sea level at Mayport for the three most recent complete tidal epochs 77

3.12 Ranges of water levels at Mayport 78

3.13 Periods and relative amplitudes of the largest harmonic tidal constituents in the ocean and at Mayport 85

3.14a The six most significant harmonic tidal constituent amplitudes and phases for Mayport and Georgetown 87

3.14b Recalculation of the six most significant harmonic tidal constituent amplitudes and phases for Mayport and Georgetown 87

3.15 Expression for the degree of mixed tide and calculated ranges 88

3.16 Statistical parameters for water levels at Mayport 92

3.17a Tides in the vicinity of the river mouth, 1989 95

3.17b Tides in the vicinity of the river mouth, 1992 95

3.18 Reference elevations at Mayport, 1992 101

3.19 Long-period tidal constituents at Mayport and the USACE dredge depot 104

3.20 Uncertainties in tidal water surface elevation predictions . . 106

3.21 Periods of record for reliable data and locations of stations used in calculations of mainstem flows 131

3.22 Published extremes of USGS-calculated daily values in some tributaries and the main stem 141

3.23 Minimums, means, and maximums of mean monthly total flows in the main stem 159

3.24 Means of monthly mean total flows over associated periods of record to 1992 168

3.25 Selected flow statistics at Jacksonville 172

3.26 Comparison of long-term monthly mean freshwater inflows to the St. Johns River (to Jacksonville) to total flows at the upstream boundary of the LSJRB 174

3.27 Types of analyses performed by USGS on March 1954–September 1966 data 176

3.28 Flow duration for three USGS stations on the main stem . . 181

3.29 High- and low-flow frequency data for De Land 182

3.30 Ranking of average annual flows at Jacksonville 182

3.31 Representative seasonal low flows at Palatka and Jacksonville 183

3.32 Flow statistics and ratios for the St. Johns River 184

3.33 Categories and representation of water body models 202

3.34 Spatial and temporal scales in models 203

3.35 Numerical model feature choices 208

A1 Locations of NOS tide stations 273

B1 Hydrographic surveys conducted by the Coast and Geodetic Survey in the lower St. Johns River 277

C1 Wind speed, direction, and percent of time wind speed is within given speed range, Naval Air Station, Jacksonville, 1973–77 281

C2 Seasonal wind frequency, Naval Air Station, Jacksonville, 1973–77 282

D1 Historical NOS tide recorder stations having data appropriate for analysis 285

D2 Stations in the 1990 NOS Index not included in Table D1 287

D3 Longitudinal distribution of water elevations from the river mouth to Lake George 288

D4 Mean and spring range of tide and mean tide level for NOS stations 289

D5 Summary of tidal characteristics 290

D6 Predicted average tidal currents, 1990 292

D7 Amplitudes and phases of harmonic constituents 293

D8 Tidal constituents for all locations having adequate water level data for analysis 294

D9 Ratios of harmonic constituents 326

D10 Relationships of tidal datums to National Geodetic Vertical Datum 327

E1 Drainage areas and long-term mean discharge to the main stem 331

E2 Station 02236000, De Land. Minimum daily flow and summaries of means and extremes 335

E3 Station 02243960, Rodman Dam. Minimum daily flow and summaries of means and extremes 336

E4 Station 02244032, Buckman Lock. Minimum daily flow and summaries of means and extremes 336

E5 Station 02244440, Dunns Creek. Minimum daily flow and summaries of means and extremes 337

E6 Summation of De Land, Rodman Dam, Buckman Lock, and Dunns Creek station data. Minimum daily flow and summaries of means and extremes 337

E7 Station 02244450, Palatka. Minimum daily flow and summaries of means and extremes 338

E8 Station 02246500, Jacksonville. Minimum daily flow and summaries of means and extremes 338

E9 Station 02236000, De Land. Mean daily flow and summaries of means and extremes 341

E10 Station 02243960, Rodman Dam. Mean daily flow and summaries of means and extremes 342

E11 Station 02244032, Buckman Lock. Mean daily flow and summaries of means and extremes 342

E12 Station 02244440, Dunns Creek. Mean daily flow and summaries of means and extremes 343

E13 Summation of De Land, Rodman Dam, Buckman Lock, and Dunns Creek station data. Mean daily flow and summaries of means and extremes 343

E14 Station 02244450, Palatka. Mean daily flow and summaries of means and extremes 344

E15 Station 02246500, Jacksonville. Mean daily flow and summaries of means and extremes 344

E16 Station 02236000, De Land. Maximum daily flow and summaries of means and extremes 347

E17 Station 02243960, Rodman Dam. Maximum daily flow and summaries of means and extremes 348

E18 Station 02244032, Buckman Lock. Maximum daily flow and summaries of means and extremes 348

E19 Station 02244440, Dunns Creek. Maximum daily flow and summaries of means and extremes 349

E20 Summation of De Land, Rodman Dam, Buckman Lock, and Dunns Creek station data. Maximum daily flow and summaries of means and extremes 349

E21 Station 02244450, Palatka. Maximum daily flow and summaries of means and extremes 350

E22 Station 02246500, Jacksonville. Maximum daily flow and summaries of means and extremes 350

F1 Water quality intensive surveys analysis, FDER 353

F2 Reports on FDEP wasteload allocation studies and water quality based effluent limitations, lower St. Johns River . . . 355

G1 Channel (link) geometry used in the Edge (Clemson) and/or WRE (Stanley Consultants) models 359

G2 Junction (nodal) geometry used in the Edge (Clemson) and/or WRE (Stanley Consultants) models 361

ABBREVIATIONS AND ACRONYMS

ac-ft	acre-foot
AVM	acoustic velocity meter
BESD	Bio-Environmental Services Division
BOD	biochemical oxygen demand
BuSM	Bureau of Survey and Mapping
BuWA	Bureau of Water Analysis
C&GS	Coast and Geodetic Survey
CEL	Coastal Engineering Laboratory
cfs	cubic feet per second
CMAN	Coastal Marine Automated Network
CSX RR	Seaboard Coast Line Railroad
CVWind	ceiling-visibility-wind
DEM	Dynamic Estuary Model
DO	dissolved oxygen
EDA	estuarine drainage area
EPA	U.S. Environmental Protection Agency
ESSM	Estuary Steady State Model
FDA	fluvial drainage area
FDEP	Florida Department of Environmental Protection
FDER	Florida Department of Environmental Regulation
FDPC	Florida Department of Pollution Control
FEC RR	Florida East Coast Railroad
FEMA	Federal Emergency Management Agency
FLCSA	Feasibility Level Cost Share Agreement
ft	foot
ft/mi	feet per mile
ft/yr	feet per year
GIS	geographic information system
GPS	global positioning system
HCU	hydrologic cataloguing unit
hr	hour
H/S	hydrodynamics and salinity
htc	half tidal cycle
ICW	Intracoastal Waterway
in.	inch
IRF	Intermediate Regional Flood

JAPB	Jacksonville Area Planning Board
LSJR	lower St. Johns River
LSJRB	Lower St. Johns River Basin
m	meter
mcf	million cubic feet
mg/L	milligrams per liter
MHW	mean high water
mi	mile, statute
mi^2	square mile
mi^3	cubic mile
MLW	mean low water
MLLW	mean lower low water
µmhos/cm	micromhos per centimeter
mph	miles per hour
MSL	mean sea level
MTL	mean tide level
MWL	mean water level
NAD	North American Datum
NAS	Naval Air Station
NAVD 88	North American Vertical Datum of 1988
NCDC	National Climatic Data Center
NEI	National Estuarine Inventory
NGDC	National Geophysical Data Center
NGS	National Geodetic Survey
NGVD	National Geodetic Vertical Datum
nm	nautical mile
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NURP	Nationwide Urban Runoff Program
ppt	parts per thousand
RM	river mile
RSH	Reynolds, Smith and Hills
RUSSWO	revised uniform summary of surface weather observations
SJRWMD	St. Johns River Water Management District
SMOS	summaries of meterological observations near the surface
SPAM	Sparse Matrix Analysis Model
SPF	Standard Project Flood

SWIM	Surface Water Improvement and Management
SWMM	Surface Water Management Model
tc	tidal cycle
TTM	Tidal Temperature Model
USACE	U.S. Army Corps of Engineers
USED	U.S. Army Engineers District
USGS	U.S. Geological Survey
WES	Waterways Experiment Station
WLA	waste load allocation
WQBEL	water quality based effluent limitation
WQTS	Water Quality Technical Series
WRC	Water Resources Council
WRE	Water Resources Engineers, Inc.
WRMP	Water Resource Management Plan
WY	Water Year

CONVERSION TABLE

Multiply	By	To Obtain
acre-foot (ac-ft)	1,230	cubic meter (m^3)
centimeter (cm)	0.393701	inch (in.)
cubic feet per second (cfs)	0.02832	cubic meters per second (m^3/s)
cubic mile (mi^3)	4.168182	cubic kilometer (km^3)
foot (ft)	0.3048	meter (m)
inch (in.)	2.54	centimeter (cm)
meter (m)	3.28084	foot (ft)
mile, statute (mi)	1.609344	kilometer (km)
mile, statute (mi)	0.868976	nautical mile (nm)
miles per hour (mph)	1.609344	kilometers per hour (km/hr)
milligram (mg)	0.0000352739	ounce (oz)
millimeter (mm)	0.03937	inch (in.)
million cubic feet (mcf)	0.028317	million cubic meters
million gallons per day (mgd)	1.5471	cubic feet per second (cfs)
million gallons per day (mgd)	0.0438	cubic meters per second (m^3/s)
nautical mile (nm)	1.852	kilometer (km)
nautical mile (nm)	1.150779	mile, statute (mi)
square mile, statute (mi^2)	2.590	square kilometer (km^2)

ABSTRACT

The lower St. Johns River (LSJR) Surface Water Improvement and Management plan requires the St. Johns River Water Management District to develop plans to manage water quality and to restore ecosystems. Surface water quality may be improved by development of nutrient and sediment loading goals. Such goals are best quantified and prioritized from the perspective of a comprehensive understanding of the dynamics of the river.

This volume of the Lower St. Johns River Basin reconnaissance report has two purposes: (1) to locate, to describe, to compare, and to evaluate published information and data on the hydrodynamics and salinity of the LSJR and (2) to recommend future work needed to develop a more complete understanding of the dynamics of the river. This report examines and evaluates the extent of present knowledge regarding the volume and movement of the waters, salinity, and past efforts to simulate the flow of the LSJR, and it shows where gaps in knowledge of river dynamics exist. This report describes water elevations, flows, the dominant forcing factors (such as tide and wind), salinity, and the physical and computer models that have been developed to describe these factors. A brief review of water quality models is included, because these models are closely tied to quantity (hydrodynamic) models. Basin hydrology and tributary inflows are not included in this report because these subjects were described in Volume 2 of this series.

Since the late 1890s, substantial effort has been directed toward describing the characteristics of the St. Johns River. Additional investigations occurred in the 1930s and continued sporadically in the 1970s and 1980s. However, the limited results from these studies only hint at the complexity of the river system. A small number of the studies attempted to develop a comprehensive description of the St. Johns River from its mouth to the region of the head of tide. Most of the other studies were limited to small areas of the river, consisted of reviews of previous reports, or covered only a few of the important variables.

Hydrodynamics, the study of the dynamics of water movement, is described in terms of water heights, currents, and volumes. Salinity is the concentration of salts in a water mass. The salinity of water is directly related to its density, and the density affects the hydrodynamics; therefore, hydrodynamic forces and salinity work together to control the movement of water in the river.

The concentration of salinity in the water at a particular location in the river is the result of the mixing of fresh water and salt water. Ocean salinity is about 36 parts per thousand; the salinity of rainwater and tributary discharges is usually close to zero. When water masses of different salinity come into contact, the amount that they will mix together will depend on the amount of local turbulence and water velocity. The water masses may travel in opposite directions. Lower density water, instead of mixing, may ride up over heavier, more dense water masses. Thus, many factors, including local hydrodynamics, affect the resulting density structure of river water. Salinity and changes in salinity are very important to the health and survival of marine vegetation and biota.

The movement and mixing of fresh water, nutrients, and sediments in the river depend to a great extent on the local movement and density of the water. Therefore, the hydrodynamics and salinity of the river must be well understood before an analysis of the dilution and transport of pollutants can be undertaken.

Depths in the river were first surveyed in 1853 and last surveyed (except in the vicinity of Jacksonville) by the federal government in 1959. The areas surveyed were usually relatively small in extent compared to the total area of the river; thus, the depths in most areas have been surveyed only once. The depths in the navigation channel, which extends from the mouth of the river to Lake Harney, have been periodically re-surveyed for channel maintenance.

River shorelines and tributary inflow locations have been well described.

The tide station at Mayport has been monitored continuously since 1928, but all other tide stations were monitored over much shorter

periods of time. This monitoring has been currently discontinued. The most notable feature of the tides is the occurrence of a minimum tidal range near Orange Park and a secondary maximum near Palatka. Annual predictions of tidal heights and times, based on the 1970s data, are published by the federal government for 15 stations located from the jetties at the mouth of the river to Welaka. Tidal currents are also predicted annually at 17 stations.

Mean flows have been determined for a few locations over some relatively short time periods. De Land has the longest flow record (58 years), followed by Jacksonville (22 years) and Palatka (13 years). The data from the Jacksonville and Palatka stations, however, are rated as poor due to the unavailability of adequate instrumentation for monitoring reversing (tidal) flows. In 1992, the U.S. Geological Survey installed ultrasonic velocity meters at Buffalo Bluff and Dunns Creek; these gages have provided more accurate and complete data. Flow measurements at Jacksonville also are expected to be improved in the future.

Flow statistics indicate that the mean net non-tidal flow at the mouth of the LSJR is on the order of 6,000 to 15,000 cubic feet per second, and total flow (including the tidal component) is an order-of-magnitude greater.

Salinity distributions have been reported a few times in the literature, but because salinity is highly variable and dependent on the hydrology and hydrodynamics of the system, it has not been well described. The salinity data have led researchers to a tentative conclusion that the river varies between slightly to highly stratified (i.e., it is generally not vertically homogeneous and not well mixed).

Several physical and numerical models of river hydrodynamics and water quality have been developed. Many of these have been numerical models, and all have been relatively simple. All were limited in calibration by a lack of data on mainstem flows, tributary inflows, and pollution loadings.

The overall water budget for the river has not been described. The water budget is a seasonal balance of the inflows, outflows, and

changes in volume over the full extent of the main stem of the river, which would account for long-term variations of ocean tide and the hydrologic cycle. The water budget would be expressed in terms of spatial changes in tidal volume, inflow from each tributary, runoff, evaporation, ground water seepage, and the salinity distribution for normal, wet, and dry seasons.

The influence of each tributary discharge and basin runoff on water levels, flows, and salinity in the tidal part of the tributary and the main stem of the river has not yet been quantified. The major difference between the less detailed description of the overall water budget and this detailed description of the dynamics of flow at the mouths of tributaries is the increase in spatial detail that will be needed. In these areas, the interflows are more complex. Managers are interested in the transient effects of stormwater inflows, the salinity ranges required by marine ecosystems in the vicinity of the tributary, the dilution and fate of pollutants, and the possible effects of reducing sediment inflows or removing existing sediments. The environment at the mouths of tributaries is complicated by complex flow patterns; incomplete mixing; salinity and temperature stratification; trapping of pollutants; different areas of deposition, erosion, and resuspension of sediments; and other local phenomena. These kinds of problems can be analyzed with the assistance of tributary-area model studies that incorporate the hydrology of the subbasin and the hydrodynamics and salinity of the contiguous tidal portion of the main stem, and that can simulate sequences of storms that can be developed according to historic hydrologic variability.

INTRODUCTION

This report is Volume 3 in a series of reconnaissance reports about the Lower St. Johns River Basin (LSJRB). This compilation of information and recommendations provides resource managers with a basis for identifying priority needs for future research and actions regarding the LSJRB. The reconnaissance reports are part of the research funded under the Surface Water Improvement and Management (SWIM) Act of 1987 (Sections 373.451–373.4595, *Florida Statutes*).

The SWIM Act declares that many natural surface water systems in Florida have been or are in danger of becoming degraded from point and nonpoint sources of pollution and from the destruction of natural systems. The state's five water management districts, in cooperation with state agencies and local governments, were directed to set priorities for water bodies of regional or statewide significance and to design plans for surface water improvement and management. Six water bodies were named for immediate action, including the LSJRB.

The LSJRB is one of ten surface water hydrologic planning units of the St. Johns River Water Management District (SJRWMD) (Figure 1). The LSJRB is located in northeast Florida and represents about 22% of the area within the boundaries of SJRWMD. The LSJRB extends from the City of De Land, in the south, to the inlet of the St. Johns River at the Atlantic Ocean. The LSJRB includes parts of nine counties: Clay, Duval, Flagler, Putnam, St. Johns, Volusia, Alachua, Baker, and Bradford (Figure 2).

The LSJRB is located in a transition area between the subtropical climate of southern Florida and the humid continental climate of the southeastern United States. The climate of the LSJRB is classified as humid subtropical, with an average summer maximum daily temperature of 32.2°C (90°F). In the winter, the LSJRB experiences below-freezing temperatures an average of 10–15 times per year. Average annual rainfall in the basin is approximately 132 centimeters (52 inches [in.]). A large portion of the annual precipitation

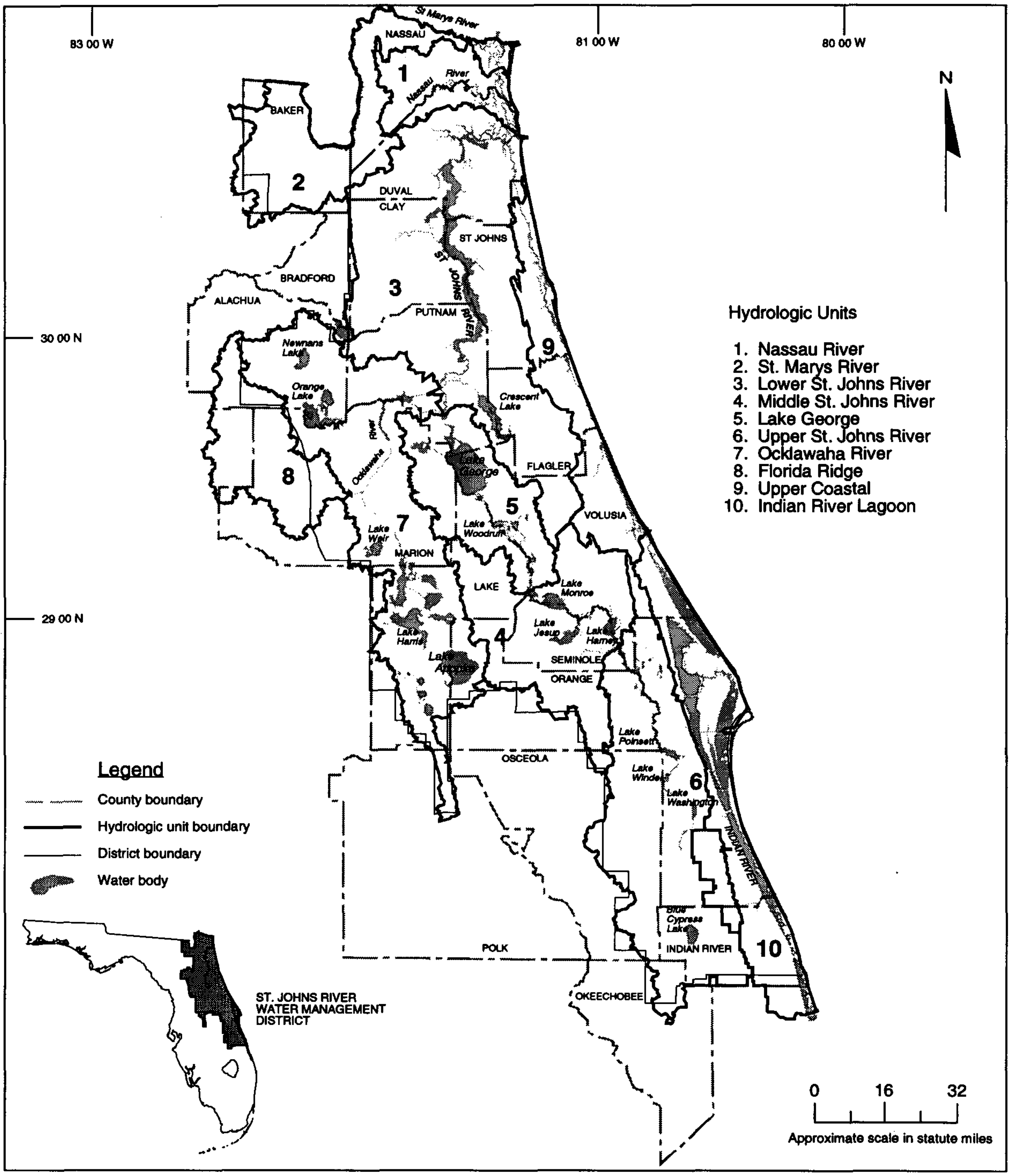


Figure 1. Major hydrologic units of the St. Johns River Water Management District

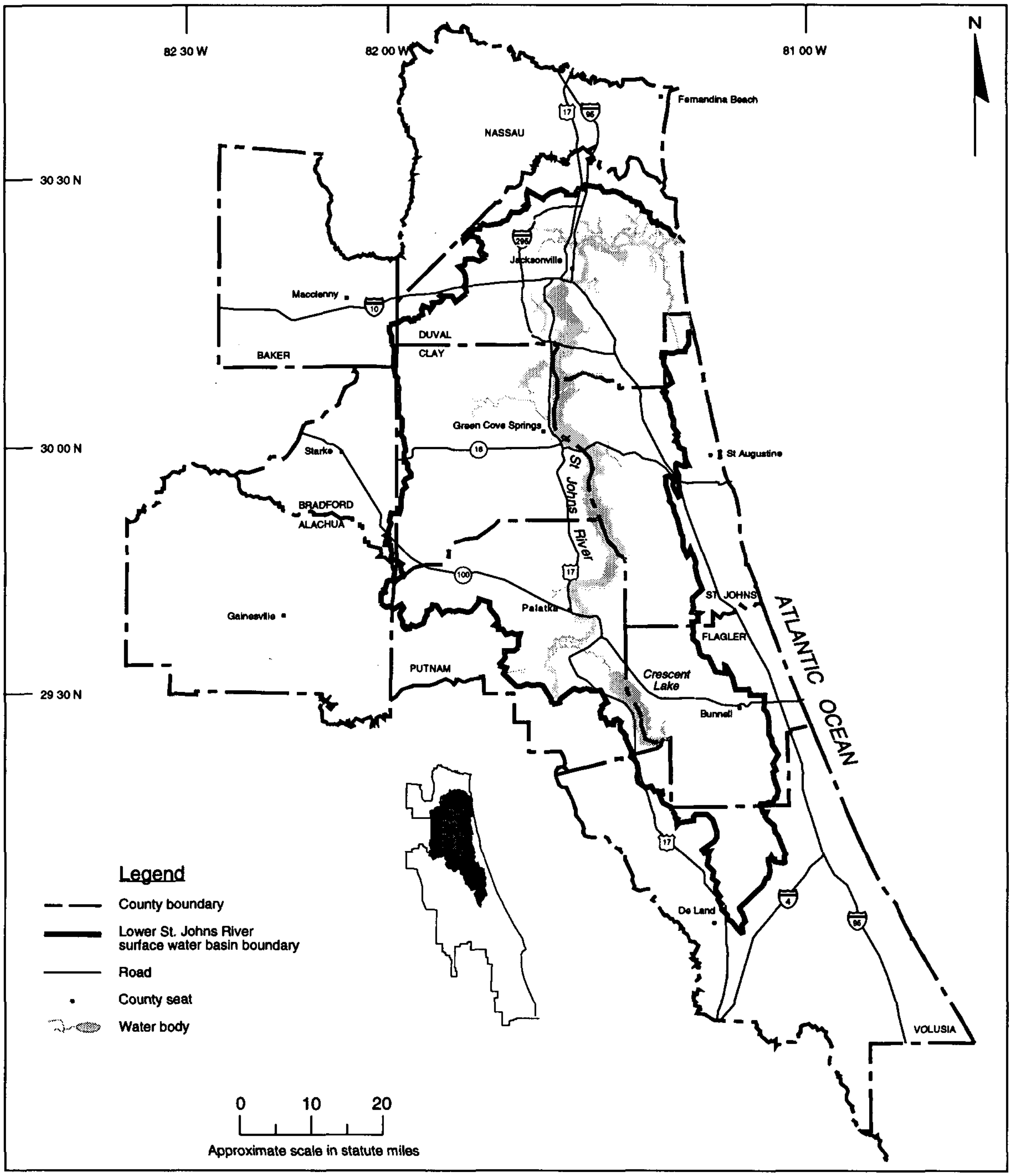


Figure 2. Lower St. Johns River surface water basin

falls between June and September, when convective activity generates showers and thunderstorms.

Landscape features within the LSJRB are relatively low and flat. Three ridge systems border the drainage area. Surface elevations range from sea level at the inlet to greater than 61 meters (m) (200 feet [ft]) in the western part of the basin.

The St. Johns River is an elongated, shallow river estuary with an extensive floodplain. The elevation of its headwaters near Blue Cypress Lake is less than 7.62 m (25 ft) above sea level, and the average gradient of the main river channel is only 0.022 meters per kilometer (0.08 feet per mile). Average annual tidal amplitude is 1.38 m (4.51 ft) at the ocean inlet and varies unequally upstream due to channel morphology and other factors. Due to the low gradient of the river, however, tides affect the entire LSJRB and the lower reaches of its tributaries. The mixing of salt water and fresh water has an influence on water quality as well as on the quantity and characteristics of sediments deposited in the LSJRB. Water quality conditions for the LSJRB range from good in the sparsely populated southern end of the basin to poor in the urban reaches of Jacksonville (Hand and Paulic 1992).

The basin is drained by 12 major tributaries. The drainage basins of the tributaries are called tributary basins (Figure 3), and each drainage basin bears the name of the major tributary flowing through it. A thirteenth tributary basin (the St. Johns River tributary basin) represents the minor tributaries draining directly into the St. Johns River.

The *Lower St. Johns River Basin Reconnaissance Report* provides a synthesis of what is known about the condition of the lower St. Johns River (LSJR) and its tributaries from three perspectives: hydrologic, environmental, and socioeconomic. Volume 1, *Hydrogeology*, presents information on the ground water system in the basin and its connection to surface water bodies. Volume 2, *Surface water hydrology*, discusses the surface water system, including hydrologic and hydraulic data collection networks. Volume 3, *Hydrodynamics and salinity of surface water*, describes relationships

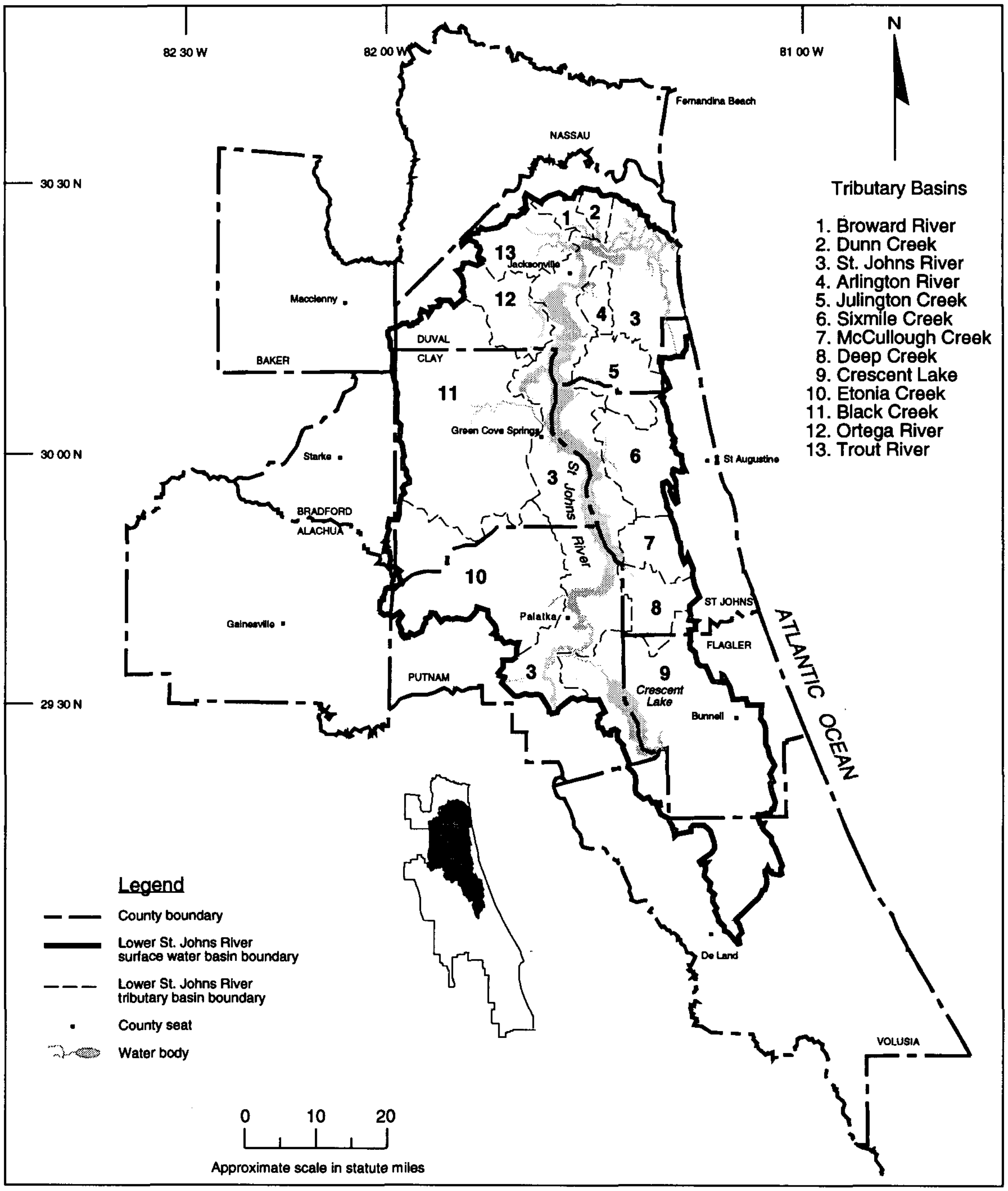


Figure 3. Lower St. Johns River surface water tributary basins

between water levels, velocity, flow, storage, and salinity in the main stem and reviews previous hydrodynamic modeling studies. Volume 4, *Surface water quality*, and Volume 5, *Sediment characteristics and quality*, present details on the levels and trends of chemical contaminants present in the water column and in the bottom sediments. Volume 6, *Biological resources*, describes plant communities and fish, shellfish, and marine animal communities. Volume 7, *Population, land use, and water use*, ties population estimates and projections to land use and residential, commercial, industrial, and agricultural water use. Volume 8, *Economic values*, discusses the commercial, recreational, and aesthetic values of the river. Finally, Volume 9, *Intergovernmental management*, discusses jurisdictional boundaries, regulatory authorities, and management efforts of governmental agencies, offices, and commissions involved in restoration or protection of water quality and habitat.

This volume, *Hydrodynamics and salinity of surface water*, begins with an introduction, which describes existing reports, relevant terminology, and the salient features of the river. A chapter on water surface elevation reviews elevation datums, causes of variations in water levels, water level measurements and flow, the effects of wind, and flooding. Tides are described next, specifically the tidal characteristics of the river, tidal measurements, tidal analyses, and the spatial variation of tide in the river. The following chapter describes water storage, a component of the water balance or the hydrologic cycle; this chapter is followed by a chapter on river flow. In the latter chapter, there are additional explanations of terminology, information on past and present flow measurements, and discussion on tidal and non-tidal flow. Next is a chapter on flow statistics, which includes statistical summaries on total, tidal, and non-tidal flow. In the chapter on river salinity, methods for classification and segmentation of the river are described, salinity is related to basic constituents and ocean values, the zone of transition is described, and stratification and mixing are explored in some detail. In the chapter on hydrodynamic and water quality models, estuarine models are described in general and particular models of the LSJR are summarized. A summary chapter reviews the scope of the report, the scope of other reports, and the status of present data collection and modeling efforts and is followed by recommendations for future work needed to improve the description of the hydrodynamics of the river.

TERMINOLOGY

The term *hydrodynamics* is used to represent all of the different aspects of the movement of water in the river. Hydrodynamics vary continually, both spatially and temporally. *Velocity* is the instantaneous speed of the water at any point in the water body, *flow* is the volume of water moving through a section of the river at a given time. The term *discharge,* often used interchangeably with flow, employs the same units of measurement (volume/time) but more correctly represents the non-tidal inflows from uplands, tributaries, and ground water sources and the outflow of the main stem. The literature often, but not always, distinguishes between the discharge of the river and total flow; the latter may be defined as the sum of the non-tidal flow and the bi-directional tidal flow. Other terminology is defined as it appears in the text.

REPORTS REVIEWED

The literature pertaining to the physical characteristics of the St. Johns River is quite extensive. Most of the available information on the hydrodynamics of the LSJR is found in reports by federal agencies, such as the Coast and Geodetic Survey (C&GS), the U.S. Army Corps of Engineers (USACE), and the U.S. Geological Survey (USGS). The first published report concerns water level and current measurements taken by C&GS in 1933 and 1934, which references observations by the U.S. Army Engineers in 1909 (Haight 1938).

Only a few core studies from the 1950s to the 1970s provide original analyses and insight into the dynamics of the river. Relatively few studies have attempted a comprehensive review of the river. The great majority of reports are limited to small areas of the river, review previous studies, or only cover a few of the important physical variables.

Additional useful information is provided by reports on developments of numerical models, both by government agencies and private contractors, but none of these reports adequately and comprehensively describe the overall hydrodynamics of the river.

General Description of the River

The LSJR extends from the confluence of the Ocklawaha River northward to the mouth of the St. Johns River at the Atlantic Ocean, east of Jacksonville. The contiguous watershed of the main stem of the river has an area of about 2,623 square miles (mi^2) (SJRWMD 1989, 4), while the total watershed, including all of its drainage basins, is about 9,430 mi^2.

The source of Florida's St. Johns River is in the floodplains north of Lake Okeechobee, near the Atlantic Coast. The river flows northward for over 300 statute miles (mi) to a point near Jacksonville, where it abruptly turns eastward and flows about 24 mi to the Atlantic Ocean. The river is normally tidal to the north end of Lake George, 110 mi from the mouth, although tides have, on occasion, been reported in Lake Monroe (south of De Land, 161 mi upstream). The LSJRB extends almost exactly 100 mi northward from its confluence with the Ocklawaha River to the Atlantic Ocean.

Reconnaissance of the River

SJRWMD is responsible for developing a plan, called the SWIM Plan for the LSJRB, to guide management and restoration of the water quality of the LSJR. This plan requires accurate and complete knowledge of the characteristics of the river. One purpose of the LSJRB reconnaissance report is to compare and to resolve conflicting information about the characteristics and movement of the river. A second purpose is to evaluate the extent and usefulness of current knowledge and understanding of the river's dynamics. Therefore, this report summarizes available information on the most significant hydro-physical variables of the LSJR. It reviews the literature describing water level, tide, flow, wind, and, because the dynamics of the flow are affected by variations in density of the water, the salinity as well. It summarizes reports on model studies and provides recommendations for future work to more completely describe the physics of the river. The focus of this report is on the main stem of the river; another report in the series (Volume 2) describes the hydrology of the river's tributaries and tributary basins (Bergman 1992).

RELATIVE SIZE OF THE RIVER

The St. Johns River is the longest north-flowing river in the United States (over 300 mi) and the longest river in Florida with its tributary basins lying entirely within the state boundaries (Figure 1). Its drainage basin, with an estimated area of 9,430 mi^2, is almost one-sixth of the total area of Florida (Anderson and Goolsby 1973, 8). It is ranked third largest of the state's coastal river drainage basins, after the Apalachicola and the Suwannee (Heath and Conover 1981, 106, 109, 113). The St. Johns River is classified as a major river, which is one that has an average discharge at its mouth greater than or equal to 1,000 cubic feet per second (cfs) (attributed to Kenner et al. 1969, by Heath and Conover 1981, 111, Table 15). A discharge of 1,000 cfs is equivalent to 646 million gallons per day or 1,983 acre-feet per day.

Some principal dimensions of the St. Johns River may be compared to those for the largest river in the world (the Amazon), the largest river in the United States (the Mississippi), and the largest river in Florida (the Apalachicola) (Table 3.1). A comparison of statistics (as of 1978) at long-term gaging sites (near De Land, river mile [RM] 144) shows that the discharge of the St. Johns River ranks fifth largest in Florida, following the Apalachicola, Suwannee, Choctawhatchee, and Escambia (Heath and Conover 1981, 111). The statistics for flow at De Land, which is not included in the drainage basin of the LSJRB, provide an approximation for flow in the main stem of the river at the upstream boundary of the LSJRB.

PHYSICAL DIMENSIONS OF THE RIVER

Not many original estimates of the dimensions of the river are found in the literature. One of the earliest sets is for a numerical model developed by Connell Associates, which provided dimensions for 69 segments (see chapter on hydrodynamic and water quality models).

Table 3.1 Comparison of principal statistics of the St. Johns River with those of some major rivers

River	Length (miles)	Drainage Area (square miles)	Approximate Average	
			(cfs)	(mgd)
Amazon	4,000	2,300,000	6,200,000	4,000,000
Mississippi	2,348	1,243,700	620,000	400,000
Apalachicola	524	19,600	27,000	17,000
St. Johns (Heath & Conover)	273	9,168	6,000	3,900
St. Johns (USGS)	---	8,200*	6,105	3,937

Note: cfs = cubic feet per second
mgd = million gallons per day

*Value is USGS published total drainage area of 8,850 square miles (mi^2) less 650 mi^2, which represents the area of Paynes Prairie, a non-contributing area included by USGS.

Source: Heath and Conover 1981, 121, Table 18
USGS 1993

When these dimensions are read from the published plots for segment length, width, depth, and volume (in cubic miles [mi^3]), and the lower approximately 100 mi (63 segments) are tabulated and summed, the following values are obtained. Here, the means and extremes of width and depth are per model segment.

	Value	Mean	Minimum	Maximum
Length (mi)	101.1			
Width (mi)		0.83	0.19	2.84
Depth (ft)		23.7	9.5	40.5
Surface area (mi^2)	123.2			
Volume (mi^3)	0.343			

The National Estuarine Inventory (NEI) Data Atlas, Volume 1, (NOAA 1985), gives the following basic physical dimensions of the lower 123 mi of the river:

	Value	Mean	Minimum	Maximum
Length (mi)	123.0			
Width (mi)		2.3	0.7*	7.2*
Depth (ft)		14.0		

*Lake George

The means and extremes of the width and depth of the lower 100 mi of the river can be most accurately calculated from a geographic information system (GIS) coverage based on the USGS 1:100,000-scale hydrography layer stored in the GIS data base of SJRWMD. For this calculation, the tributaries are not included. The dimensions obtained from GIS are as follows:

	Value	Mean	Minimum	Maximum
Length (mi)	103.1			
Width (mi)		1.28	0.12	3.17
Depth (ft)		11	1	80
Surface area (mi^2)	131.6			
Volume (mi^3)	0.27			

When tributaries are included and the calculations are based on GIS data, the length increases to 154.6 mi, surface area increases to 154.6 mi^2, and volume increases to 0.29 mi^3.

SALINITY CLASSIFICATION

Estuaries are classified based upon the degree of salinity stratification, which is often used to infer circulation features. Salinity profiles, being governed by circulation, are affected by such factors as the amount of freshwater inflow, the size and shape of the basin, and the effects of tides and strong winds. Since estuaries are dynamic, circulation patterns may vary and salinity structures will change as a result. When using any classification scheme, it is important to recognize this dynamic quality and to realize that generalizations concerning salinity profiles do not reflect such variability (NOAA 1985, Introduction, 3).

As part of its effort to compare the features of 92 major estuaries around the United States coastline, the NEI developed criteria for defining "estuarine zones" and "salinity zones." The estuarine zones are the parts of the water body that have the typical characteristics of an estuary. These areas are characterized by mixing of river and ocean water and support marine organisms that are traditionally associated with estuaries for at least part of their life cycle. The salinity zones are the parts of an estuary that contain water in which measurable quantities of salt ions are present. If the measurements used to define the salinity zones are based on conductivity, as is usually the case, it is possible that other dissolved substances besides salts could affect this determination.

For the NEI, the National Ocean Service subdivided the river into three zones between the normal extent (or "head") of tide (as far south as Lake George) and the seaward boundary, according to average annual depth-averaged salinities. Salinity data were obtained from published and unpublished sources and through consultation with experts and used to determine boundaries. Measurements taken by SJRWMD since the 1980s indicate that the long-term (approximately 10 years) mean spatial salinity distribution in the LSJR compares reasonably well to the NEI segmentation. However, SJRWMD has observed that salinity varies considerably over the length of the river and in time. It is, therefore, somewhat misleading to consider the river in terms of fixed salinity zones. More detailed descriptions of river salinity are found in the chapter on river salinity and in Volume 4 on water quality.

STRATIFICATION CLASSIFICATION

> The stratification classification assigned to an estuary is specific to the mixing zone of a system where fresh water interfaces with seawater. ... Because freshwater inflow and tidal prism volumes can vary during the year, the classification of an estuary can vary seasonally. To account for this, salinity classifications are reported for the three-month period of highest freshwater inflow and the three-month period of lowest freshwater inflow (NOAA 1985).

Stratification classification for both 3-month high flow and 3-month low flow in the LSJR was determined to be vertically homogeneous, that is, "tidal mixing and turbulence is sufficient to break down stratification" (NOAA 1985, Introduction, 3).

The delineations of estuarine and salinity zones and stratification are summarized in Table 3.2. The estuarine zones are described in terms of approximate salinity ranges called the "tidal fresh zone," which extends from South of Lake George to the Naval Air Station (NAS), the "mixing zone," which extends from NAS to Trout River, and the

Table 3.2 The NEI classifications of the St. Johns River

Estuarine Zone			
Salinity Regime	Approximate Salinity Range (parts per thousand)	Geographic Extent of Zone	Area of Zone (square miles)
Seawater	≥25.0	River entrance to Trout River	44
Mixing	0.5–25.0	Trout River to Naval Air Station	95
Tidal fresh	0.0–0.5	Naval Air Station to Lake George	119

Salinity Zone Boundary	
Degree of Variability	Location
High variability	Entrance to Pablo Creek North of Blount Island East of Trout River mouth
Moderate variability	At Naval Air Station

Stratification Classification	
Flow Characterization	Degree of Stratification
3-month high flow	Vertically homogeneous
3-month low flow	Vertically homogeneous

Flow Ratio	
Flow Characterization	Flow Ratio
Average annual	0.185
High-flow period	0.252
Low-flow period	0.125

Source: NOAA 1985, 2.16

"seawater zone," which extends from Trout River to the mouth of the St. Johns River.

According to the NEI, a river may be divided into zones of low, moderate, and highly variable salinity. The St. Johns River does not have any areas with low salinity variability. Four locations at which moderate and highly variable levels of variability interface are listed in Table 3.2.

FLOW RATIOS

The NEI classification of estuaries in the United States included estimates of flow ratios. A flow ratio is the "proportion of the volume of fresh water entering a coastal system during a tidal cycle to the volume of the tidal prism." This ratio can be used to estimate the relative importance of freshwater inflow compared to tide as the dominant force in the estuary. In the St. Johns River, the NEI flow ratios indicate that freshwater volumes are, at most, a quarter of the tidal volume (Table 3.2) (NOAA 1985, Introduction, 4).

ESTUARINE ZONES

Each estuary was subdivided into three zones between the heads of tide and the seaward boundaries based on average annual depth-averaged salinity concentrations. Salinity data were obtained, and subsequent boundaries determined, from published and unpublished sources, and through consultation with experts.

Several guidelines were therefore developed to provide a uniform approach and to account for variability in data presentation.

First, episodic anomalies of salinity conditions that occur during low or high freshwater inflows were screened out to provide an average annual scenario of the system. Second, surface and bottom salinities were averaged to determine salinity gradients along the length of the estuary. Finally, delineation between zones was depicted by a band which indicated the spatial variability which could be experienced over an annual cycle. Low, moderate, and high variability classifications are a function of the relative proportion of the variability to the length of the estuary. For example, an estuary with a length of 5 mi and salinity zone boundary of 4 mi, would be classified as highly variable (NOAA 1985, Introduction, 3).

ESTIMATES OF DRAINAGE AREA

Total flow in a river may be estimated by relating mean total flows at gaging stations located on the river to the contributing drainage area upstream of those gaging stations. Assuming that the discharge-to-drainage area relationship is uniform over the entire reach of the river, the freshwater discharge at the mouth of the

St. Johns River is calculated, by extrapolation, to be 6,500 cfs (see Figure 3.29, river flow chapter).

The NEI (NOAA 1985) defines two different drainage areas:

Estuarine Drainage Area (EDA): That land and water component of an entire watershed ... that most directly affects an estuary. ... EDAs were defined based on the limits of tidal influence within an estuarine system and the boundaries of the ... USGS hydrologic cataloguing units [HCUs]. EDAs were drawn to coincide with ... [HCUs] that contain the heads of tide and seaward estuarine boundaries. In many cases ... the EDA extends landward beyond the head of tide" (i.e., to the boundaries of subbasins).

Fluvial Drainage Area (FDA): The land and water portion of the entire watershed upstream of the EDA.

The EDA of the St. Johns River is given as 6,500 mi^2 and the FDA as 2,860 mi^2. The total drainage area reported in the NEI, assuming that the EDA and FDA can simply be summed, is 9,360 mi^2 (NOAA 1985) (compare to the estimate of 9,430 mi^2 by Anderson and Goolsby 1973, p. 13 of this report).

LONG-TERM MEAN NON-TIDAL FLOW

The total flow in the river is the sum of the tidal flow and the non-tidal (primarily freshwater and wind-induced) flow. Based on data from February 1954 to September 1966, the average net, or freshwater, flow was calculated to be about one-seventh of the average tidal flow, or 12,500 cfs (Anderson and Goolsby 1973, 1, 5). The long-term average daily discharge was 7,800 cfs, and therefore the resulting discharge-to-drainage area relationship computed from these values at (assumed) Jacksonville is 7,800 divided by 9,360, or 0.83 cfs per square mile (NOAA 1985, 2.16).

The most recent calculation of long-term net flow at Jacksonville is 6,105 cfs, corresponding to 4,423,000 acre-feet per year (USGS 1992, 134). Thus, more recent data tend to be somewhat lower than earlier estimates, although reliable measurements of flow have still not been produced.

RIVER MILES

A river mile is the distance of a location along the river from a designated point at the ocean inlet. Distances from the river mouth to tide observation stations were first listed by the Ocala Office, U.S. Army Engineers District (USED, the former common name for USACE), in a table dated December 2, 1935. Variations in tidal characteristics of the river, as a function of distance upstream, were published in 1938, using a scale of nautical miles (nm) referenced to the ocean entrance at the outer end of the jetties (Haight 1938, 22).

The Water Resources Division of USGS, Tallahassee, Florida, established a river mile scale in February 1964 using standards similar to those published later by the Hydrology Committee of the Water Resources Council (WRC), an advisory group for federal agencies. These standards describe a recommended procedure for measuring river miles to promote consistency in referencing locations on rivers. The standards specify that river miles should be measured along the *sailing line* (navigation channel), and these standards describe how to determine the precise location of the mouth of a tributary relative to the main stem (WRC 1968).

The Jacksonville District, USACE (USACE Jacksonville), developed a standard set of project maps to show river miles for projects authorized under the Rivers and Harbors Act (maps included in Appendix A). The procedure used by USACE to develop the mileages used in all USACE Jacksonville Navigability Studies is assumed to be the WRC method, although this assumption could not be confirmed by USACE Jacksonville personnel (Jim Sohm, pers. com., USGS 1993). River miles have been used by USACE in tables of mainstream and first-order tributary locations, lengths, slopes, and observed mean ranges of water levels (e.g., USACE Jacksonville 1975, Exhibit B). River miles are also used in the 1976 Atlantis Scientific report (p. II-1d, Figure II-2). The origin of the USACE river mile scale is set at the approximate intersection of the projected shoreline and the jetties, 1.2 mi west of the ocean end of the north jetty. Unfortunately, the river mile scales used by USED, Haight, and USACE are not exactly the same.

A clearer and more detailed river mile map was needed for this reconnaissance report. The 1:100,000-scale, digital-line graph water body coverage in the GIS (ARCInfo) data base maintained by SJRWMD served as the basis for the map. The origin was set approximately at the intersection of the upland shoreline behind the beach and the centerline of the navigation channel. River miles (statute) were measured along arcs that followed the navigation channel upstream. Locations along the river that are discussed in this report are shown in Figures 3.1a–d, generally within 1 mi of the values used by USACE (USACE Jacksonville 1986, 3–9, Table 1). Latitude and longitude lines in these figures coincide with the boundaries of the USGS 7½-minute quadrangle sheets.

For this report, the river mile scale has been extended into major tributaries. This addition allows distances to the mouths of secondary tributaries and tide stations located in secondary tributaries to be shown directly. The locations of tide gages are given to the nearest tenth of a river mile; general areas are given in whole river miles.

DETAILED DESCRIPTION OF THE RIVER

The mouth of the St. Johns River, bracketed by the north and south jetties, lies east of Jacksonville, Florida, at the Atlantic Ocean, at latitude 30°24′ N, longitude 81°23′ W. The river is ordinarily tidal to at least Crescent Lake (RM 96) and Lake George (RM 110) (USACE Jacksonville 1986, 71). Mean widths, depths, and volumes over the lower 120 mi of the river are summarized in Figure 3.2 (Connell Associates 1974, 4-52, Figure 4-21, values in Table B-5, A-39).

The headwaters of the St. Johns River originate inland of Fort Pierce, over 300 mi south from the river mouth at Jacksonville. The headwater drainage boundary to the west is a ridge that separates the St. Johns River from the headwaters of the Kissimmee River, which flows south to Lake Okeechobee. Elevations on the Atlantic Coastal Ridge reach as high as 90 ft above mean sea level. The portion of the ridge that acts as the eastern drainage boundary of the St. Johns River Basin reaches approximately 35 ft. According to

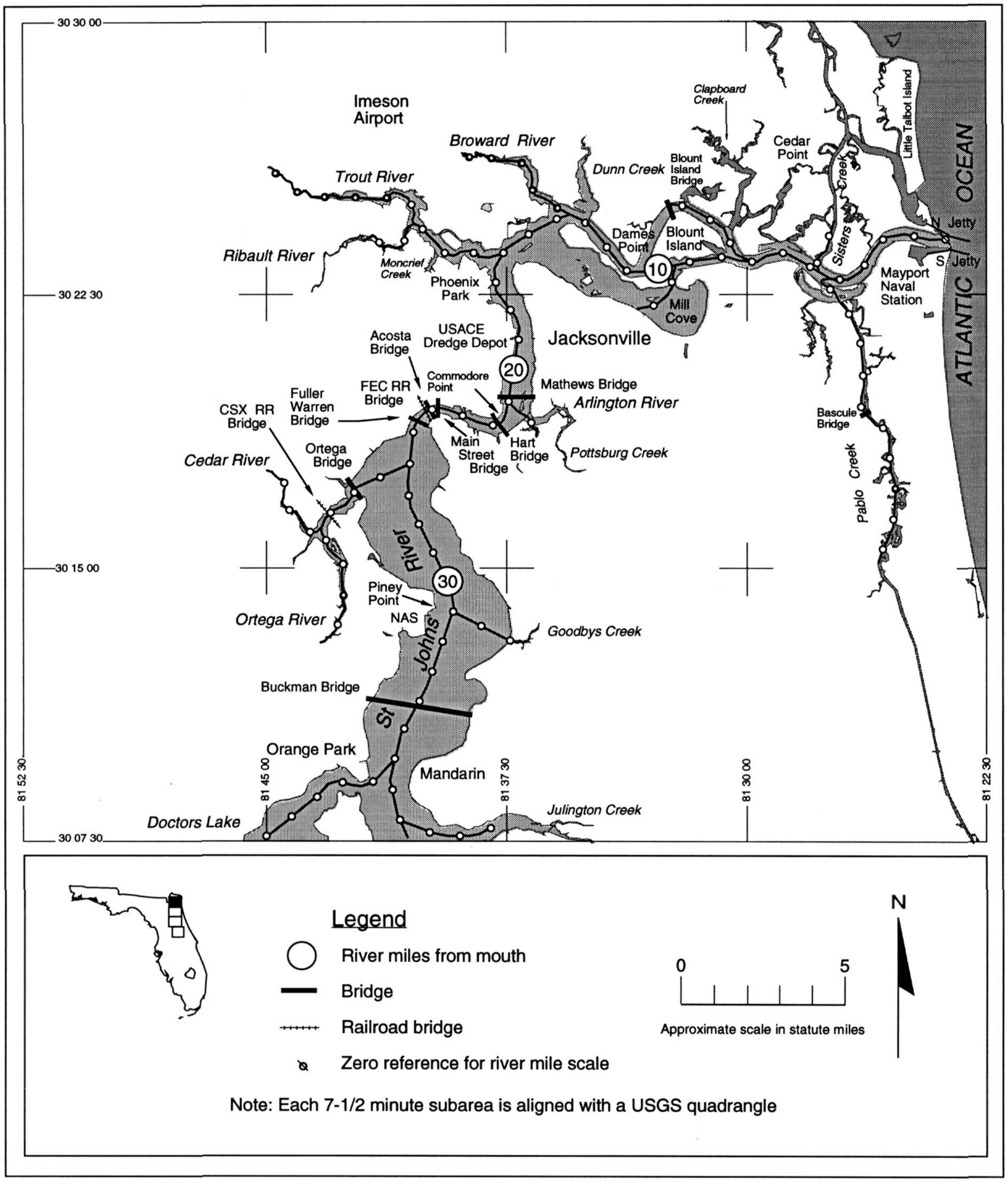


Figure 3.1a Location map, by river mile, for significant locations on the St. Johns River between the river mouth and Julington Creek

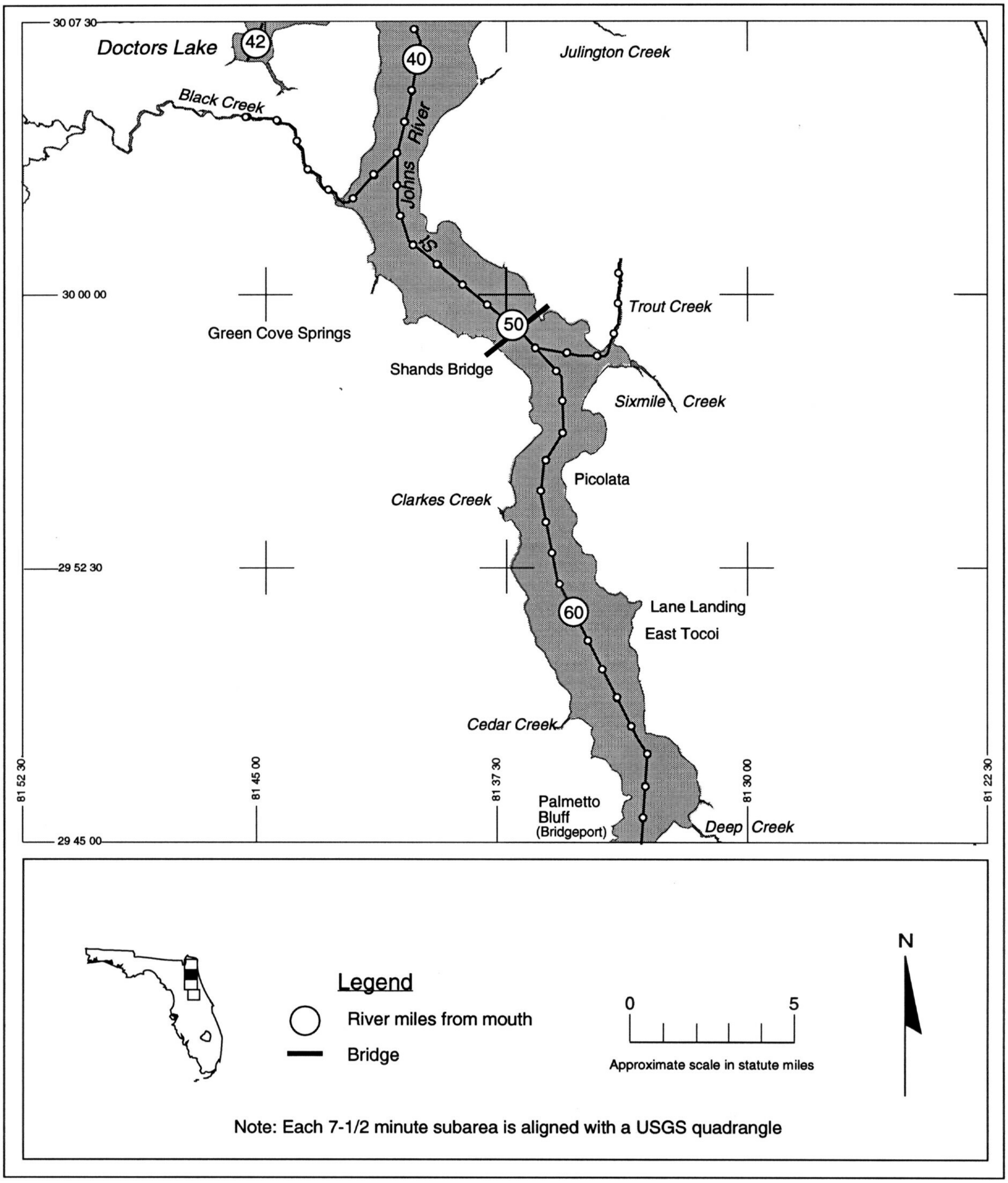


Figure 3.1b Location map, by river mile, for significant locations on the St. Johns River between Julington Creek and Deep Creek

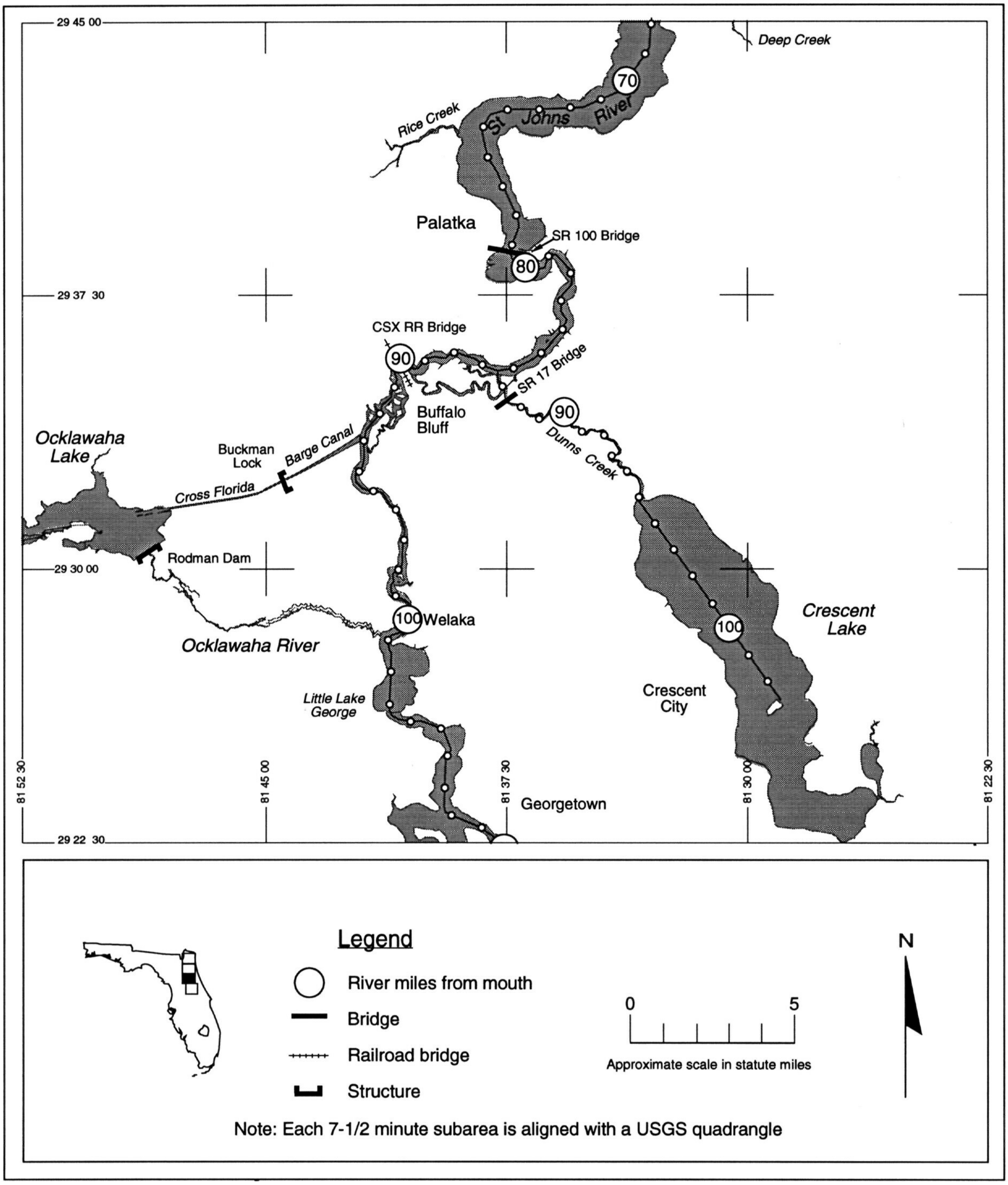


Figure 3.1c Location map, by river mile, for significant locations on the St. Johns River between a location north of Rice Creek and Georgetown

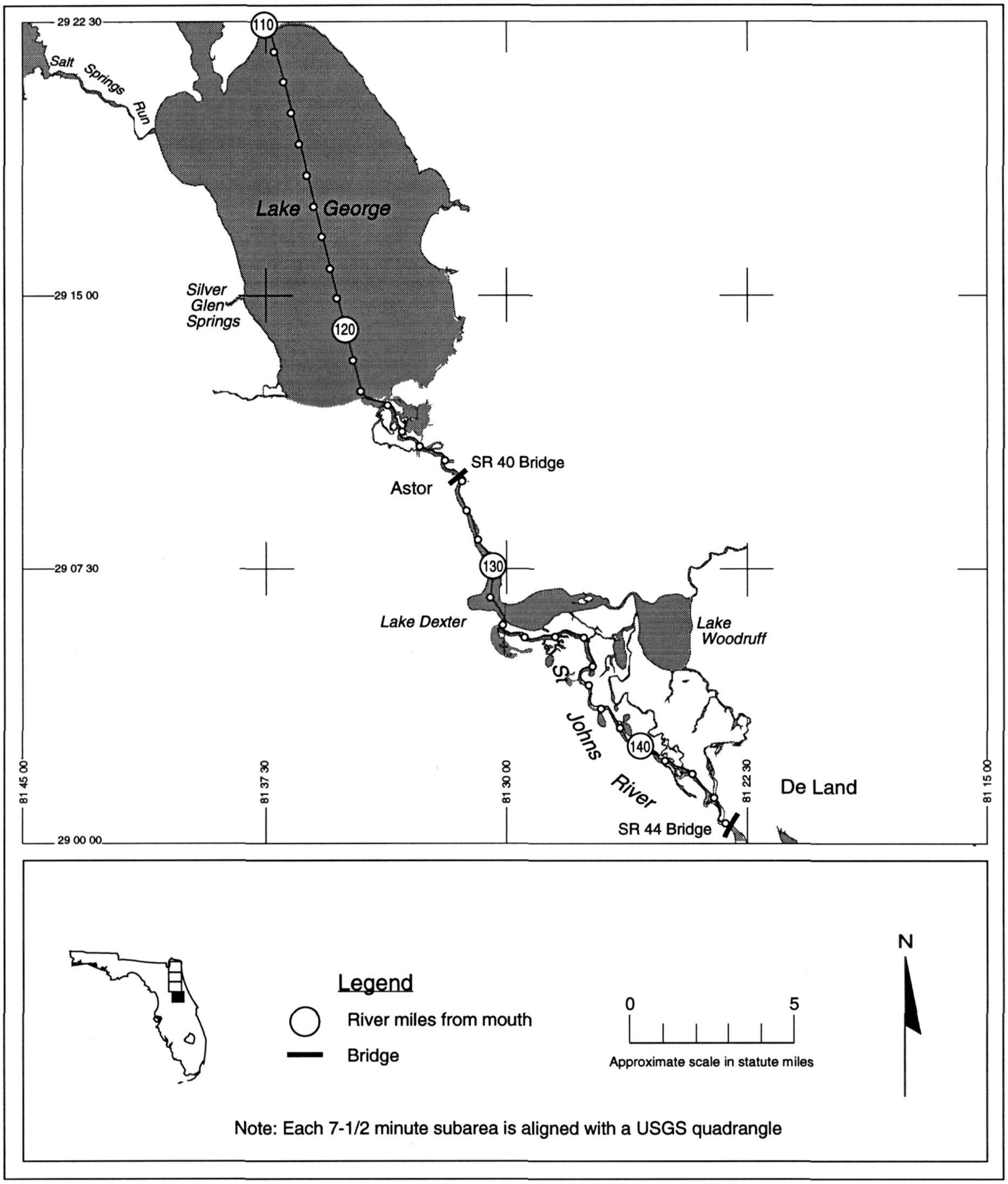
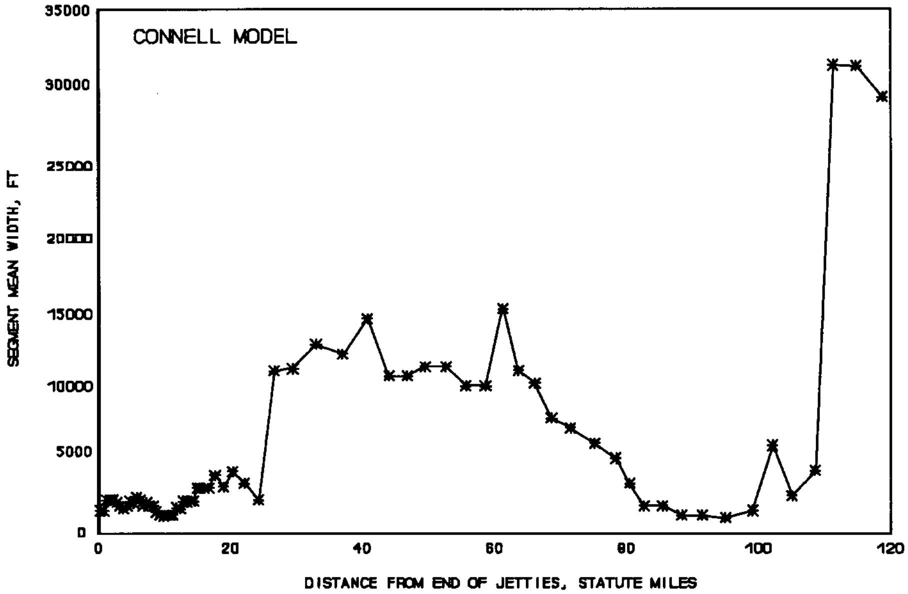


Figure 3.1d Location map, by river mile, for significant locations on the St. Johns River from Lake George to De Land

A



B

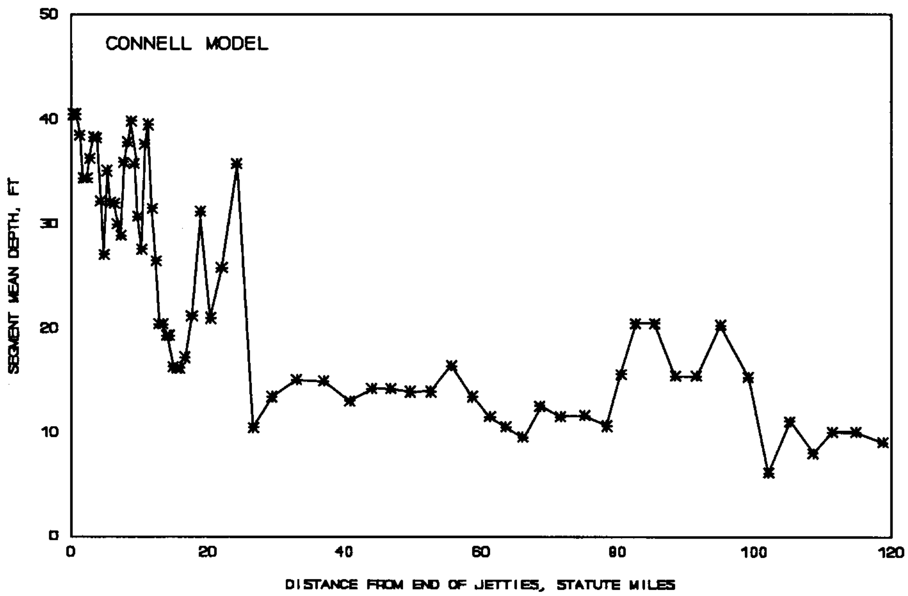


Figure 3.2 Mean widths (*A*), mean depths (*B*), and mean volumes (*C*) over the lower 120 miles of the St. Johns River (Connell Associates 1974)

C

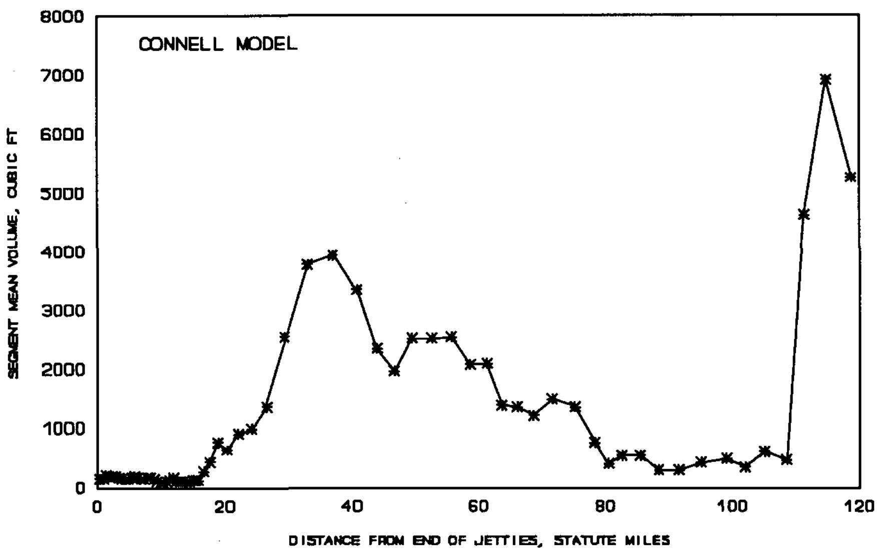


Figure 3.2—*Continued*

Connell Associates, in the (recent) past, three outlets in the upper reaches of the river permitted easterly flow to the Indian River Lagoon during high-water periods, but these drainage patterns have been considerably modified by the construction of large drainage projects (Connell Associates 1974, 2–3). There are no longer any flows out of the basin, under ordinary conditions, except via the river.

The City of De Land is located near RM 144. Although considerably upstream of the head of tide, the long-term flow record at a nearby location on the river serves as the only available measurement of the mainstem flow into the lower part of the river. Analyses of 61 years of stage records have provided a mean flow of 3,028 cfs, a maximum daily discharge of 17,100 cfs (October), and a maximum daily reverse flow of 3,030 cfs (August) (USGS 1994, 60) at De Land.

The height of tide and mean high water gradually increase from Lake George (RM 110) to Palatka (RM 79), then decrease to Orange Park (RM 36) and increase again to the ocean.

From the north end of Lake George to Palatka, the width of the river varies from less than 0.5 mi to about 600 ft. The Ocklawaha River flows through Rodman Dam into the St. Johns River from the west, at RM 101. Since the completion of the dam in September 1968, an average discharge of 1,353 cfs over a 25-year period of record (1969–93) has been calculated. A maximum daily mean discharge of 9,560 cfs occurred at Rodman Dam in February 1970 (USGS 1991, 118).

The Cross Florida Barge Canal channel flows north and east from Ocklawaha Lake through the Buckman Lock until it intersects the St. Johns River at RM 93. At RM 86.5, Dunns Creek enters from Crescent Lake, which lies to the east. At Palatka, the river widens to about 1 mi. A water level gage at Palatka with an intermittent period of record of 12 years (1969–82) provided data for calculations of an average discharge of 5,945 cfs for a drainage area of 7,094 mi^2, a maximum daily discharge of 31,300 cfs, and a maximum reverse flow of 20,400 cfs (USGS 1982, 124).

Downstream of Palatka, the river widens to about 1½ mi and continues to flow generally northward. Rice Creek joins from the west at RM 75. From RM 72 to RM 25, the width of the river fluctuates between 1½ and 3 mi. Near RM 67, Deep Creek enters from the east. Sixmile and Trout creeks join near RM 52. Black Creek enters from the west at RM 45. Julington Creek flows into the river from the east at RM 38, and Doctors Lake joins from the west at RM 37.5. NAS is located on the west bank at RM 31. The Cedar and Ortega rivers combine about 2 mi west of the St. Johns River and join it at RM 26, one of the widest parts of the St. Johns River.

At RM 25, near the Jacksonville city limits, the St. Johns River suddenly narrows, deepens, and turns eastward to flow to the ocean. Near the Florida East Coast Railroad (FEC RR) bridge, at RM 24, the river deepens to about 80 ft. The average discharge at this location over a 19-year period of record was 6,909 cfs; calculations using data from 1971 to 1974, 1981, and from 1987 through 1991 indicate that the maximum total daily downstream flow was 25,515 cfs (August) and the maximum daily upstream flow was 10,428 cfs (May) (USGS

1990, 140). These are daily average values and, therefore, do not include tidal extremes.

The river, through and downstream of Jacksonville, is about 0.25 mi wide, except at Mill Cove. Arlington River joins the St. Johns River from the south at RM 21.5. Near this location, the navigation channel is 575 ft wide and 34–38 ft deep. Downstream from this point to the ocean, the channel has an average depth of 38 ft and its width ranges from 400 to 1,000 ft. The dredge depot at the USACE dock is located at RM 19. Trout River joins the St. Johns River from the west at RM 16. Mill Cove, an embayment on the south side of the river extending from RM 16 to RM 9, with depths ranging from 1 to 4 ft and width of about 2 mi, lies alongside the south side of Blount Island, which is encircled by navigation channels. The Atlantic Intracoastal Waterway (ICW), with a mean depth of 12 ft, follows Sisters Creek from the north, joins the St. Johns River at RM 5, crosses, and extends southward into Pablo Creek. Mayport Naval Station is located about 1 mi from the ocean entrance. The jetties extend about 1.9 mi east of the river mile origin.

The St. Johns River has an estimated maximum freshwater discharge of 64,000 cfs and a maximum monthly mean total flow of about 25,515 cfs in Jacksonville (USGS, various years). Other analyses provide comparable values; for example, the Interim Water Quality Management Plan Findings gives a maximum (total) daily discharge of 61,100 cfs and a maximum reverse flow of 51,040 cfs at the mouth (USACE Jacksonville 1986, 72–73). Total discharges are usually derived from measurements and, therefore, include tidal flows.

Maintained Navigation Channel

A navigation channel 200 ft wide and 13 ft deep was dredged between Jacksonville and Palatka in 1899 (SJRWMD 1989, 15). This channel is shown on the USACE map set in Appendix A.

In 1964, the federally maintained navigation channel was 34 ft deep (referenced to mean low water [MLW]) and 200 ft wide from the Atlantic Ocean to Jacksonville, 13 ft deep and 200 ft wide from Jacksonville to Palatka, 12 ft deep and 100 ft wide from Palatka to

Sanford (RM 166), and 5 ft deep and 100 ft wide from Sanford to Lake Harney (RM 186) (Pyatt 1964, F27–28). More recent increases in channel dimensions are 38 ft deep and 400–1,200 ft wide from the ocean to RM 20, 34 ft deep and 590 ft wide via Terminal Channel from RM 20 to Commodore Point (RM 22), and 30 ft deep and 300–600 ft wide from Commodore Point to the FEC RR bridge at RM 24 (USACE Jacksonville, unpublished information).

Segmentation of the River

To account for the variability in its water levels, flows, and salinity, the river can be divided, or segmented, into different, relatively homogeneous zones or sections. The size of a section usually depends on which variable in the section is to be described and on the degree of resolution that is required in the description of the variation between sections. For example, segmentation according to the geometry of the river is required for calculations of the dimensions of segments for a one-dimensional computer model of river flow (e.g., Figure 3.2, showing geometry used for the Connell model).

At an instant in time, the volume of a section of the river is characterized by the length and width of the channel, the height of the water surface, and the depth. The depth of water measured to a common datum defines the bottom topography. River volume and flow at any location and time are primarily dependent on the past history of tide, wind, inflows, and outflows. The volume of a section can be estimated from measured water surface elevations and known widths and depths. Furthermore, because the water surface is usually not level, the surface slope should be taken into consideration if an accurate quantification of volume and flow is to be achieved.

Bottom Topography

A survey of bottom topography requires a series of determinations of both the depth of the water and the instantaneous position of the vessel from which the depth is measured. Historically, the primary purpose for conducting depth surveys has been to collect data for the production of navigation charts. Since water depth soundings are time consuming and expensive to acquire, the federal government assumed this responsibility for major water bodies of the United States with the formation of the Survey of the Coast in 1807. In 1836, the Survey of the Coast became the Coast Survey, and in 1878 the name was changed again, to the Coast and Geodetic Survey (C&GS). C&GS was responsible for conducting hydrographic surveys and producing charts for rivers, estuaries, and coastal areas. In 1970, C&GS was incorporated into the National Ocean Survey (NOS), which was renamed the National Ocean Service (NOS) in 1985. C&GS, renamed the National Geodetic Survey (NGS), and the Office of Charting and Geodetic Services—both part of NOS—are responsible for the national networks for geodetic control, field surveys, and map production (Hicks 1984, 25–26).

Bathymetric soundings in the LSJR were collected by C&GS by hand, using lead lines, beginning in 1852. In the early 1920s, C&GS and NOS began using echo-sounding depth indicators (fathometers); in the late 1930s, chart records were added to the fathometers. Originally, vessels were positioned by means of sextant angles and distances were measured along wire cables stretched between boats or between a boat and the shore. Since the 1940s, radio and other electronic systems have replaced sextants for positioning (Wraight and Roberts 1957, 58). Several decades later, fathometers were integrated with electronic navigation systems to record positions and depths automatically. Now (in the 1990s), the locations of measured depths can be determined automatically with the assistance of global positioning systems (GPS) using satellite transmissions, corrected for tide, referenced to the geodetic datum, and plotted in real time on shipboard.

The soundings are plotted on large-scale charts called "boat sheets" and made available on paper (bromide) or mylar. A small set (about 10%) of these soundings is selected for transfer to navigation charts, but the charted depths are not necessarily representative of the average depth in a particular area. Instead, the charted depths are selected to show the locations of hazards to navigation or the significant shallow depths or shoals. Thus, bottom topography digitized from navigation charts may provide a biased representation of the actual depth. Many of the boat sheets for United States waterways have been digitized and archived in computer format at the National Geophysical Data Center (NGDC) in Boulder, Colorado.

Detailed boat sheets for the LSJR are available from the series of hydrographic surveys conducted by C&GS and NOS between 1852 and 1959. The areas of coverage of these hydrographic surveys are shown on a series of small-scale maps which are available from NOS (Table 3.3). Some, but not all, of these boat sheets have been

Table 3.3 Summary of Coast and Geodetic Survey hydrographic surveys of the lower St. Johns River*

Hydrographic Index Number	Year Range	Overall Location Description
76A	1853–1872	From the inlet into the Intracoastal Waterway and west to vicinity of Arlington River
76B	1876–1889	From the inlet to Jacksonville and south to Tocoi
76C	1885–1939	From north of the inlet to south of Welaka and into Crescent Lake and a few surveys in Jacksonville
76D	1937–1959	From the river mouth off inlet and a few surveys around Jacksonville, and south to south end of Crescent Lake and into Lake George

*See Appendix B for complete list.
Map scales range from 1:5,000 to 1:20,000.

Source: NOS 1992

digitized, and the digitized data are available from NGDC in 1-degree squares. NOS Nautical Charts 11490, 11491, 11492, and 11495, as well as other navigation chart series, such as locally produced fishing maps, also show some of the river depths. Other special project depth surveys, such as those conducted by USACE in Mill Cove, and surveys of the navigation channel for purposes of channel maintenance have been carried out at various times. The most recent of the latter is the navigation channel survey by USACE Jacksonville for Jacksonville Harbor, entitled "Examination Survey, 34- and 38-foot Project," March 1992.

A more detailed summary of the areas of coverage of these hydrographic surveys is given in Appendix B. Figure 3.3 is a plot of the locations of bathymetric data in the NGDC data base for the St. Johns River, showing the area in which bathymetric data has *not* been archived on the NGDC data base. The data are so dense in most parts of the lower river that, when plotted on an 8½- x 11-in. page, the areas with depth data appear almost black. All digitized bathymetric data from Jacksonville to the ocean are missing from federal government data bases.

Other Hydrographic Surveys and Maps

Numerous studies and surveys of the river have been authorized under the Rivers and Harbors Act and federally authorized flood damage prevention and navigation projects. The Rivers and Harbors Act and the surveys are listed in the *Interim Water Quality Management Plan Findings* (Findings Report) (USACE Jacksonville 1986, 32–34, Table 3, and 35–41, Table 4).

USGS and NOS jointly publish a series of small-scale (1:100,000, metric) topographic-bathymetric maps depicting contours and elevations (in meters). These maps indicate highways, water features, and bathymetric contours. The 1980 Jacksonville, Florida, map (30081-A1-TB-100) includes the area from the mouth of the river to Green Cove Springs. The sources of bathymetric survey data used in this map are summarized in Table 3.4. The maps for St. Augustine and Daytona Beach, to the south of Green Cove Springs, do not include bathymetric contours.

CLIMATOLOGY AND HYDROLOGY

The general hydrologic characteristics of each tributary drainage basin of the LSJRB are described in the Findings Report (USACE Jacksonville 1986, 66, 70–71) and in Volume 2 of the LSRB Reconnaissance Report (Bergman 1992).

Local weather patterns cause the river to have a pronounced seasonal flow. High flows predominate during the rainy season, which is late summer to early fall. Low flows, probably augmented

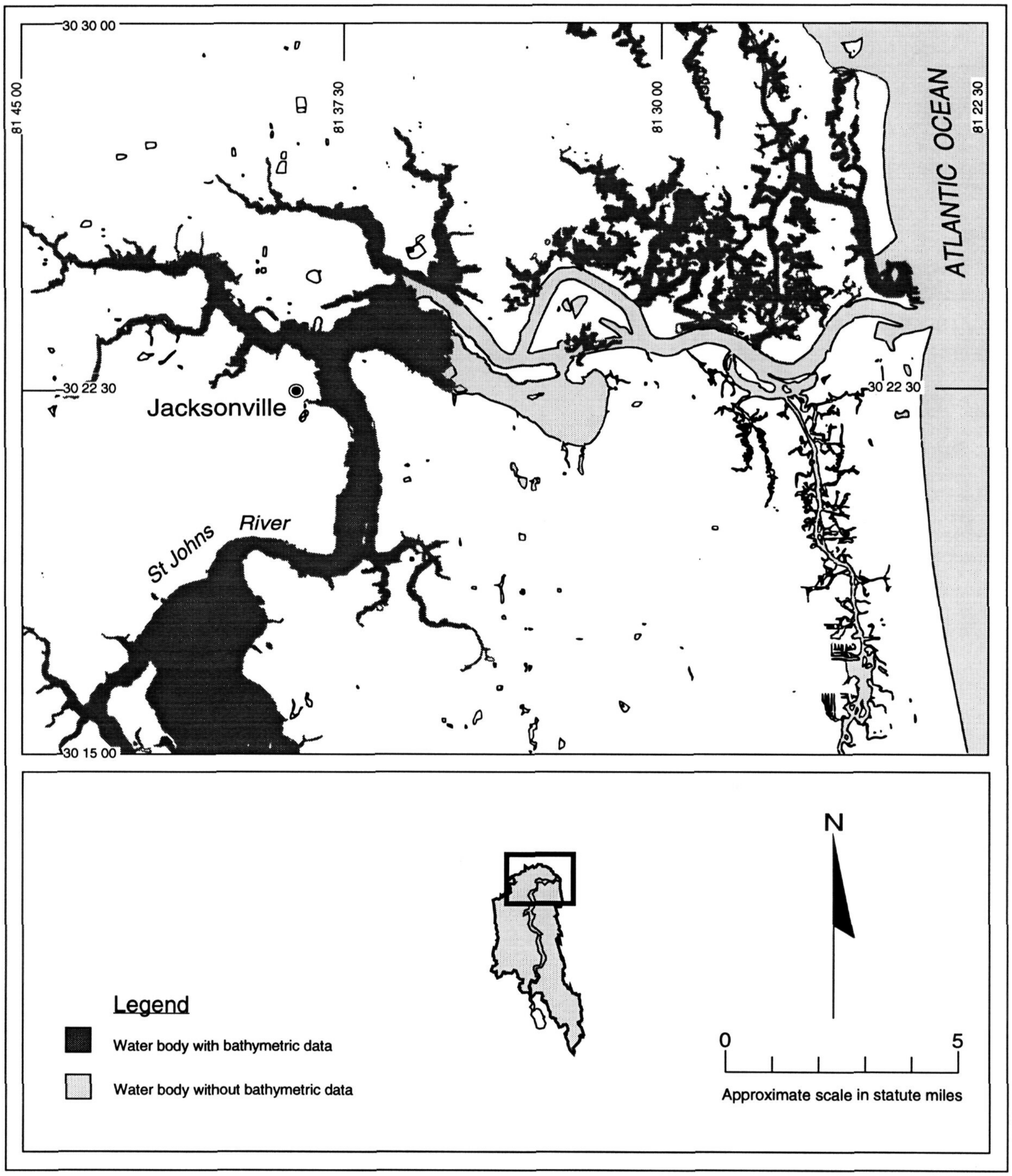


Figure 3.3 Areas in the St. Johns River covered by Coast and Geodetic Survey hydrographic survey data

Table 3.4 Bathymetric surveys used in USGS/NOS 1:100,000-scale metric topographic-bathymetric map number 30081-A1-TB-100 (1980) of the Jacksonville, Florida, area

Survey Number	Survey Date	Survey Scale	Survey Line Spacing (nautical miles)
C-11491*	---	---	---
H-6127	1935	1:10,000	0.01–0.06
H-6296	1935	1:20,000	0.02–0.08
H-6297	1935	1:20,000	0.05–0.10
H-6530	1939	1: 5,000	0.01–0.03
H-8412	1959	1:20,000	0.05–0.20
H-8463	1959	1:10,000	0.03–0.11
H-8464	1960	1:10,000	0.02–0.05
H-8107	1954–55	1:10,000	0.01–0.15
H-8462	1959	1:20,000	0.02–0.12
H-9474	1974	1:40,000	0.03–0.06

*Special survey covering Chicopit Bay and Mill Cove

Coverage: Latitude 30°0' to 30°30' North, longitude 81°0' to 82°0' West

by contributions from ground water, are the norm during the dry season, in winter. In an effort to describe a "design flow" for the LSJR, monthly averages of daily net flows at Main Street Bridge (RM 23.8) were first calculated by USGS for data collected between 1955 and 1966 (Anderson and Goolsby 1973, 49, Figure 31). After some difficulties with instrumentation, USGS resumed the publication of daily flows in 1972 and intermittently continued with calculations until January 1991. Data for 1991 and 1992 were published in the Water Year (WY) 1992 report (USGS 1993). A daily net flow is the average of all measured upstream and downstream flows over one day.

The seasonal flow regime at Jacksonville consists of a rainy season from June through October (highest mean flows), a dry season from

November through May (lowest mean flows), a period of increasing storage from April through September, and a period of decreasing storage from October through March (first described by Anderson and Goolsby 1973, 48; corroborated by USGS data to 1992) (Figure 3.4).

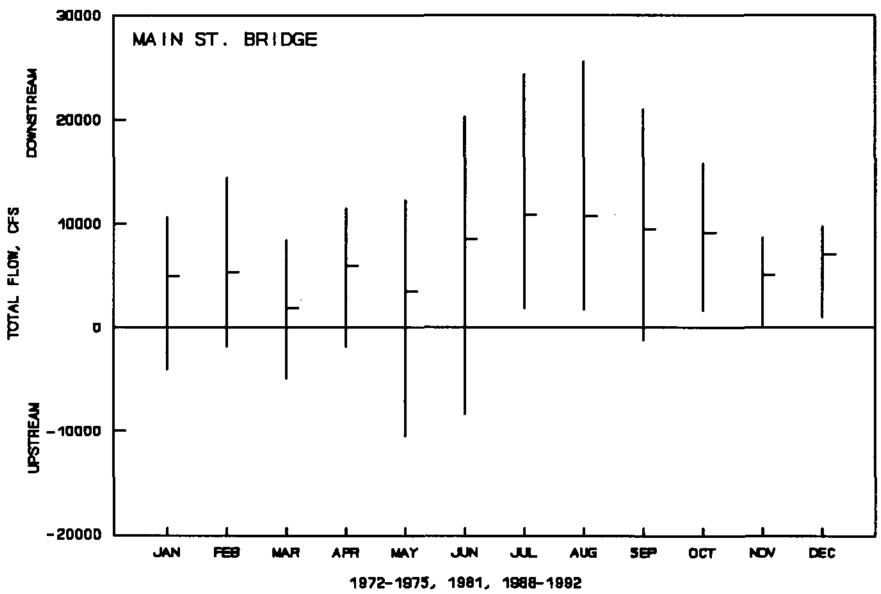


Figure 3.4 Monthly means and high and low daily net flows at Main Street Bridge, 1972–92

Seasonal flows are summarized in more detail in the following chapter on tides and river flow. A detailed description of weather and climate is given in the Findings Report (USACE Jacksonville 1986, 57).

TRIBUTARY DISCHARGE AND SEDIMENT LOADINGS

Tributary discharges are one of the principal sources of sediment loading to the river. Large tributary storm discharges may erode banks of streams, which changes the shape and flow characteristics and introduces significant loads of sediment into the main stem of the river. Sediment accumulations (shoaling) in the river change the bottom topography, which also affects river hydrodynamics. Sediments may concentrate toxic substances in locations in which bottom currents are not strong enough to maintain the sediment in suspension, such as in the navigation channel. Sediments may contain organics that deplete benthic oxygen or dissolved oxygen in the water column. The physics of sediment movement and transport are usually described in terms of erosion, deposition, resuspension, and dispersion. These phenomena are principally influenced by hydrodynamics, salinity, and chemistry.

The literature on the hydrodynamics of the LSJR does not provide insight into the locations and magnitudes of sediment phenomena. However, reviews of sediment and sediment management in the LSJR are found in Keller and Schell (1993) and in USACE Jacksonville (1994e).

SUMMARY OF RIVER LOCATION, DESCRIPTION, AND DRAINAGE AREA

The LSJR is designated, for management purposes, as that part of the St. Johns River extending from the confluence with the Ocklawaha River, 101 mi upstream from its mouth, to the Atlantic Ocean. The lower part of the river flows northward through a relatively narrow channel to Palatka (79 mi upstream), widens for another 54 mi to Jacksonville, and then narrows again and flows eastward to its mouth. A navigation channel of varying dimensions is maintained by the federal government throughout its reach.

The LSJR is tidal throughout its length, and its average monthly freshwater discharge is on the order of 6,000 to 8,000 cfs. Average annual total flow (tidal plus non-tidal) over half tidal cycles is most likely to be in the range of 30,000 to 50,000 cfs. Peak total flows exceeding 100,000 cfs have been reported. Partially diluted seawater extends at least 17 mi upstream to Trout River, and a mixing zone extends 15 mi more to NAS. Salinity fluctuates between low and moderate values to the head of tide, depending on the volume of freshwater inflows.

Depths have been charted at least once in all areas of the river from 1852 to 1959. In addition, the navigation channel has been surveyed every few years to determine changes in bathymetry for maintenance dredging.

WATER SURFACE ELEVATION

The elevation of the water surface, or "water level," in a tidal river such as the LSJR is dependent on tide, wind, inflows and outflows, and, to a lesser degree, atmospheric pressure. Water level changes continually, both spatially and temporally.

WATER SURFACE DATUMS

Water Level Geodetic Network

"Geodesy" is the measurement of the shape of portions of the earth's surface. A network of vertical and horizontal geodetic reference stations is maintained by NOS through NGS and the Office of Charting and Geodetic Services. The vertical reference points on this network for water bodies were established originally by a series of measurements of water level over several decades at selected locations. Even though river and ocean water levels fluctuate continuously over a considerable range, these measurements were a practical approach to establishment of a level plane because hourly values were averaged over many years. NOS reference station elevations are determined by standard surveying techniques to first- or second-order accuracy referenced to the standard datum.

Datums and Benchmarks

A "datum" is the reference surface from which both vertical and horizontal distances are measured. The network of accurately surveyed stations used to establish the datum is called a "control network." The first comprehensive datum to be established for the North American continent was the National Geodetic Vertical Datum (NGVD) of 1929. This datum was based on mean sea level, as calculated in 1929, at 26 tidal stations in the United States and Canada (Harris 1981, 4). In June 1991, an adjustment to this datum, called the North American Vertical Datum of 1988 (NAVD 88), was completed. This datum has been established to correct irregularities in the level plane that have been detected since 1929 by using more accurate measurements.

The horizontal control network is now based on the North American Datum (NAD) of 1983, which was readjusted in 1990. This datum, called NAD 83/90, is the preferred reference for the horizontal control network in Florida. The Bureau of Survey and Mapping/ Florida Department of Environmental Protection (BuSM/FDEP) uses both NAVD 88 and NAD 83/90, while also maintaining references to NGVD.

A "benchmark" is a station, referenced to a control network, that has an accurately measured location and elevation. A "monument" marks the location of a benchmark. Descriptions of benchmark locations and monuments along the St. Johns River are available from NOS and various local agencies, such as the BuSM/FDEP and SJRWMD. The accuracy of benchmarks established by agencies other than NOS may have been determined to first-, second-, or third-order standards. A complete survey of existing tidal benchmarks on the LSJR has been prepared by BuSM/FDEP (USACE Jacksonville 1994c).

Since 1989, the vertical datum of all navigation charts in the vicinity of the LSJR has been mean lower low water (MLLW), which is defined as the mean value of the lowest of the two daily measured low water levels that occur at a given location in the river. If the MLLW datum changes, relative to NGVD, from one location to another in a river (as it does in the LSJR), then the datum for the depths on navigation charts in that river is not a horizontal plane. This change in datum must be considered in setting up a hydrodynamic model of the river because the depths in a model are referenced to a horizontal datum.

WATER LEVELS

The common term for "water surface elevation," the instantaneous height of the water above a datum, is "water level." Water levels in a tidal river such as the LSJR depend on other factors besides the tides, and all water level measurements include the effects of all of the factors causing changes in water levels. Total water levels are described in this section, while the tidal effect is described separately in the following chapter.

Water Level Data

NOS is the primary source of long periods of record of water surface elevations, now typically recorded at 6-minute intervals, which are used to calculate mean water levels. Mean water level (MWL) at a site—which is published annually in the tide tables for each station—is simply the average of the available series of water level measurements. The calculated mean value of local water level measurements will not usually coincide with NGVD or NAVD because sea level is constantly changing.

Mean Sea Level

Mean sea level (MSL) is defined as the long-term mean elevation of the ocean surface in the vicinity of the monitoring station. It is the average of continuous measurements of water surface elevation over a period of time that is long enough to eliminate the short-term effects of tide, wind, and waves; the effects of atmospheric pressure changes; and other local storm effects. MWL is a more general term for the mean of a set of measured water levels.

Monthly means are calculated from 6-minute values of measured water surface elevations. NOS has calculated MSLs for each available 19-year record, which provides a period of record that is long enough to eliminate, through analysis, the periodicities of the principal tidal constituents and to average out most of the meteorological fluctuations that occur during the period. Also, analysis over a long period of record permits long-term trends in sea level to be evaluated. Longer period trends in water level are a major factor in requiring that datums be revised at approximately 25-year intervals (Harris 1981, 36). The trend in MSL at Mayport from 1929 to 1992 is an increase of 0.007 feet per year (ft/yr) (Figure 3.5).

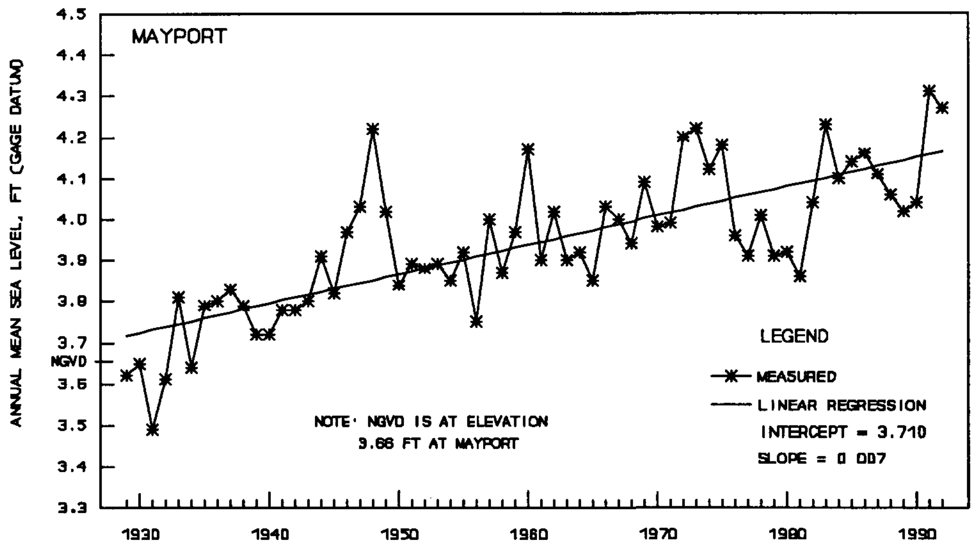


Figure 3.5 Annual mean sea level at Mayport, 1929–92

Long-Term Changes in Mean Sea Level

Changes in the level of the ocean affect water levels in the river. In general, long-term changes in the level of a river also may be caused by subsidence (which may be the result of large withdrawals of water from below ground or increased loading by large structures such as dams), sediment deposition, or changes in the shape of the earth.

Glaciologists have estimated that, from preglacial periods to the present, MSL has fluctuated from 300 ft higher to at least 300 ft lower than at present (Fairbridge 1966, 478). Evidence further indicates that, between 6,000 years ago and the present, sea level on the Atlantic Coast exceeded present levels in at least four periods but has not been greater than 12 ft above the present level (Harris 1981, 57). Sea level was about 1.5 ft below current sea level during the period between 600 and 200 years ago (from Fairbridge 1966, as quoted by USACE Jacksonville, 1990c, G1-8).

According to some researchers, sea level has increased about 1 ft along the Atlantic Coast in the past 100 years (Hicks, Debaugh, and Hickman 1983, as quoted by Titus 1987, 3). Comparative studies of tides around the coast of North America, using 1930–48 data, indicated a steady rise in sea level on the United States east coast since 1930 of about 0.02 ft/yr (2 ft/100 yr) (Marmer 1951, 58). NOS measurements since 1948 have determined that the rate of change of sea level along the Florida east coast between 1940 and 1980 is on the order of 0.79 ft/100 yr, whereas for the United States as a whole, it is between 0.49 ft/100 yr (reference to Hicks 1978, in Harris 1981, 57) and 0.62 ft/100 yr (NOS 1988[a], as quoted by USACE Jacksonville 1990c, G1-9).

At Mayport, sea level rise was found to be 2.69 millimeters per year (0.61 ft/100 yr) from 1940 to 1972 (Harris 1981, 54). The rate of sea level rise at Mayport, calculated from 64 years of record (1929–92), is 0.007 ft/yr or about 0.7 ft/100 yr (Figure 3.5).

Assuming the rate of change of sea level rise remains constant over the next 100 years, USACE estimates that water levels at the mouths of tributaries in the LSJR will rise about 0.94 ft (USACE Jacksonville 1990c, G1-9). Another report, based on analyses of increases in the concentrations of atmospheric carbon dioxide and other greenhouse gasses, predicts that sea level will continue to rise at least until the year 2100 (Hoffman et al. 1983, vi). These authors conservatively estimate the future rate of rise to be twice the historical rate until the year 2000 and three times the historical rate to the year 2025. Along the Atlantic and Gulf coasts, the rise is predicted to be at least 2.5 ft by the year 2100 (2.1 ft/100 yr) (Hoffman et al. 1983, vi).

Historical Water Level Measurements

The measured water surface elevation at a particular location is a function of the superimposed effects of tide, wind, inflows and outflows, atmospheric pressure, and water movement in the vicinity of the measurement over the period of the measurement. Wind is often the predominant force involved in changes in water level. "Tide measurements" are water level measurements sampled at a frequency of at least 1 hour (hr) that have been analyzed to extract the tidal components. Water levels sampled or calculated at intervals greater than 1 hr do not resolve tidal fluctuations and therefore can only be used for reporting on long-term trends in water levels, effects of droughts or floods, or for estimating daily flows.

Measurement records of water surface elevations along the shorelines of the United States have been maintained since the 1800s by survey parties of USACE and C&GS. USACE conducted some relatively short series of observations in the St. Johns River, which are reported in U.S. Army 1890, U.S. Army 1891, and House of Representatives 1910.

The first substantive hydrographic observations in the river were taken during the winter of 1933–34 by C&GS. During this survey, water levels and currents were measured at the surface and at several depths at 35 stations. The number of water level stations at which data were taken during this survey is not stated (Haight 1938, 17).

Present Water Level Measurements

NOS is one of the few sources of long-term estuarine water level data in the United States. NOS maintains "reference" (primary) and "subordinate" (secondary) water level measurement stations throughout the world to obtain data for calculations of MSL and analysis and prediction of tidal characteristics. Reference stations are installations with long-term, reliable records; there are presently 26 such stations on the east coast of North America and a total of 50 on this continent. Subordinate stations have considerably shorter periods of record. The closest of the coastal reference stations to the St. Johns River are located at Fernandina Beach, Mayport, and Miami. NOS tabulates the hourly, quarter-hourly, or 6-minute data recorded at reference and subordinate stations and performs analyses to obtain daily, monthly, annual, and 19-year statistics for calculating harmonic constants, which are used in tidal predictions (see tides chapter). The period of record for water level measurements at Mayport, the only reference station on the LSJR, begins in April 1928.

USGS and NOS have maintained stage monitoring stations on the St. Johns River since 1928 (Table 3.5). The term "stage" is synonymous with "water surface elevation." The data from these stations are used for obtaining mean and extreme values of water levels, for assessing the magnitudes and extents of floods and droughts, and for calculating flows. All measurements have been made with float recorders except the levels at De Land from 1933 to 1934, which were not automatically recorded. Each of the recorded water level values is archived in a "unit value file." Daily mean values are published annually by USGS, along with minimum and maximum elevations for the period of record. A few of these stations are located in tidally affected areas (Figures 3.6a–d).

Table 3.5 Periods of record for reliable data and locations of water level stations on or near the main stem from De Land to the river mouth

Station and USGS ID Number	Published Period of Record	Reporting Interval	Gage Type	Location Description
De Land USGS 02236000	Oct 1933–Feb 1934	Day	Non-recording	Near site of former Crows Bluff Bridge, about 1,000 feet downstream
	Feb 1934–May 1936			(same as 1933–34)
	Jun 1936–Jul 1970		Stage recorder	0.4 miles downstream of above station
	Jul 1970–Sep 1994			Near west bank, downstream of Whitehead Bridge at State Road 44, 5 miles west of De Land
Buffalo Bluff USGS 02244040	Sep 1943–Jul 1948	Day	Stage recorder	Downstream of CSX RR bridge, north bank at boat dock
	Aug 1990–Sep 1994	15 minutes	Stage recorder with shaft encoder	Under CSX RR bridge, near south bank
Dunns Creek USGS 02244440	Jan 1978–Apr 1989	Day	Stage recorder	Under U.S. 17 bridge, near center span
	Apr 1989–Sep 1994	15 minutes	Stage recorder	Under U.S. 17 bridge, near center span

Table 3.5—*Continued*

Station and USGS ID Number	Published Period of Record	Reporting Interval	Gage Type	Location Description
Palatka USGS 02244450	Jan 1968–Feb 1976	Day	Stage recorder	Under U.S. 100 bridge, near center span
	Jul 1976–Sep 1979	Day	Stage recorder	6 miles upstream of U.S. 17 bridge, near east bank at Edgewater Light 13, 1.4 miles downstream from Dunns Creek
	Oct 1980–Sep 1982	Day	Stage recorder	(same as 1976–79)
Jacksonville USGS 02246250	Sep 1945–Oct 1973	Day	Stage recorder	NAS crash boat dock, 7.9 miles upstream from Main Street Bridge
Jacksonville, vicinity of Main Street Bridge USGS 02246500				
(a) Florida East Coast RR Bridge	Oct 1971–Sep 1986	Day	Stage recorder	Near center of RR bridge, 0.3 miles upstream of Main Street Bridge
(b) Main Street Bridge pier	Feb 1954–Apr 1966	Day	Stage recorder	Downstream side on pier, near east bank
(c) Main Street Bridge, downstream side	Oct 1986–Sep 1994	Day	Stage recorder	Downstream side, on walkway, near east bank of river
(d) Fireboat dock	Apr 1966–Sep 1971	Day	Stage recorder	Southeast corner of dock, on west bank of river, 0.3 miles downstream of Main Street Bridge
(e) Jacksonville USGS 02246530	Oct 1972–Sep 1994	Day	Stage recorder	USACE dock (dredge depot), west bank, 1.2 miles downstream of Deer Creek, 5.1 miles downstream of Main Street Bridge
Mayport NOS 8720220	Apr 1928–Sep 1994	15 minutes	Float recorder	West of Mayport Naval Station, on dock on south bank

Note: CSX RR = Seaboard Coast Line Railroad
AVM = acoustic velocity meter
NAS = Naval Air Station

Source: Jim Sohm, USGS Jacksonville, pers. com. January and July 1993
USGS, pers. com. 1995

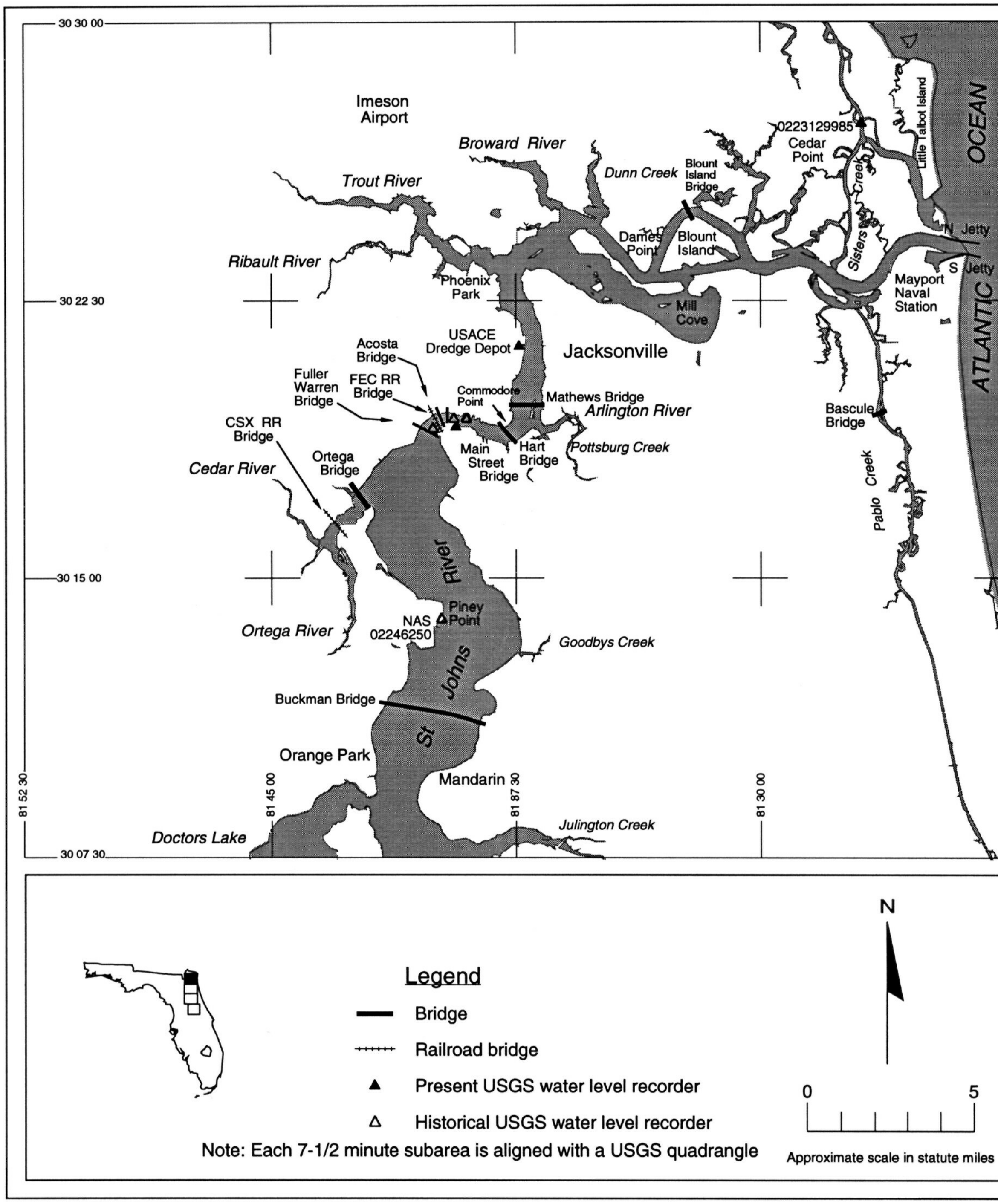


Figure 3.6a Locations of USGS water level stations between the mouth of the St. Johns River and Julington Creek

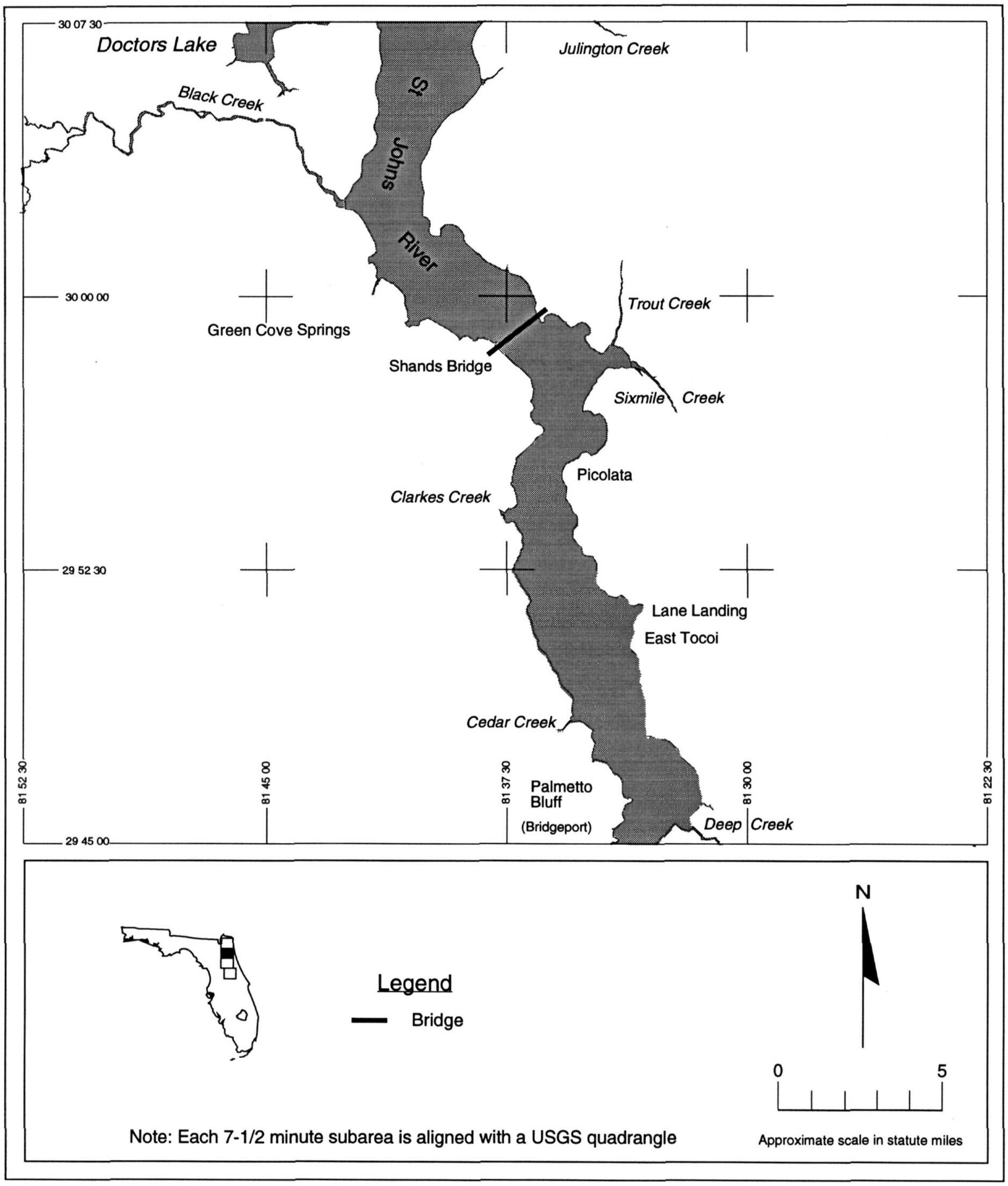


Figure 3.6b Locations of USGS water level stations between Julington Creek and Deep Creek

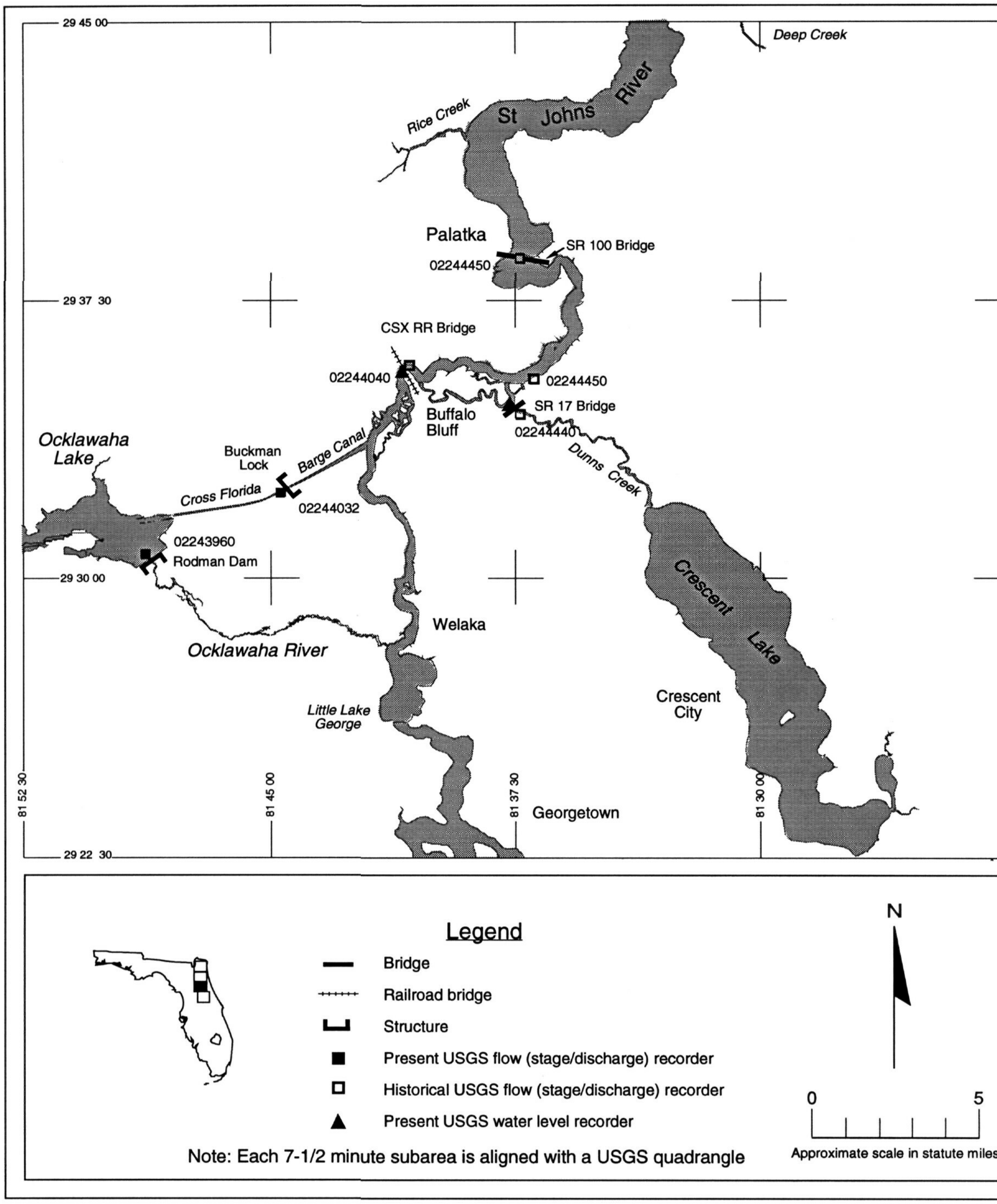


Figure 3.6c Locations of USGS water level stations between a location north of Rice Creek and Georgetown

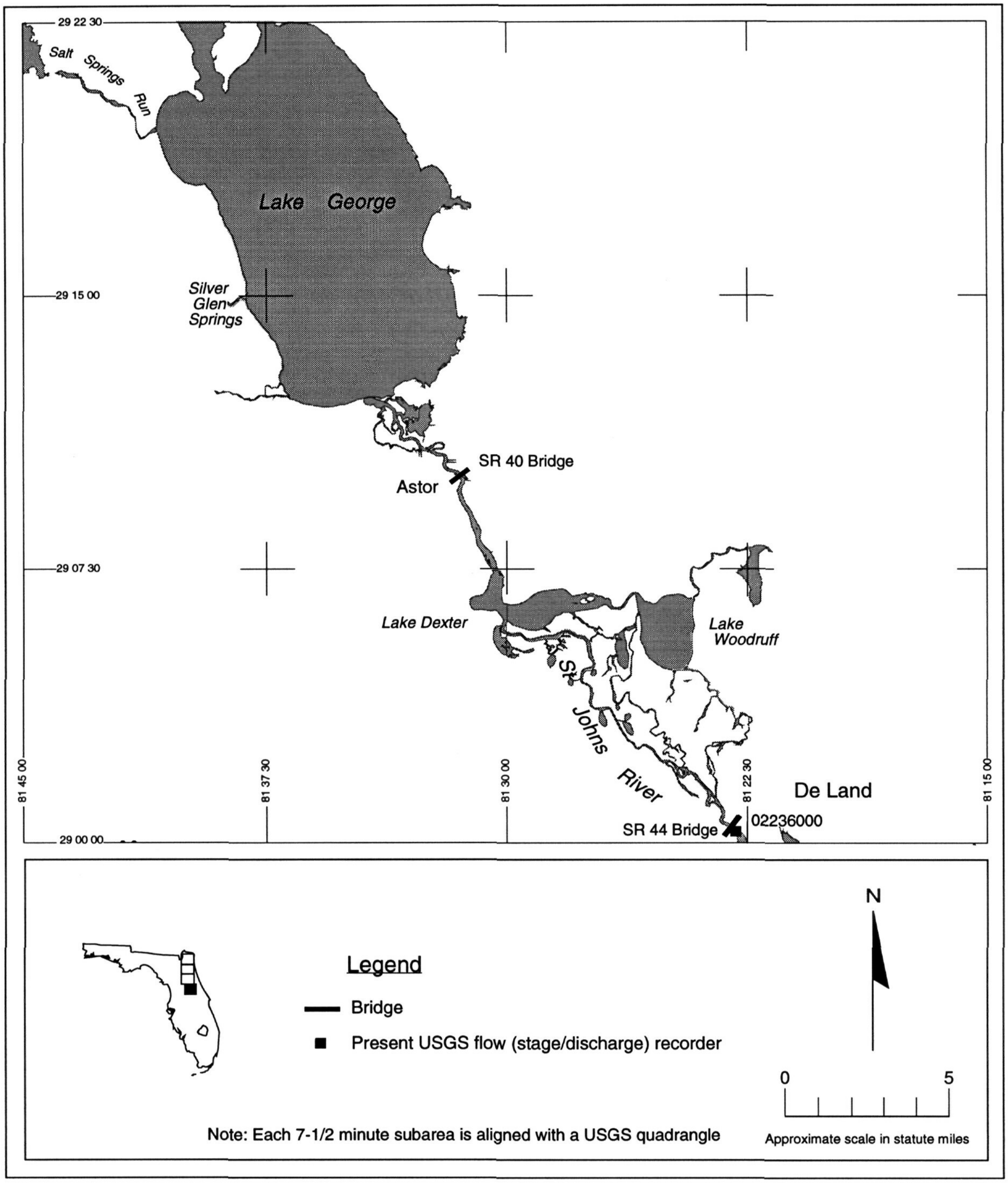


Figure 3.6d Locations of USGS water level stations from Lake George to De Land

As of 1994, stage recorders were being maintained on the main stem of the LSJR at De Land, Buffalo Bluff, Dunns Creek, Main Street Bridge, and the USACE dock (dredge depot). Water level is also measured at the tide stations maintained by NOS (see tides chapter).

Monthly Mean Sea Level

The variability of sea level from month to month is influenced by seasonal changes in tidal forces and the hydrologic cycle. Therefore, monthly MSL is described in the tides chapter.

ATMOSPHERIC PRESSURE EFFECT ON WATER LEVEL

Except under storm conditions, atmospheric pressure changes have a direct, but relatively minor, effect on water level of 1 centimeter (0.39 in.) per 1 millibar of pressure. In tropical storms, the decreasing central pressure is accompanied by high winds and ocean surge. Fluctuations in barometric pressure can cause measured mean stage differences at NAS ranging from −0.43 to 0.5 ft (Pyatt 1959, 122).

WIND CONSIDERATIONS

Wind Effect on Water Level

Wind pushes the surface water and causes it to flow and build up its elevation in the prevailing direction of the wind. The surface flows cause the water below to be moved at speeds that decrease with depth. If the wind blows toward a shoreline, it causes water to pile up (or "setup") against that shoreline; this can result in flows in an opposing direction lower in the water column. The longer the wind blows in the same direction, the higher the water levels will build up, until a maximum is reached that is determined by the counteracting head of the setup and the balance of forces. Also, setup, in general, increases to a maximum value with the fetch, the unobstructed water distance over which the wind acts. Because the wind usually fluctuates considerably in both speed and direction, currents and setup caused by the wind also continually change. The response of water level and flow to wind change integrates much of the wind fluctuation and may be considerably lagged behind it. Additional observations, data, and summaries on the effects on the LSJRB of wind, precipitation, and atmospheric pressure can be found in Pyatt (1959, 108–132).

Wind is extremely variable spatially. No one set of measurements at one location in a water basin will necessarily resemble those from another location. Therefore, because wind is a significant influence on flow in the LSJR, several measurement sites located as close as possible to the study site are required to accurately quantify the wind effect on the river.

Wind data collected over long time periods are routinely averaged over 24 hr for storage in the National Climatic Data Center (NCDC) data base. Such averaging does not preserve the means and extremes of wind at the smaller time steps needed to describe the hydrodynamics of the LSJR. Therefore, for any study that requires a quantification of the effect of wind on water levels, wind data will have to be collected and analyzed as needed during the particular study. For example, wind effect is modeled as a stress on the surface of the water. Most hydrodynamic models use a spatially constant wind field over the domain of the model; some models use a wind field that is constant with time, and others can use a temporally and spatially varying wind field. Typical time steps in hydrodynamic models are 1 to 5 minutes. Adequate wind data for calibration and verification of a particular model must be made available, depending on the capability of the model.

Wind Measurements

Hourly wind data are being collected at Jacksonville NAS, Mayport Naval Station, Jacksonville (Imeson International) Airport, and Daytona Beach Airport. Hourly wind data collections were discontinued at Craig Field in 1991 and at Cecil Field in 1993. These data are reported to the National Weather Service Office, NCDC, and some data are available in digital form for the period of record (Table 3.6 and Figure 3.7).

Table 3.6 Availability of daily wind data and monthly and annual summaries of wind data in the Lower St. Johns River Basin

Station Name	Period Digitized
Hourly Wind Data*	
Mayport Naval Station	Oct 1984–Sep 1994
Jacksonville Airport	Jan 1970–Sep 1994
Jacksonville Naval Air Station	Jan 1981–Sep 1994
Jacksonville Cecil Field	Jan 1981–1993
Jacksonville Craig Field	Aug 1974–Dec 1991
Daytona Beach Airport	Aug 1981–Sep 1994
Coastal Marine Automated Network (CMAN)	
St. Augustine (SAUF1)	Sep 1986–Sep 1994
St. Johns Light (SJLF1)	May 1984–Sep 1986
Data Summaries†	
Summaries of meteorological observations near the surface (SMOS)	
Mayport	1956–72; 1973–82
Jacksonville Airport	1973–82
Jacksonville Naval Air Station	1945–77
Jacksonville Cecil Field	1947–77; 1973–82**
Revised uniform summary of surface weather observations (RUSSWO)	
Jacksonville Airport	1948–81
Ceiling-visibility-wind (CVWind) (annual wind roses)	
Jacksonville Airport	Jan 1972–Dec 1978
Daytona Beach Airport	Jan 1948–Dec 1978

*Digitized and available on diskette and tape
†Not digitized; available on paper only
**Separate summaries with different periods of record

Source: Elizabeth Love, National Climatic Data Center, pers. com. July 1992, August 1994

On the coast, hourly wind has been reported at an elevation of approximately 10 m at the St. Johns Light (1984–86) and off St. Augustine (1986 to September 1994) by the Coastal Marine Automated Network (CMAN) of ocean buoys. These data are also available in digital form.

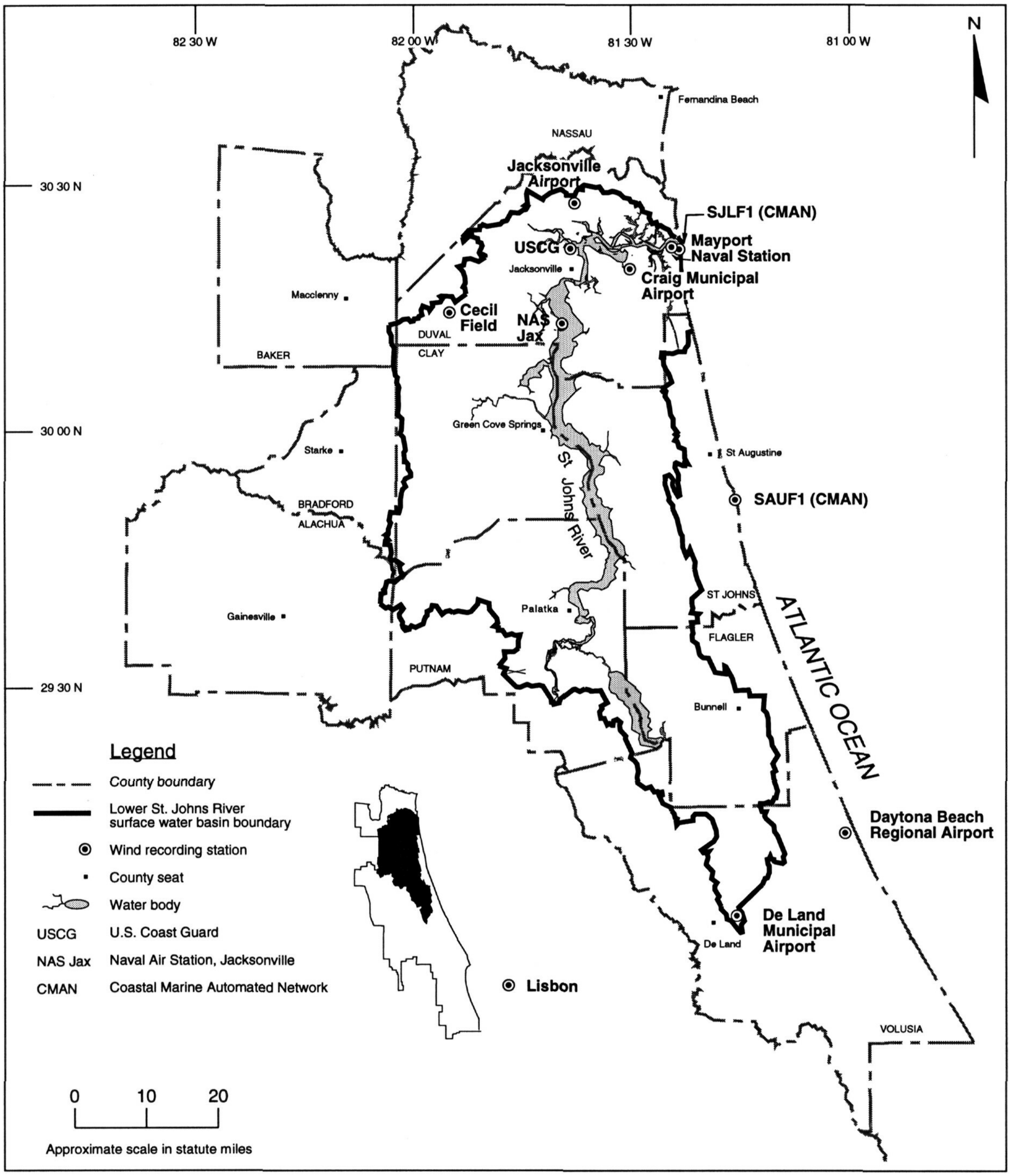


Figure 3.7 Locations of long-term wind recording stations

Historical Analyses of Wind Effects

Haight (1938) was the first investigator to publish the results of analyses of the effects of wind on water levels in the St. Johns River. Winds from 0 to 180 degrees (north to south clockwise) cause an increase in stage at NAS; winds from 180 to 360 degrees cause a decrease, to a limit. There is also a limit to the amount of water that can be set up by northeast winds. Northeast winds greater than 10 miles per hour (mph) may cause a large increase in stage at NAS, but continued northeast winds at gradually diminishing intensities will allow the stage to fall. Stage fluctuation depends upon the initial stage and upon the intensity, duration, and direction of the wind. Superimposed stage fluctuations caused by runoff may obscure the effects of the wind (Haight 1938, 23, as reported in Pyatt 1964, F45).

Daily wind data were analyzed in a study by Pyatt (1959). His conclusions are summarized in Table 3.7.

Summaries of wind, which do not contain daily values, are available from NCDC. They may be ordered in three different forms: Summaries of Meteorological Observations near the Surface (SMOS), Revised Uniform Summary of Surface Weather Observations (RUSSWO), and Ceiling-Visibility-Wind (CVWind). The SMOS and RUSSWO summaries are produced continually and may be obtained as monthly or annual reports; the CVWind summaries were produced only once, in 1980, for data through 1978.

SMOS data are prepared from U.S. Navy meteorological records and updated every 5 years. These data are available in three forms: (1) monthly and annual with extremes, (2) 3-hourly groups, or (3) complete summary. The percentage frequency of wind speed (knots) is tabulated for each month over the entire period of record in 11 ranges from "1 to 3 knots" to "greater than 56 knots" and also is summarized annually for each of 16 directions. The percentage of time the wind blows from each direction and the mean wind speed in each direction also are tabulated. RUSSWO data, collected by the Air Weather Service, are similar to the Navy SMOS data.

Table 3.7 Wind characteristics and effects on the Lower St. Johns River Basin

Characteristic	Effect
Wind speed	Measured wind at Imeson Airport averages 8.4 miles per hour (mph)
Wind setup	Significant wind setups occur at sustained wind velocities above 7 mph
	Wind setup ranges from -0.92 to 3.20 feet
Wind direction	Winds blowing in any direction from south to west account for most of the precipitation in the Lower St. Johns River Basin
	Exceptions may occur, especially during summer months when winds are from northeast to southeast
	Winds blowing in any direction from north through east to south cause increasing stage at the Naval Air Station on the west side of the river
	There is a limit to the setup that can be caused by northeast winds. Northeast winds greater than 10 mph may cause large increases in stage, but continued and gradually diminishing wind will permit stage to fall
	Winds from south through west to north cause stage decreases
Wind effect on stage	Stage fluctuations depend on the location, the initial water level, and the intensity, duration, and direction of the wind

Source: Pyatt 1959, 122–123

The NCDC prepared CVWind tables in 1980 for selected cities (in the study area, Jacksonville [at the airport] and Daytona Beach). The tables summarize the available data over the period of record. Twelve tables for each station show wind direction versus wind speed distributions, which are also available in the form of wind roses (circular graphs). These data are divided into six CV classes for daytime winds and six CV classes for nighttime winds. The CV classes range from ceiling greater than or equal to 1,500 ft and visibility greater than or equal to 3 mi, to ceiling less than 100 ft and/or visibility less than 0.25 mi. A seventh class provides summaries of all other classes. All tables are divided into 16 wind directions, calm conditions, and five speed groups (including calm [<1 knot]) and include the average wind speed in each direction.

A monthly wind rose from the National Oceanic and Atmospheric Administration (NOAA) data at an unspecified station in Jacksonville is given in a water quality analysis report (Atlantis Scientific 1976, II-5a, Figure II-9). A comparison of monthly surface wind mean directions and speeds, recorded at Cape Kennedy Air Force Base (1951–52, 1957–70), Jacksonville NAS (1945–70), and McCoy Air Force Base, Orlando (1944–45, 1952–67), are tabulated in the draft Water Resource Management Plan (WRMP) (SJRWMD 1977, as referenced in USACE Jacksonville 1986, 56, Table 10). A more recent wind rose, accompanied by graphs of seasonal wind frequencies, is based on data collected from 1973 to 1977 at NAS Jacksonville (Figures 3.8 and 3.9; data for Figures 3.8 and 3.9 are included in Tables C1 and C2, Appendix C).

Other Periodic Wind Analyses

NCDC analyzes hourly wind data and publishes 4-hr and daily averages as monthly local climatological data. These data are summarized in terms of resultant direction and speed (miles per hour), average speed, peak gust speed and direction, and fastest 1-minute speed and direction. These summaries are prepared on a daily, monthly, or annual basis.

NCDC has published a monthly summary entitled *Climatological Data, Florida* (month, year) since 1896. The closest station to the LSJR that is summarized in this publication, and the only one near the river, is located at Lisbon, southwest of Lake Yale, 9.4 mi south and 28.3 mi west of De Land. Wind run, the summation of wind speed over a period of time converted to nautical miles, is given for each day.

FLOODING

Data on floods that have occurred in the area before 1970 have been reported by USGS and the Bureau of Geology/FDEP. Frequencies for mean annual and specific return-period floods for the main stem

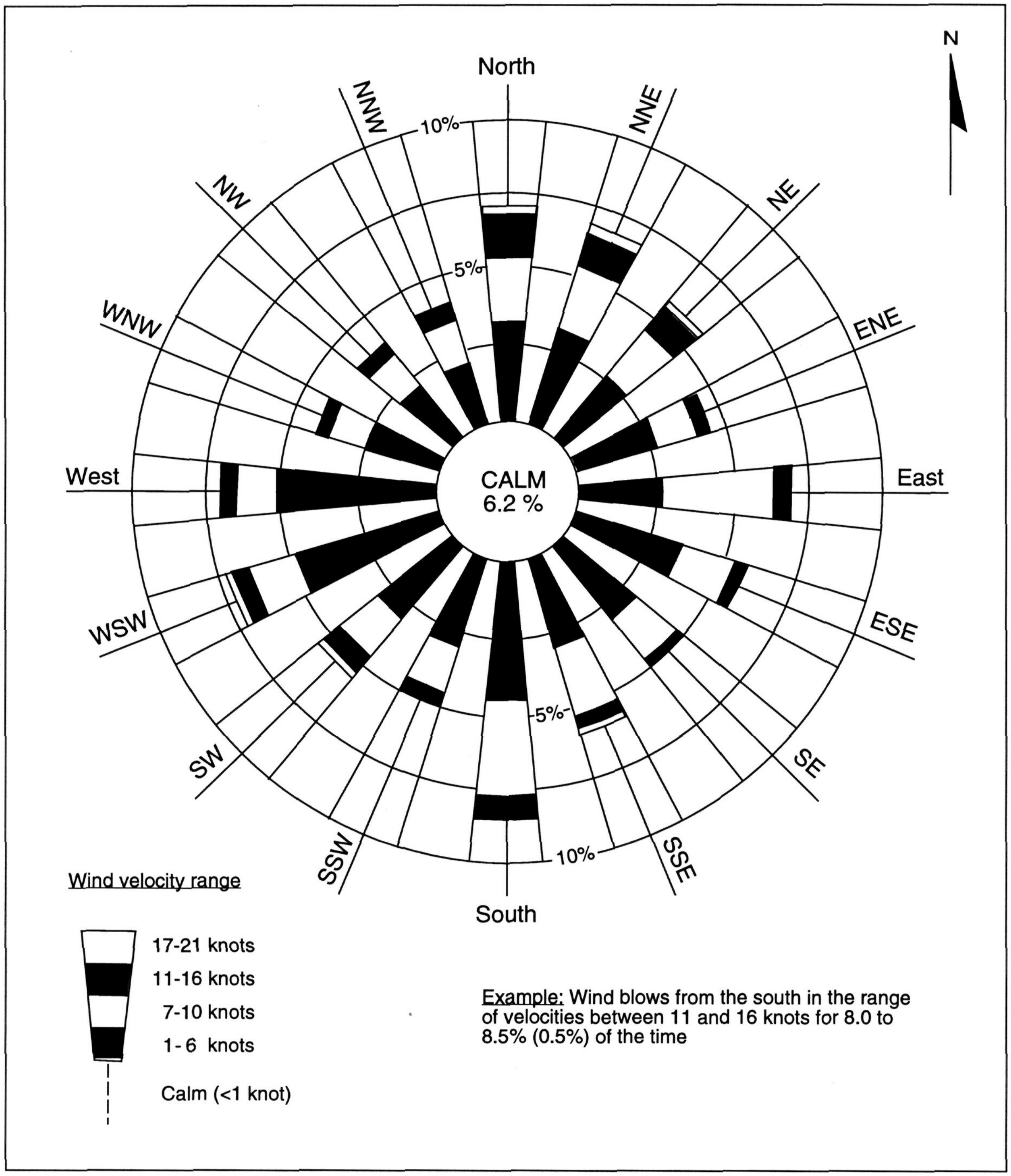


Figure 3.8 Wind rose, Naval Air Station, Jacksonville, Florida, 1973–77

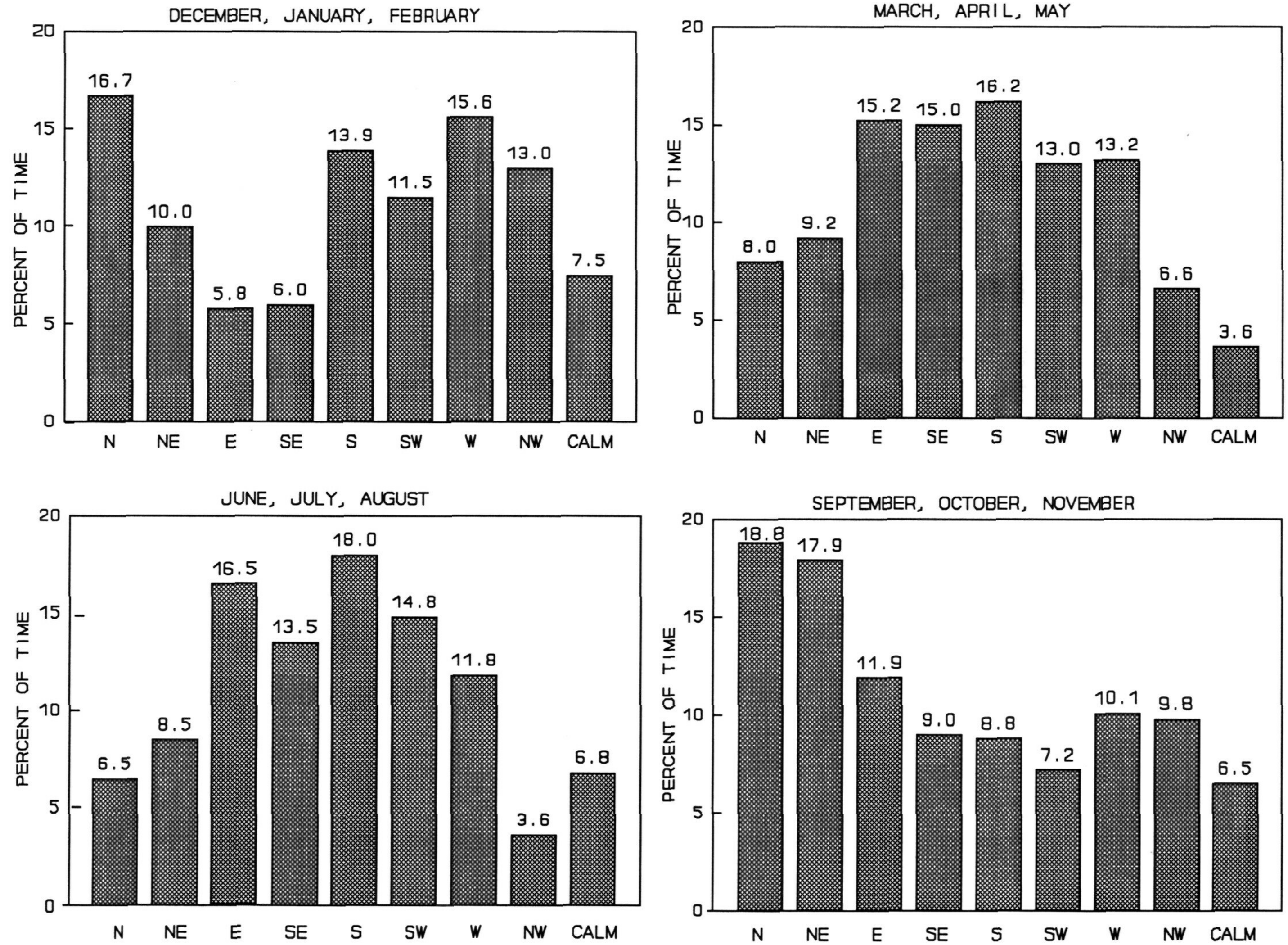


Figure 3.9 Seasonal wind frequency, Naval Air Station, Jacksonville, Florida, 1973–77

are reproduced from a USGS report (Snell and Anderson 1970, 15, Figure 4, attributed to Barnes and Golden 1966). Flood stages from De Land to the south are shown in Snell and Anderson's Figure 10. Near De Land, the annual flood was 3 ft, the 5-year flood was 4.5 ft, the 10-year flood was 5 ft, and the 30-year flood was 8.5 ft above MSL (Snell and Anderson 1970, 15–23).

Flooding has occurred in both urban and non-urban locations in the LSJRB, including Jacksonville (FDNR 1970, as quoted in SJRWMD 1977, D-40). Flooding may be caused by excessive water levels due to tide, wind, heavy rainfall and runoff, and/or insufficient channel capacity. The first of several "floodplain/hazard information" reports for the St. Johns River Basin was completed by USACE in March 1969 for Jacksonville (summary of publication dates: SJRWMD 1977, D-42, Table D-6). A summary of observed flood stage data for four storms from 1944 to 1964 showed that flood stage has been reached at Mayport at least three times, at the dredge depot twice, and at Main Street Bridge, NAS, and Palatka at least once during the 20-year period (Table 3.8) (SJRWMD 1977, D-46, Table D-10). These recorded flood stages were reported originally by USACE from data collected up to March 1969.

Table 3.8 Flood stages recorded at tide gages, 1944–64

Location	Recorded Flood Stage (feet)			
	Oct 1944	Oct 1950	Mar 1962	Sep 1964
Mayport	5.4		4.3	4.8
Jacksonville				
Dredge depot		4.7		5.3
Main Street Bridge				5.2
Naval Air Station				5.8
Palatka				5.7

Source: SJRWMD 1977, D-46, Table D-10

USACE conducted an analysis of measured water levels (which they labeled "tidal elevations") for the river and the ICW in order to define flood elevations. Peak flood elevations were derived for the Intermediate Regional Flood (IRF) and the Standard Project Flood (SPF) for zones from Mayport to Palatka from data collected to 1969. The peak water levels expected to be produced in the main stem, calculated from the IRF and SPF analyses, are summarized in Table 3.9 (SJRWMD 1977, D-47). The IRF is defined as the 100-year

Table 3.9 Peak water levels in the St. Johns River, Mayport to Palatka (data to 1969)

Location	IRF (100-year) (feet)	SPF (feet)
Mayport to Eastport	6.5–7.0	8.5–9.0
N. Jacksonville (east part to I-95)	6.5	8.0–8.5
S. Jacksonville (I-95 to Doctors Lake)	6.0	7.5–8.0
Doctors Lake to Federal Point	6.0	7.0–8.0
Federal Point to Palatka	5.5–6.0	7.0

Note: IRF = Intermediate Regional Flood
SPF = Standard Project Flood

Source: SJRWMD 1977, D-47, Table D-11

flood, caused by a 100-year rainfall (which has a probability of occurrence of 1% in any year). The 100-year storm has a magnitude in SJRWMD of about 12 in. The SPF is "the flood that may be expected from the most severe combination of meterological and hydrological conditions that is considered reasonably characteristic of the geographical area" (James and Lee 1971, 235). The SPF is ordinarily calculated using one-half of the Probable Maximum Precipitation, which is about 18 in. in SJRWMD.

Minimum and flood levels at sites on or near the main stem (at De Land, Dunns Creek, Palatka, and Jacksonville) are given in Table 3.10. These values can be compared to flood levels previously published (Tables 3.8 and 3.9). To complete the comparison, observed extremes of water level at Jacksonville before 1964 are included in the table. In general, it can be seen that maximum

Table 3.10 Published extremes of measured water levels on or near the main stem of the St. Johns River (data to 1991)

Station	Maximum Daily Stage		Minimum Daily Stage	
	Date	ft NGVD	Date	ft NGVD
De Land	10/11/53	5.97	04/02/45	-0.68
Dunns Creek	10/30/85	2.94	01/22/91	-1.92
Palatka	09/30/69	3.90	06/06/68	-1.46
Jacksonville	10/00/53	6.00	02/29/84	-2.09

Note: ft NGVD = feet, National Geodetic Vertical Datum

Elevation reference is station (local arbitrary) datum. The National Ocean Service reports maximum stage at Mayport of 5.44 ft NGVD and minimum stage of -5.26 ft NGVD (see tides chapter).

Source: USGS 1991
Jacksonville (1953): Snell and Anderson 1970, 22, Figure 11

measured daily water levels observed to 1991 are significantly less than those calculated using the IRF and the SPF (Tables 3.9 and 3.10).

SUMMARY OF WATER LEVELS

Water level in the St. Johns River is principally a function of the tidal stage at the mouth, the progression of the tides, the volumes of freshwater inflows and outflows, the magnitudes and directions of the wind, and atmospheric pressure. Pyatt's study of data collected from 1954 to 1957 noted the following:

- Changes in water levels depend upon the initial water level and the intensity, duration, and direction of the wind.

- Changes in water levels that are caused by runoff may affect the wind/stage relationship.

An Atlantis Scientific report on USGS data from 1954 through 1966 provides the same conclusions as Pyatt. Neither of these conclusions nor the data have yet been supplemented or updated in the available literature.

Strong winds may cause a setup on the river banks toward which they blow. Significant wind setup may occur as a result of sustained velocities of 7 mph or more. Wind setup ranges from less than 1 to over 3 ft. However, there is a limit to the height that setup can reach, which depends on the site location, the fetch, and the intensity, duration, and direction of the wind. Wind setup can dominate over tidal heights. Changes in barometric pressure, except during extreme storms, produce MWL deviations of up to about 0.5 ft in the LSJR.

TIDES

As indicated in the introduction, the St. Johns River is usually influenced by the tide from the mouth to as far upstream as Crescent Lake (RM 96) and Lake George (RM 110). In an early study of the river, the extent of spring tide was reported to be as far upstream as 283 mi (De Land is located near RM 144) (Federal Security Agency 1951, quoted in Pyatt 1964, F27). These observations, however, were probably of wind-tide or wind-induced changes in water levels. In 1992, after completing a review of existing tidal data, NOS reported that tide is measurable at Dunns Creek (RM 86.5) and Welaka (RM 100) (USACE Jacksonville 1994b). At Crescent City (on the west bank of Crescent Lake [RM 102]) the tide can be detected but is masked by larger components in the measurements, and at Georgetown (RM 108) it is negligible.

Measured water surface elevations are clearly not the same as the water surface elevations that would be due to tidal forces alone. Water level measurements provide data on the combined or "total" water surface elevations. The tidal water surface elevation in these records can be extracted from the total water surface elevation by tidal analysis.

It is somewhat misleading, although a common practice, to refer to water surface elevations as the "tides" without distinguishing between the astronomic tide and the other, superimposed effects. References to "meteorological tides" or "wind tides" also can be found in the literature. Wind tides are quasi-periodic water level changes that are caused by the wind, but the periodicity of the wind is seasonal, and wind tides cannot be predicted.

The forces that generate the tides change water surface elevations, and the differences in tidal elevations cause tidal currents. Both tidal elevations and tidal currents are predictable. Because tidal currents are only part of the total flow, they are often obscured by random or non-tidal flow patterns. Tidal elevations are important because the depth of water affects aquatic ecosystems and navigation. Tidal currents are important because they can influence the types of vegetation and sessile and mobile aquatic communities that become established in the river and they can substantially reduce or increase the speed at which boats and ships can travel between different locations.

Water elevation is not a simple function of distance along the river because changes in river geometry, winds, and inflows and outflows affect the water surface elevation locally. A substantial constriction of depth or width causes the level of the flowing water in a confined channel to increase upstream of the constriction. Also, because the speed of the tidal wave is proportional to the local depth, natural decreases in depth, or shoaling, also will retard the tide.

The differences between the astronomic tidal heights, caused by gravitational forces in the sun/moon/earth system, and the measured water surface elevations that are caused by the added effects of wind, atmospheric pressure, lateral flows, and inflows and outflows are called the "residual elevations" or non-tidal water levels. The magnitude of the residual elevation is an indication of the effects of non-tidal forces and events on the river. None of the investigations in the reviewed literature, however, indicated that a residual analysis had been performed for the St. Johns River.

In this section of the report, the basic categories of tidal information are summarized, including characteristics of the tide, measurements of the tide, tidal statistics, tidal analysis, the variation of tide along the length of the LSJR, and a 1992 NOS update on tides in the river (USACE Jacksonville 1994b).

BASIC CHARACTERISTICS OF THE TIDE

The variations in water surface elevation and flow that are caused by the gravitational attraction between the earth and the sun and moon are called the tides. Although the height of tide and the time of occurrence of high and low water at a location are reasonably predictable, the flow characteristics of a river or estuary are very complex and not easily predicted.

Tides are classified as diurnal, semidiurnal, or mixed, depending on the fundamental periodicity. A diurnal tide has one high water level and one low water level each day, a semidiurnal tide has two highs and two lows each day, and a mixed tide is a combination of the two; the full range of combinations in between also can occur. Semidiurnal tides generally are found on open coastlines, while diurnal and mixed tides are caused by and occur within complex shorelines and embayments. The tide along the Atlantic coast and in the lower 100 mi of the St. Johns River is classified as mixed semidiurnal, where "mixed" means that the successive heights of highs and lows of water alternate in elevation.

The tide is often referred to as a wave because it is sinusoidal, it has harmonics in shallow areas, and it has repeatable and predictable amplitudes and phases, and because the associated water level elevation progresses in and out of the river or estuary at a predictable rate. The tide may not be recognized as a wave because it has a relatively long period (24.83 hrs).

Other noticeable periodicities in the tide include a semimonthly (14.76 day) cycle in which there is a set of highest peaks, called the spring tide, and a set of lowest peaks, called the neap tide. The spring tides occur in conjunction with the new or full moon, but during a month, the ranges of the spring tides alternate between a high spring and a smaller spring, as do those of the daily semidiurnal tides. The annual or seasonal variation in the tides is due to meteorological causes and seasonal variations in the orbits of the sun and the moon.

Any period of time used to describe tidal phenomena is called a tidal epoch. The principal tidal forces are periodic over an interval of time, called the Metonic cycle, that is exactly 19 years. During this period of time (epoch), all of the different phase relationships between the earth and the sun and the moon occur; the period of the regression of the lunar node, for example, is 18.61 years (Speer 1984, 55). Three 19-year epochs used for some historical analyses were the periods 1930–48, 1948–66, and 1966–84. For the LSJR, data for all three of these Metonic cycles are available only for Mayport.

In November 1980, a National Tidal Datum Convention was convened to establish a continuous tidal datum system for all tidal waters of the United States. Among other actions, the convention lowered chart datum to MLLW on the Atlantic coast of the United States and updated the National Tidal Datum Epoch, previously 1941–59, to 1960–78. The National Tidal Datum Epoch is the official time period over which tide observations are taken and reduced to obtain mean values for tidal datums, such as MSL. Standardization is necessary because there are both periodic and aperiodic variations in the tidal elevations. NOS uses the National Tidal Datum Epoch for reporting MSL at Mayport (Hicks 1984, 14).

The amplitude and phase of the tide can be altered substantially by local changes in depth, positions of shorelines, and inflows and outflows as the tidal wave progresses up the river. These distortions are often evident in the amplitudes and phases of some of the harmonics of the tide, and they can be used to explain cause and effect relationships and to predict, to some extent, the effects of modifications in river geometry. The changes in water surface elevation that are caused by the tide are important as indicators of changes in water volume and flow.

Tributary Tidal Extent

Tidal influences in the LSJR extend into each tributary to the location at which the effects of channel geometry and freshwater inflows balance the energy in the tidal motion. As the freshwater inflow into a tributary changes, the extent (or head) of tide migrates upstream or downstream. This location, the "extent of tidal influence" or the location at which the tide becomes negligible under average conditions, has been estimated by USACE for many of the LSJR tributaries, although no explanation of the procedure that was used to determine these locations is given in the report (USACE Jacksonville 1986, 3–9, Table 1). BuSM/FDEP has recently implemented a comprehensive program to determine the locations of the head of tide in major tributaries of the LSJR. The BuSM definition of the head of tide is that it is the upstream location at which the mean range of tide becomes less than 0.2 ft. Interim results of this study show that some of the USACE locations of head of tide may not be reliable, although the project is currently incomplete.

Tidal Currents

The same forces that generate tidal water elevations also generate tidal currents. Tidal currents can be analyzed using techniques that are comparable to those used for tidal heights. Because tidal currents are closely related to flow, they are described in the chapter on river flow. In general, the term "tides" refers to heights as well as to currents, so one must determine the meaning of the term in a particular context.

MEASUREMENTS OF TIDE

Historical Tidal Measurements

Tidal elevation measurements on the LSJR were first recorded at a C&GS station at Phoenix Park (RM 17) in 1923. Prior to the first major tidal current survey in 1933–34, the U.S. Army Engineers and C&GS conducted short surveys which were primarily related to projects for channel (navigation) improvements. The results of the first of these surveys were published in 1890 (Haight 1938, 17).

Reference and Subordinate NOS Stations

As mentioned in the previous chapter, NOS measures water levels at reference, or primary, stations and at subordinate, or secondary, stations. The elevations of reference and subordinate stations are determined by standard surveying techniques to first- or second-order accuracy. Benchmarks have been established near the shores of the river to provide references to the established vertical network. Descriptions of benchmark locations along the St. Johns River are available from NOS and various local agencies, such as BuSM and SJRWMD, and are described in USACE Jacksonville 1994c.

Data from the reference stations and the subordinate stations have been collected and analyzed to determine the tidal components, which are then used to predict and to publish the heights and times of the tide at those stations. These predictions, in general, estimate the total water surface elevations that may be expected when wind and freshwater inflows are negligible, which are equivalent to tidal elevations. The data used in the analyses are total water surface elevation measurements, but if the measurements are taken over a period of time that is long enough, wind and inflow effects should be filtered out of the data.

Every year, NOS publishes predictions of tidal water surface elevations at the reference stations in the United States. The tide tables also provide conversion factors from the reference station values for predictions of the height and time of tide at the subordinate stations.

Tide and Depth Datums

Water surface elevation measurements are referenced to NGVD. Until January 1, 1989, depth of water on nautical charts was referenced to MLW. In 1989, the chart datum and tide datum for the United States Atlantic coast were changed to MLLW. Thus, depths on nautical charts and heights in the Tide Tables published before 1989 are referenced to MLW; after 1989, they are referenced to MLLW.

NOS Tidal Stations

NOS maintains, or has maintained in the past, a total of 50 tidal stations from the mouth of the St. Johns River to De Land (see Tables D1 and D2, Appendix D). For this report, the locations of these stations were obtained initially from the NOS index of tide stations (NOS 1990a), were plotted, and were corrected to the closest shoreline. Before this volume of the reconnaissance report had been completed, NOS reviewed all of these stations and identified those for which data were acceptable. The resulting list of 37 stations (Table D1) covers the reach from Mayport to Sanford on Lake Monroe. Eight stations that are in the NOS index but are missing in Table D1 are summarized in Table D2. Although all of the stations numbered 8720877 (Georgetown) and higher are outside the LSJRB, some of these stations are included in Appendix D for completeness, because the NOS report contains new information on almost every tidal station on the St. Johns River. The availability of data in digital form, existence of a connection to the geodetic network, availability of harmonic constants, and availability of published or issued tidal datums are indicated in the rightmost four columns in Table D1.

The locations of all historical tide stations are shown in Figures 3.10a–d and 3.11. Only two of these stations were in operation in 1994: Mayport and the Mayport backup. The historical stations were operated at various times during the period 1923–80 (Table D1). The Phoenix Park station was the first to be installed on the river, operating for over a year in 1923 and 1924. Annual predictions of tide heights and times at 15 of these stations are published by NOS using the tidal constituents collected while these stations were operating (Table D4). Stations indicated by a circle enclosing an "x" have a period of record that is too short for tidal analysis.

Tidal Data Collection

Over the years, tidal elevation data have been collected by NOS at hourly, 15-minute, or 6-minute intervals, depending on the particular station. The monitoring equipment used originally consisted of a float in a stilling well and a mechanical strip-chart recorder. This system, modified over the years with special stilling well designs, plastic floats, digitizers, solid-state memories, and electronic data loggers, provided a range of choices in water surface elevation measurement and data storage and transmission. The current system is called the "Next Generation Water Level Measurement System." It uses an acoustic ranging sensor and air column temperature sensors to correct for any non-uniformity in the sound path. The raw data on water surface elevations from this system are adjusted by NOS to the vertical datum (NGVD and NAVD 88).

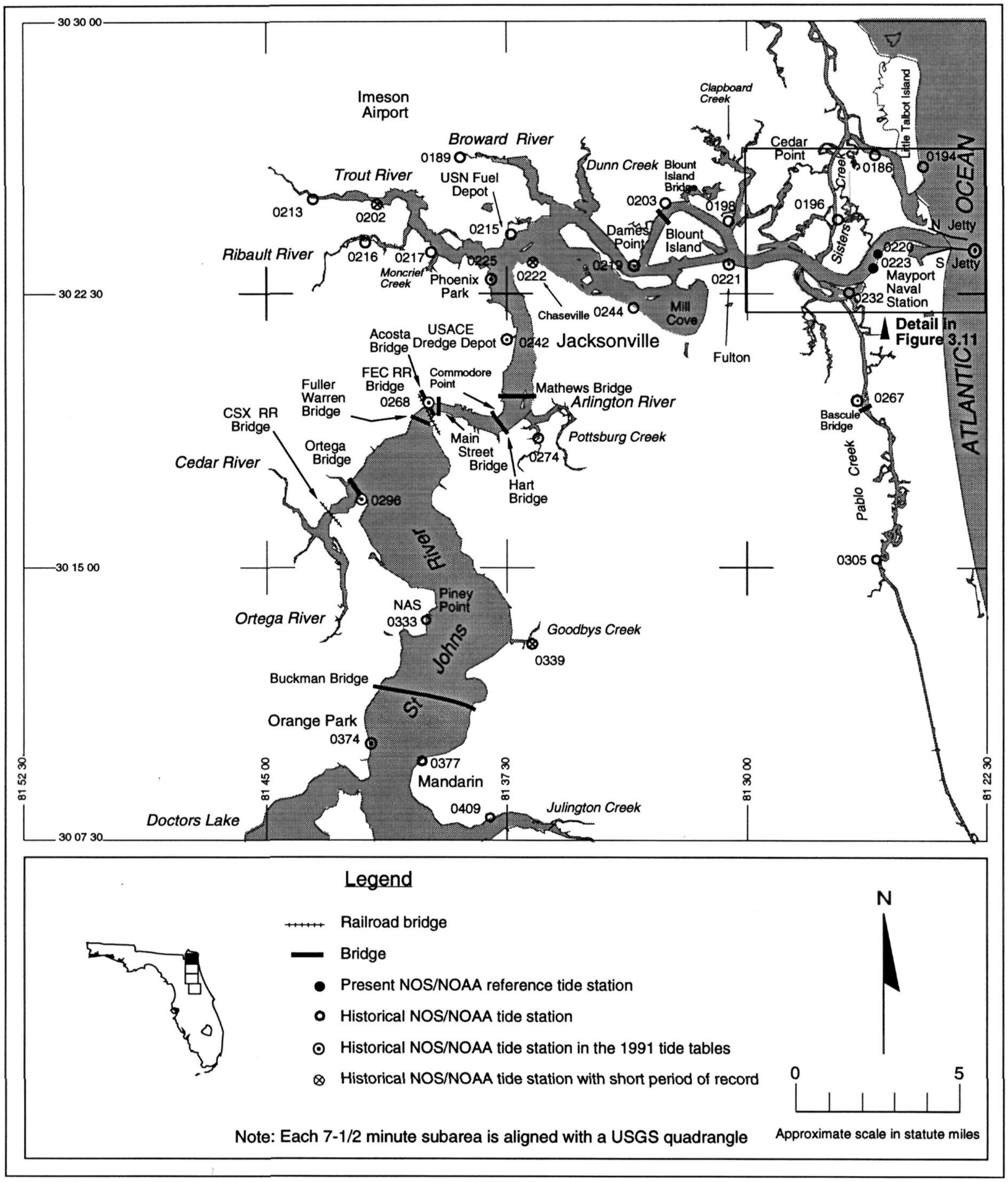


Figure 3.10a Locations of NOS tide stations between the mouth of the St. Johns River and Julington Creek

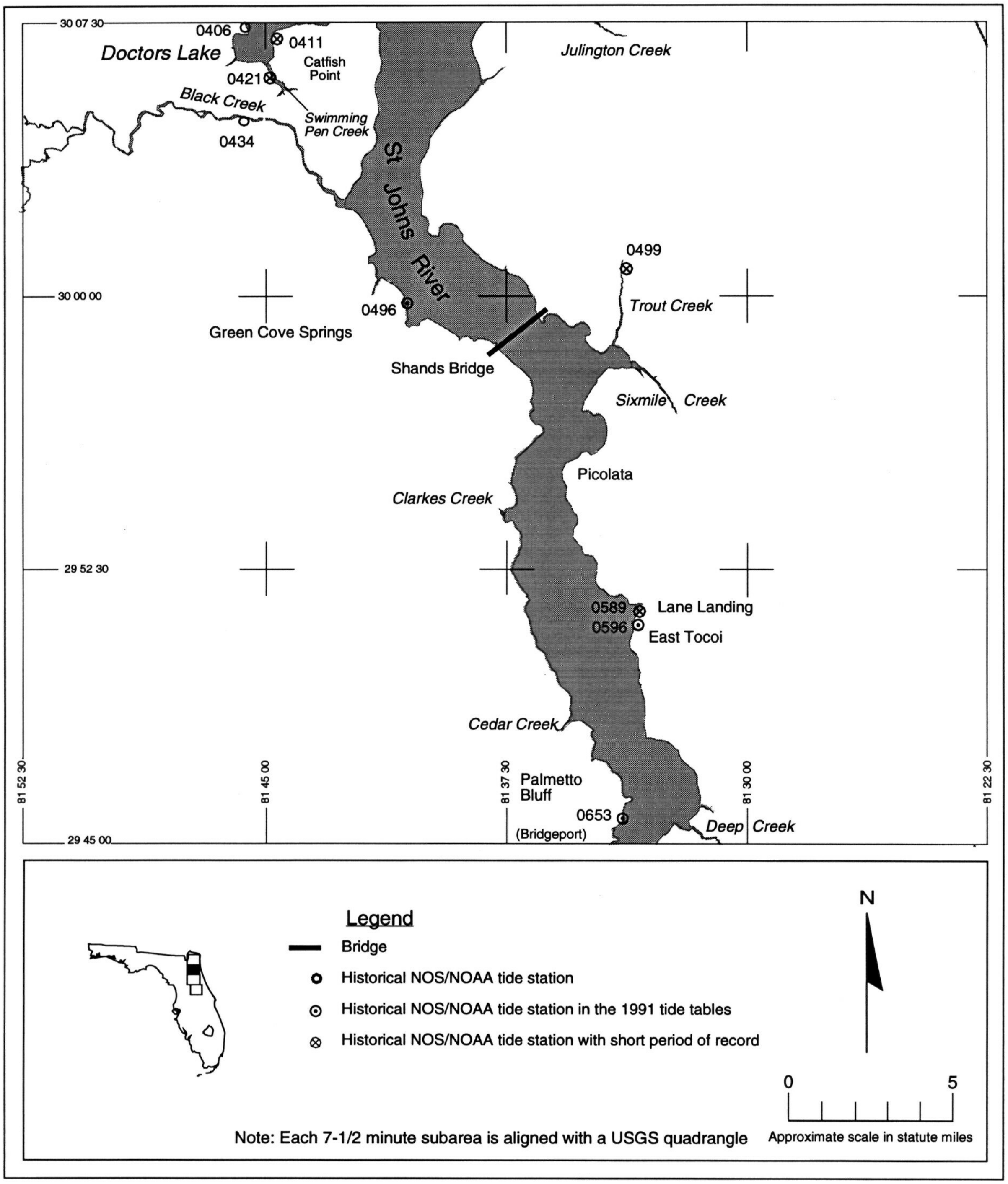


Figure 3.10b Locations of NOS tide stations between Julington Creek and Deep Creek

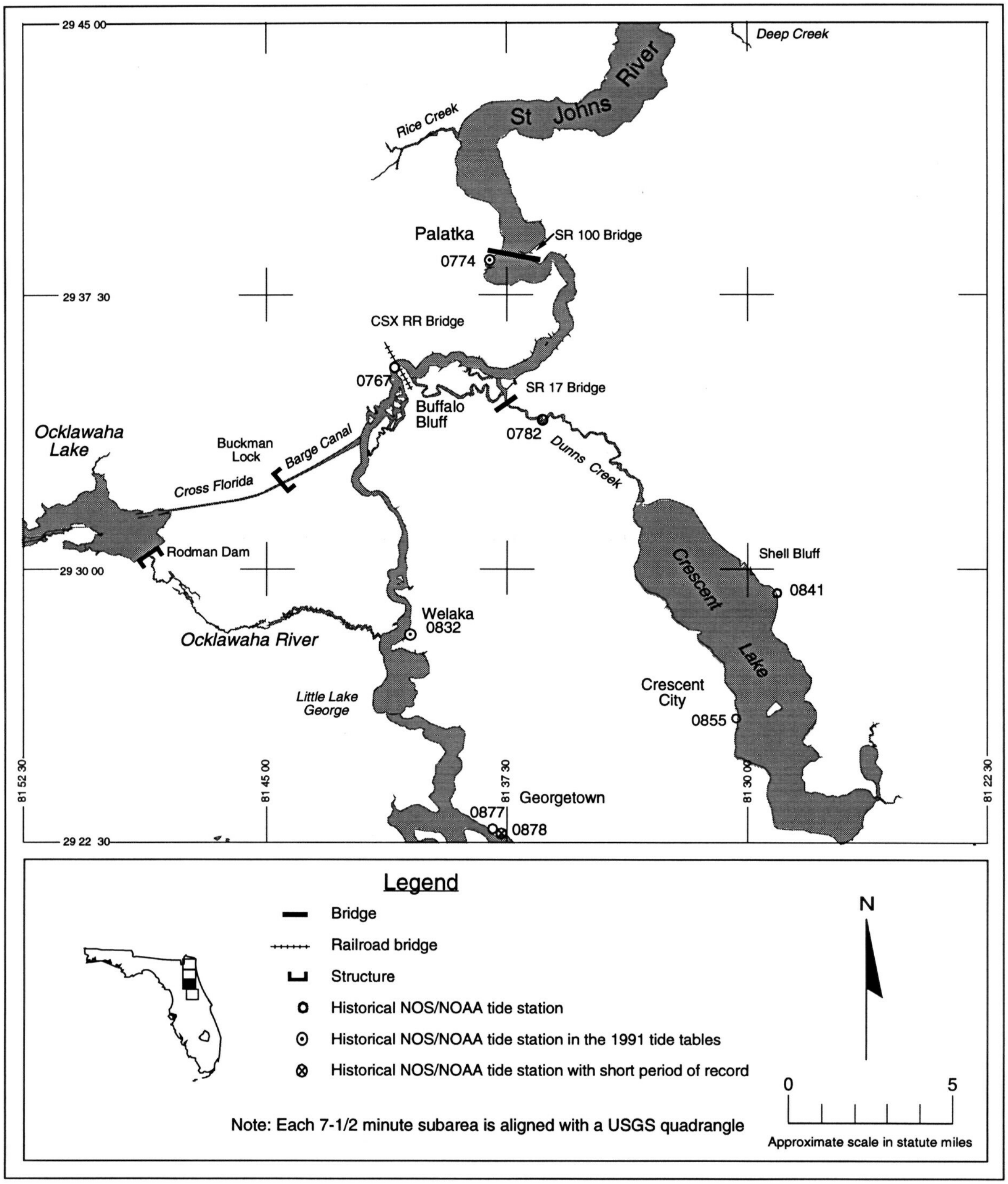


Figure 3.10c Locations of NOS tide stations between a location north of Rice Creek and Georgetown

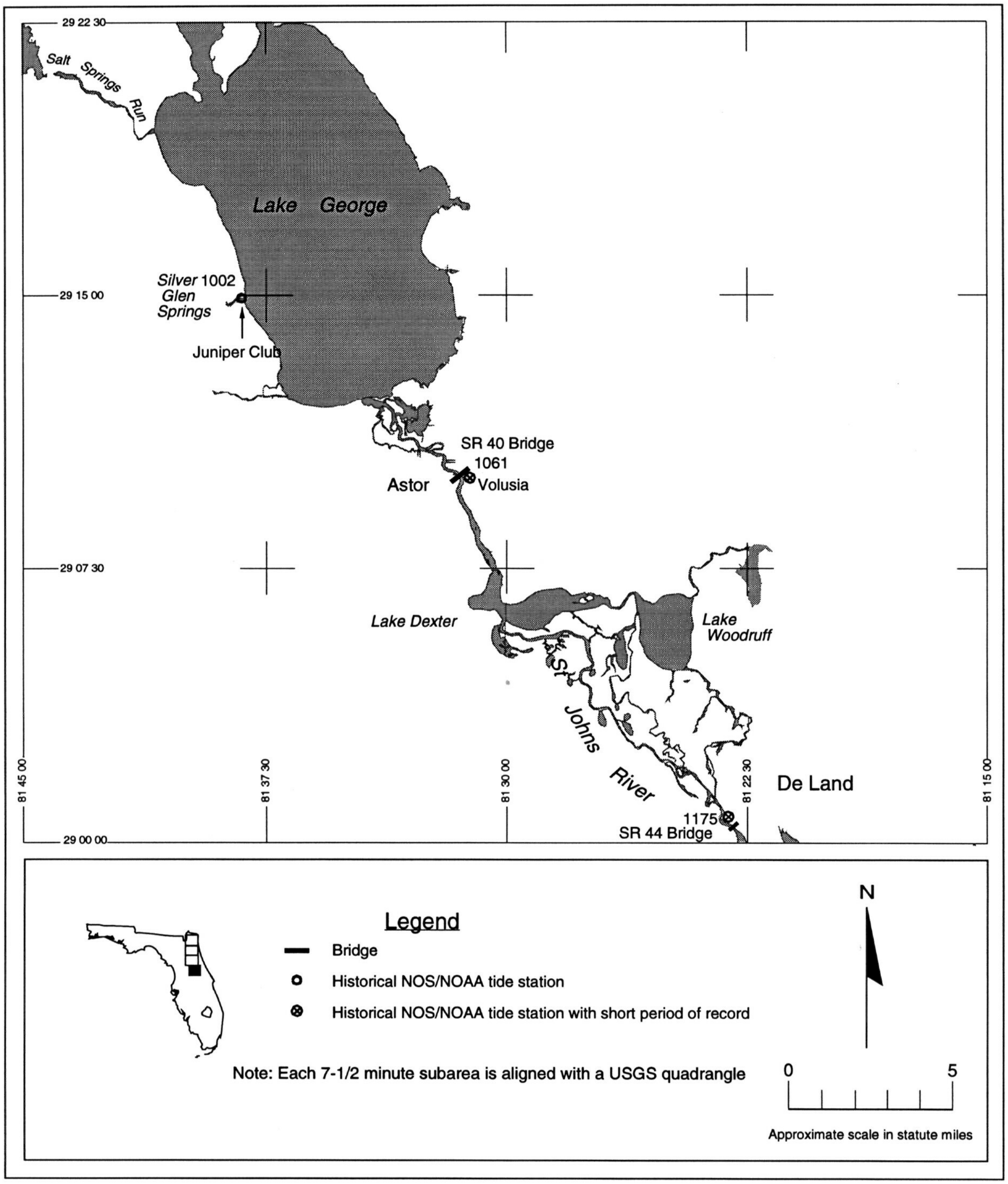


Figure 3.10d Locations of NOS tide stations from Lake George to De Land

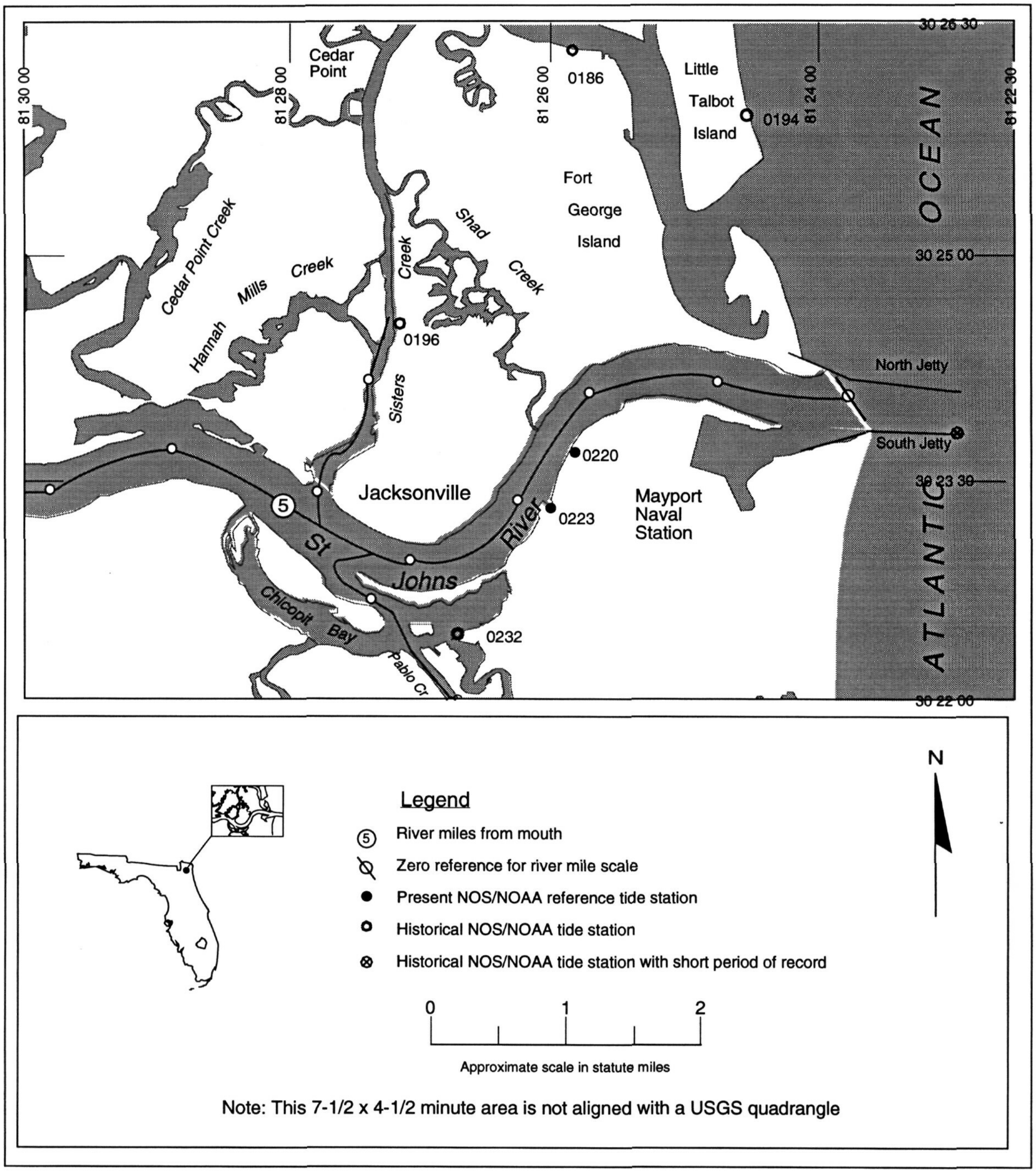


Figure 3.11 Detailed map of locations of NOS tide stations in the vicinity of the St. Johns River inlet to Jacksonville

TIDAL STATISTICS

Mean Sea Level

MSL, as described in the previous chapter, is the long-term mean of periodically sampled water elevation measurements. The annual MSLs for Mayport, for the three most recent complete tidal epochs, are listed in Table 3.11.

Table 3.11 Mean sea level at Mayport for the three most recent complete tidal epochs

Tidal Epoch	Mean Sea Level (feet) (station [instrument] datum)
1930–48	3.69
1948–66	3.82
1966–84	3.89

Gage at USACE dock, river mile 19

Source: NOS 1993, Form 472a

Mean Tide Level

Mean tide level (MTL), sometimes called half-tide level, is the average of the heights of all measured high and low waters at a station. MLLW is the mean value of the lowest (every other) of two successive low tides. Because the curve representing the rise and fall of tide is not a simple sine wave, the average rise of high water above MSL is not exactly equal to the average fall of low water below MSL. Therefore, MTL does not exactly coincide with MSL. At Mayport, the MTL is 0.05 ft below MSL, and the distance varies progressively upstream (NOS 1991).

Statistics for Mayport Tides

The range of tidal values at Mayport were published by Harris for data collected from 1963 to 1981 (Table 3.12) (Harris 1981, 47). Since that time, NOS is the only source for published results of analyses on long-term water surface elevation data in the LSJR. Some of these statistics are available from the annual tide tables, including the relationships of MSL to MLLW for each reference station (e.g., NOS 1991) and MTL to MLLW for each subordinate station. Other statistics, such as the elevations of mean higher high, mean high, and the same for lows, also were analyzed and published by Harris (1981, 65). NOS also calculates these relationships annually.

Table 3.12 Ranges of water levels at Mayport (1963–81)

Range Type	High Water (feet)	Low Water (feet)	Range (feet)
Extreme	5.10	-5.50	10.60
Diurnal	2.49	-2.30	4.79
Mean	2.20	-2.30	4.50

Datums based on 1941–59 tidal epoch

Source: Harris 1981, 47, Table 4

Monthly Variation in Tide

During a year, water level fluctuates in response to changes in the ocean tide caused by changes in the relative positions of the sun and the moon and in response to meteorological conditions. Comparative studies of tides around the coast of North America have shown that the range of the annual variation (maximum variation from lowest low tide to highest high tide in a year) increases reasonably uniformly from Maine to Chesapeake Bay. South of Chesapeake Bay, the annual variation increases to 1.03 ft at Mayport (October), then decreases to 0.85 ft at Miami (March) (Marmer 1951, 54). Also, along this reach of the Atlantic coast, a significant secondary maximum mean tidal height occurs in May or June, and a secondary minimum occurs in July. This secondary characteristic occurs all along the Atlantic coast.

The monthly MSL at Mayport varied from a low of -0.32 ft (NGVD) in March to a high of 0.71 ft (NGVD) in October during the 1930–48 epoch, as shown in Figure 3.12 (Marmer 1951, 53).

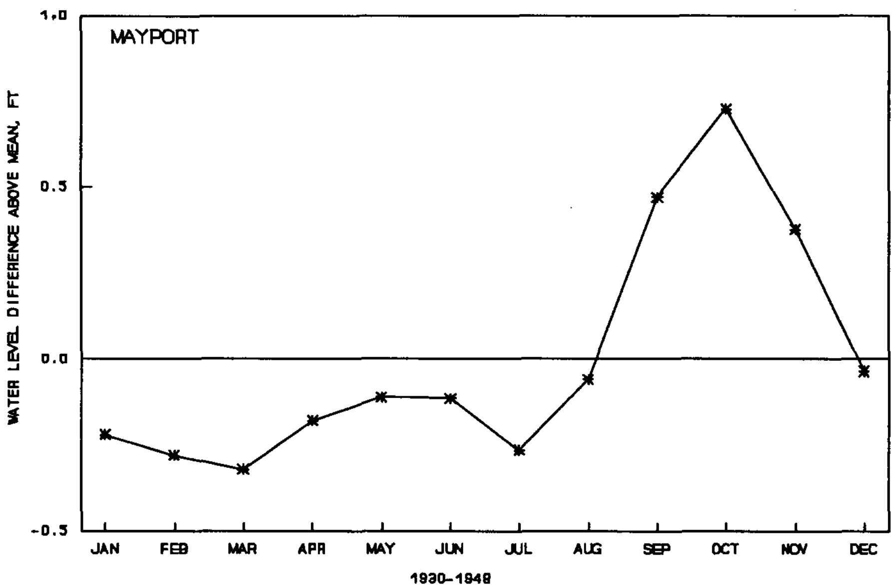


Figure 3.12 Monthly mean sea level at Mayport (1930–48) (Marmer 1951, 53, Figure 26)

A plot of corresponding NOS data for the period of record at Mayport (1930–86) shows that the secondary maximum normally occurs in June. The NOS monthly mean tides are compared to Marmer's values in Figure 3.13.

Relationships among MSL, MTL, MLW, and MLLW at Mayport

As of 1966, MSL at Mayport was 0.6 ft above MLW (Anderson and Goolsby 1973, 10). According to NOS, MSL is 2.46 ft above chart

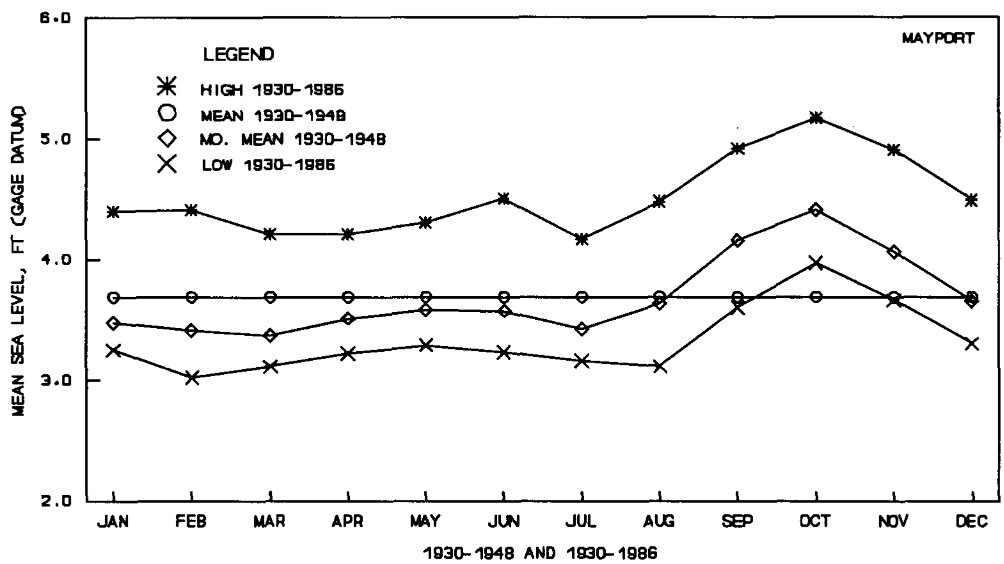


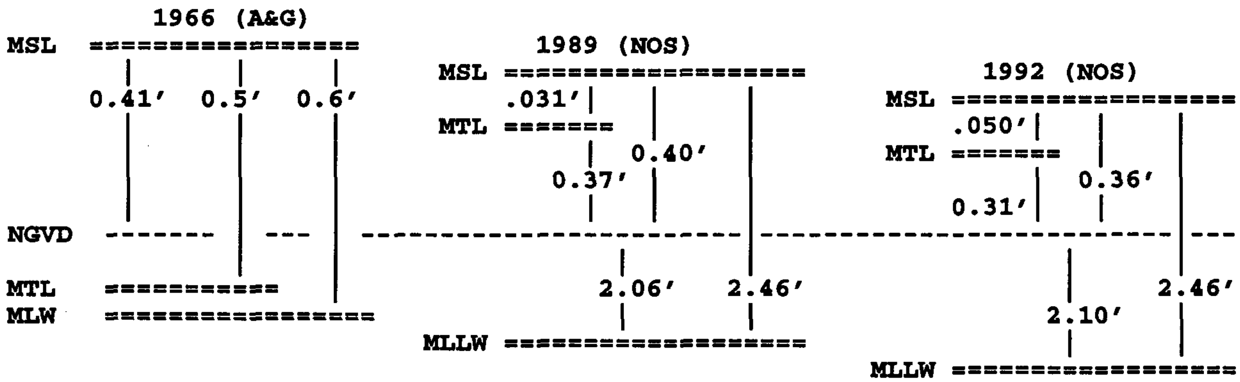
Figure 3.13 Comparison of monthly mean sea level and range for data at Mayport (1930–48: Marmer 1951, 53; 1930–86: NOS 1993, Form 472a)

datum (MLLW). A list obtained from NOS for 1989 data for Mayport provides -0.031 ft for MTL relative to MSL (NOS 1989). The 1991 tide tables (NOS 1990b, vi) give 2.5 ft for the elevation of MSL above MLLW, and the 1992 NOS analysis of tidal characteristics provides a value of 0.31 ft for MTL relative to NGVD (USACE Jacksonville 1994b). These values are summarized in Figure 3.14.

TIDAL ANALYSIS

Tidal Harmonics

The part of the water level caused by the gravitational attraction between the earth and the sun and between the earth and the moon is often called the astronomic tide. Because the relative positions of



Legend: == indicates changing water level
-- indicates fixed water level (datum)
sta is station datum
NGVD = National Geodetic Vertical Datum

MSL = mean sea level
MTL = mean tide level
MLW = mean low water
MLLW = mean lower low water

MSL (1966): 4.03' (MSL:sta) - 3.62' (NGVD:sta) = 0.41' (MSL:NGVD)
MSL (1989): 4.02' (MSL:sta) - 3.62' (NGVD:sta) = 0.40' (MSL:NGVD)
MSL (1992): 4.02' (MSL:sta) - 3.66' (NGVD:sta) = 0.36' (MSL:NGVD)

Note: All datums except NGVD change continually.
The elevation of NGVD relative to station datum (NGVD:sta) changed from 3.62 to 3.66 ft in 1973 due to re-leveling of the geodetic network. The 3.66 value was first used by NOS in 1982 (NOS, pers. com. January 1993).
MSL is not decreasing from year to year; the 3 years shown in this figure are random samples from the set of annual MSLs (see Figure 3.5 in water surface elevation chapter). In addition, the change of NGVD:sta from 3.62 to 3.66 ft applies to the entire period of record (see text), and therefore the more correct values for MSL:NGVD are 0.37 (1966), 0.36 (1989), and 0.36 (1992).

Source: A&G: Anderson & Goolsby 1973
NOS (1989): NOS 1988c
NOS (1992): USACE Jacksonville 1994b, Table 5

Figure 3.14 Relationships among MSL, MTL, MLW, and MLLW at Mayport

the earth, sun, and moon are well known, the astronomic tide is the most predictable of the several causes of changes in water surface elevation in the river.

The effects of the sun and the moon on water level can be expressed as a summation of a set of sinusoidal harmonic constituents, each of which has an amplitude and a phase that is associated with one of the periodicities of the sun and/or the moon. Each constituent may be written in the form

$$y = a \cos(\omega\tau + \phi) \qquad (1)$$

where:

y = height of constituent relative to a datum, usually MTL, a measure of its magnitude
a = amplitude of constituent
$(\omega\tau + \phi)$ = "phase" (the term used in the literature, different from mathematical usage) of the constituent, uniformly changing with time
ω = speed of the constituent, or its rate of change with time
τ = time
ϕ = phase of the constituent at instant from which time is reckoned

A mathematical analysis of the sun/earth/moon system can produce the theoretical harmonic constituents for a frictionless ocean on a spherical earth with no land. The tide defined in this simplified case is called the "equilibrium tide." Constituents of the tide which are predicted from periods of record that are less than a year in length are "equilibrium constituents."

Period of Data Collection for Analysis

NOS performs tidal analyses on measurements taken (1) over as long a period of record as is available and (2) that are of sufficiently high quality to be analyzed for tidal constituents. Periods of at least 29 days, and preferably 369 days, are used for analyses of tides at subordinate stations. The 369-day period contains multiples of nearly all of the short-period constituents and is appropriate for elimination of seasonal effects. Periods of 19 years and more are maintained for analyses of changes in MSL at reference stations.

The 29-day period—the minimum length record needed for a standard "short series"—provides enough data for an analysis of the more important constituents up to a total of 25 (Schureman 1958, 51–52). However, the 29-day analysis, based on Fourier techniques, usually produces amplitudes and phases for only 10 significant constituents, depending on the site and the resulting measurements. The remaining 15 constituents are "inferred" using the equilibrium-tide ratios of these 15 constituents to the 10 basic constituents. Alternatively, it is possible to use the ratios resulting from an analysis of a nearby station to infer the harmonics for a station. The constituents developed from the 29-day analysis are adequate for prediction of tidal elevations for most applications, including model boundary conditions.

A 369-day record is usually analyzed by a least-squares procedure, which produces values for up to 37 standard tidal constituents. NOS has found that this more accurate procedure is adequate for predicting tidal water surface elevations at most stations in the United States.

Tidal Constituents

Tidal constituents (which are also called "coefficients," "harmonic components," or just "the components") are characterized by an amplitude and a phase or time shift. Normally, tidal harmonic *analysis* is performed with a computer program that calculates the phase angles required for the particular starting date of the measurement series, using internally stored data, and then combines the sinusoidal components with the corresponding phase shifts. A reasonably accurate *prediction,* for most applications, will be obtained by using only the six largest constituents. However, in shallow waters, some of the other constituents and some of the harmonics of the fundamental constituents, called "overtides," also may be significant and should be included if available.

Standard nomenclature for the tidal constituents includes the symbol "M" for constituents related to lunar motions, "S" for solar motions, and "K" for combined lunar and solar. Subscripts (or appended digits) indicate the number of cycles of that constituent that will occur in 1 day. The M_2 tidal constituent, the largest of all of the tidal components, represents the gravitational force between the moon and the earth. Because it occurs twice a day, it is a "semidiurnal" constituent. Likewise, S_2 is the major semidiurnal constituent that is caused by the gravitational force between the sun and the earth. M_2 and S_2 interact over a period of a month to cause the variation of neap and spring tides. N_2 represents the effect of the moon's elliptic orbit, which results in the monthly perigee/apogee cycle in the tide. K_1, a "diurnal" constituent, has both a lunar and a solar component at the same frequency. K_1 and O_1 interact on a monthly basis to cause maximum diurnal (tropic) tides during the maximum declinations of the moon. K_1 also interacts with P_1 on a yearly basis to cause greater diurnal tides during times of maximum solar declination.

The M_4 constituent is the first harmonic, or overtide, of the M_2 constituent, occurring four times daily and having a period of 6.24 hr; M_6 is the second harmonic. Constituents M_4 and M_6, also called the shallow water constituents, are produced by the friction, inertia, flow, and resonance in a given embayment or estuarine area. Table 3.13 lists the major semidiurnal and diurnal constituents, periods, and relative sizes in the open ocean and at Mayport. The change in the relative magnitudes of the constituents over the short distance from the ocean mouth to Mayport is evident, but has not yet been adequately quantified.

NOS Analysis of Tidal Characteristics Prior to 1992

NOS was funded by USACE and SJRWMD in 1990 to review the available tidal data on the St. Johns River, to summarize the tidal characteristics of the river, and to recommend any additional measurements needed. NOS produced a draft report in 1992 and delivered the final report in 1993 (USACE Jacksonville 1994b). The final report, subsequently published as one of seven volumes

Table 3.13 Periods and relative amplitudes of the largest harmonic tidal constituents in the ocean and at Mayport

Harmonic Constituent	Name of Constituent	Period (hours)	Constituent Amplitude		
			Mayport (feet)	As Percent of M_2 Amplitude in the Ocean	As Percent of M_2 Amplitude at Mayport
		Semidiurnal Constituents			
M_2	Principal lunar	12.4167	2.17	100	100
S_2	Principal solar	12.00	0.36	47	17
N_2	Larger lunar elliptic	12.7	0.49	19	23
K_2	Luni-solar semidirunal	11.97	*0.11	13	5
		Diurnal Constituents			
K_1	Luni-solar diurnal	23.9	0.27	58	12
O_1	Principal lunar diurnal	25.8	0.20	42	9
P_1	Principal solar diurnal	24.1	0.09	19	4
Q_1	Larger lunar elliptic	26.9	*0.04	8	2
		Long-Period Constituents			
M_f	Lunar fortnightly	328	*0.00	17	0
MS_f	Luni-solar fortnightly	354.37	*0.28	2	13
M_m	Lunar monthly	661	*0.09	9	4
S_{sa}	Solar simiannual	4,382.91	0.25	8	12
S_a	Solar annual	8,765.82	0.38	1	18
		Overtide			
M_4	Second harmonic of M_2	6.208	0.08	not applicable	4
M_6	Third harmonic of M_2	4.139	0.03	not applicable	2

Constituent subscripts:

- $_1$ = one cycle per day
- $_2$ = two cyles per day
- $_4$ = four cyles per day
- $_6$ = six cyles per day
- $_f$ = one cycle per fortnight (13.66 days)
- $_m$ = one cycle per month (27.55 days)
- $_{sa}$ = two cycles per solar year (182.62 days)
- $_a$ = one cycle per solar year (365.24 days)

Source: Col. 2, 3: Pond and Pickard 1978, 201, Table 13.1; Schureman 1958, 164, Table 13.1
Col. 4: NOS 1992, Table 3
Col. 4*, 6: NOS 1978a, Form 444
Col. 5: Foreman 1977, Tables 1–3. Values for S_{sa} and S_a are corroborated in the NOS 1992 analysis (USACE Jacksonville 1994b, 10)
M_4 Table 3.14a, Table D9 (Appendix D)
M_6 Figure 3.21, Table D9 (Appendix D)

(USACE Jacksonville 1994a–g), is summarized in this chapter under *NOS 1992 Tidal Analyses and Statistics* (p. 98).

Before NOS undertook the 1992 analysis, the agency had performed two harmonic analyses on tidal station data of the St. Johns River: an analysis of the 365-day dataset beginning January 1, 1975, at Mayport and an analysis of the 29-day dataset beginning March 1, 1976, at Georgetown. The amplitudes and phases of the six major components for Mayport and Georgetown, as determined in those analyses, are summarized in Tables 3.14a and 3.14b (for data collected to 1989).

Diurnal Inequality

It has been stated that the tide at the entrance to the St. Johns River is "mixed semidiurnal." It is semidiurnal because it is characterized by two high waters and two low waters each day; because successive highs and lows do not have the same amplitude, it is a "mixed" semidiurnal tide.

The difference in the height of the two daily high waters or the two daily low waters in a semidiurnal tide is called the "diurnal inequality." This difference increases as the declination of the moon and, to a lesser extent, the declination of the sun increases in the direction away from the equator (Hunt and Groves 1965, 35). The diurnal inequality is caused by the interaction of the daily and semidaily constituents, which can be quantified in terms of the magnitudes of lunar and solar constituents. A formula that is frequently used for this purpose is based on the ratio (K_1+O_1) to (M_2+S_2), in which the first term represents the amplitudes of the principal daily constituents and the second term represents the amplitudes of the principal semidaily constituents. At least three slightly different classification systems for mixed tides have been proposed by Dietrich, Marmer, and C&GS; these classifications systems are summarized in Table 3.15.

The term "mixed" can be confusing, because it is used in general to describe a tide that has characteristics between semidiurnal and diurnal, which is true of nearly all tidal locations. Tide is mixed if it

Table 3.14a The six most significant harmonic tidal constituent amplitudes and phases for Mayport and Georgetown (calculated from data collected to 1989)

Harmonic Constituent*	Mayport, Florida		Georgetown, Florida	
	Amplitude (feet)	Phase (degrees)	Amplitude (feet)	Phase (degrees)
M_2	2.198	223.34	0.0236	172.69
N_2	0.475	202.75	0.0031	147.39
S_2	0.352	248.82	0.0038	277.22
K_1	0.273	123.39	0.0163	20.27
O_1	0.190	129.86	0.0167	50.58
M_4	0.084	196.22	0.0027	225.07

*See Table 3.13 for name of constituent
Constituent subscripts: $_1$ = one cycle per day
$_2$ = two cycles per day
$_4$ = four cycles per day (first harmonic of semidiurnal constituent)

Source: Mayport: NOS 1978b (based on NOS 365-day least-squares analysis beginning January 1, 1989, with mean 2.46 feet above mean lower low water [MLLW])
Georgetown: NOS 1978 (NOS printout based on a 29-day harmonic analysis beginning March 1, 1976, with mean 1.908 feet above MLLW)

Table 3.14b Recalculation of the six most significant harmonic tidal constituent amplitudes and phases for Mayport and Georgetown (from data collected to 1989)

Harmonic Constituent*	Mayport, Florida		Georgetown, Florida	
	Amplitude (feet)	Phase (degrees)	Amplitude (feet)	Phase (degrees)
M_2	2.17	225.3	0.02	562.0
N_2	0.49	207.3	—	—
S_2	0.36	248.6	—	—
K_1	0.27	122.5	0.01	337.6
O_1	0.20	130.8	—	—
M_4	0.08	204.8	—	—

Source: USACE Jacksonville 1994b

Table 3.15 Expression for the degree of mixed tide and calculated ranges

Description of "Mix" of Tide	Dietrich—Expression for Calculation of Mix: $(K_1+O_1)/(M_2+S_2)$*	Marmer—Expression for Calculation of Mix: $(K_1+O_1)/(M_2+S_2)$*	C&GS—Expression for Calculation of Mix: $(K_1+O_1)/M_2$*
Semidiurnal	0.25–1.5	<0.25	<0.5
Predominantly semidiurnal	N/A	0.25–1.5	N/A
Mixed	1.5–3.0	N/A	0.5–2.0
Diurnal	>3	>1.5	>2

*See Table 3.13 for name of constituents

Source: Dietrich 1963, 442; Marmer 1951, 22; C&GS in Dronkers 1964, 82

is not purely semidiurnal or diurnal. The degree of mixing has been quantified in different ways by at least three researchers using the expressions in Table 3.15. These expressions use the tidal harmonics K_1, O_1, M_2, and S_2. By substituting the values of the harmonics derived from the tidal record for a station, a value can be calculated that falls within one of the three ranges given under each expression. In Table 3.15, the tide has the degree of mixing given in the row of the first column corresponding to the appropriate range. Thus, the tide at a specific location is considered to be mixed if it falls into the "mixed" or "predominantly semidiurnal" ranges given in the table.

Using the most recently available tidal constituents, the $(K_1+O_1)/(M_2+S_2)$ ratio (Dietrich 1963; Marmer 1951) for Mayport is 0.186, and the ratio $(K_1+O_1)/M_2$ (Dronkers 1964) is 0.21. The ratios for Georgetown, from an earlier analysis, are 1.24 and 1.4. By the above classifications, the reach from Mayport to Welaka has a semidiurnal (not mixed) tide. The tide at Georgetown is either semidiurnal (Dietrich) or mixed (C&GS, Marmer). The $(K_1+O_1)/(M_2+S_2)$ ratios for many of the stations on the river are summarized in Table D9. The 1992 NOS analysis did not produce a significant value for this mixing ratio for Georgetown.

Flood and Ebb Dominance and the Shallow Water Constituents

Distortion or asymmetry of tidal characteristics in an estuary relative to tides in the open ocean results from irregular shorelines and bathymetry, especially shallow channels, and can cause significant resulting overtides. An estuary is said to be flood or ebb dominant, depending on the time duration of flow in one direction of tide relative to the other.

A flood-dominant estuary is one that has stronger flood currents and longer falling tides. Conversely, an ebb-dominant estuary has stronger ebb currents and a longer period of rising water. Such asymmetries in amplitudes and phases of the tides occur because the offshore tide tends to become distorted in the inlet by asymmetries in the geometry of the inlet, as well as by asymmetries in shorelines and bathymetry elsewhere in the estuary. Flood and ebb dominance are important because flood-dominant estuaries tend to import sediment (if the supply is sufficient), while ebb-dominant estuaries tend to flush out sediment. The degree of this non-linear tidal distortion in an estuary is indicated by the ratio of the amplitudes of components M_4/M_2 and the relative phases. An M_4/M_2 ratio of zero indicates an undistorted tide. If M_4 leads M_2 by 90 degrees, the estuary is flood dominant (Speer 1984, 58).

At both Mayport and Georgetown, the amplitude of the M_4 constituent is almost an order of magnitude less than M_2, indicating relatively little distortion. The LSJR is an ebb-dominant river. Flood and ebb dominances are described in more detail in the chapter on river flow.

TIDAL PREDICTIONS

Predictions of each daily high and low tide for each reference station in the tide tables, in terms of feet above chart datum (MLLW) and time, are published by NOS each year. The 15 stations for which predictions are provided in the 1991 tide tables are listed in Table D4 with high- and low-water time differences, height ratios, mean and spring tide ranges, and mean tide elevations.

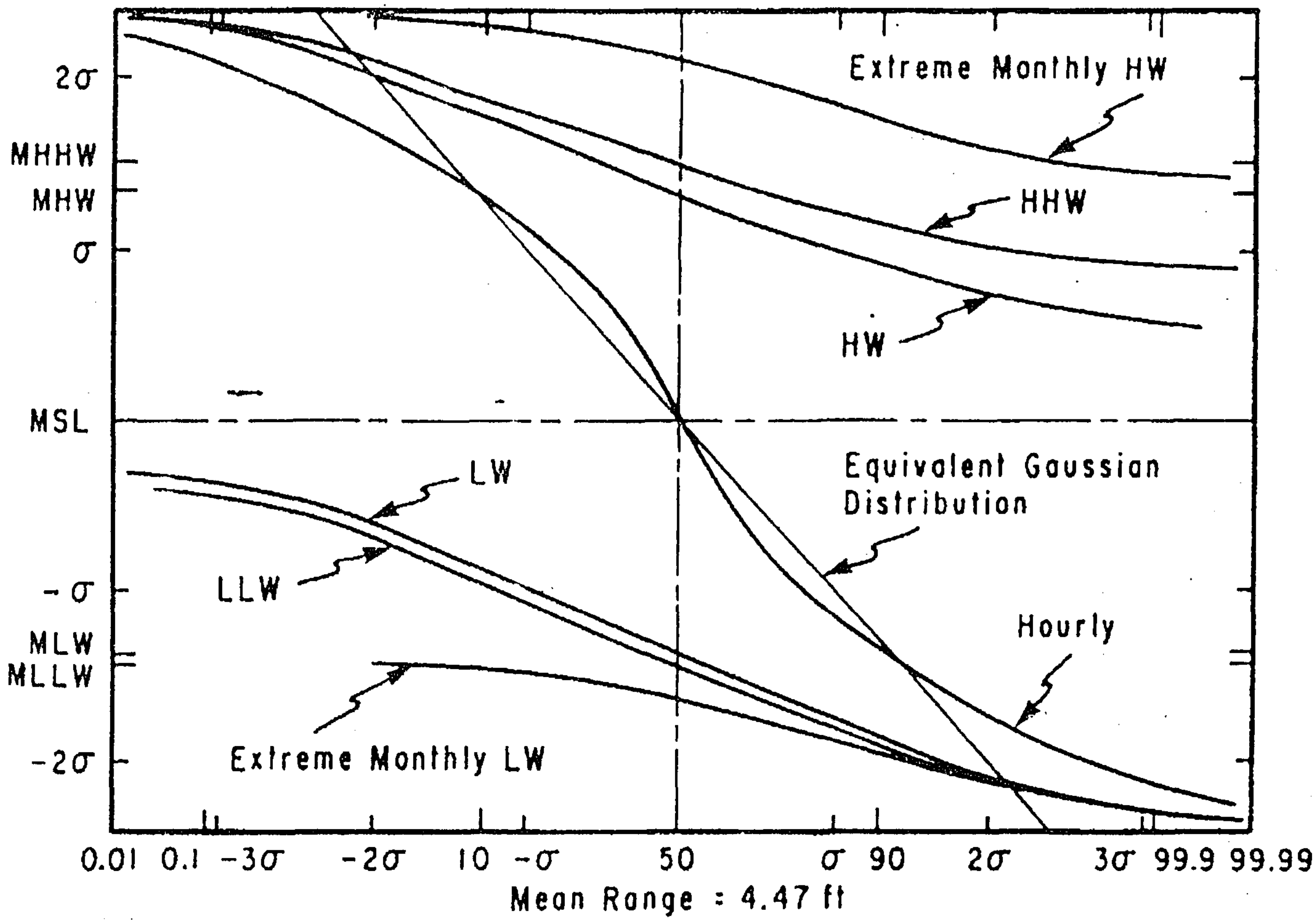
Tidal Elevation Frequency Distributions and Probability

Tidal probabilities can be calculated from either measured or predicted values of water surface elevations, as long as the datasets are long enough. The longer the dataset, the less the analysis will be influenced by winds and non-tidal flows. If the probabilities are calculated from measured values, they will include the effects of wind, rainfall, and the other climatic factors that have occurred during the period of measurement and that have not been filtered out of the dataset. If, on the other hand, the probabilities have been calculated from predicted values, which have in turn been calculated from tidal constituents that were derived from long datasets, then the random climatic factors should be relatively insignificant.

Probability tables and graphs can be used to answer such questions as (1) What is the probability that high tide will exceed a certain height? (2) What is the highest water surface elevation that has a probability of occurring in any year? and (3) What is the probability that the water surface elevation will fall between one value and another? Examples of such calculations are described by Harris (1981, 76–77).

Using 19 years of water surface elevation measurements (1963–81), Harris derived the following six predicted monthly and annual means and standard deviations of water surface elevations for each NOS reference station in the United States from hourly values: daily highs and lows, higher highs and lower lows, and extreme highs and lows. The values for Mayport, shown in Harris (1981), Figure B-22c, are accurate to the nearest 0.1 ft.

Harris also used these data to develop frequency distributions for each of the stations. His graph of cumulative frequency densities for Mayport is reproduced in Figure 3.15 (1981, 201). The statistical parameters derived for the Mayport water surface elevations are arranged by magnitude and adjusted to MSL in Table 3.16. Frequency analysis has not been updated in the literature on the LSJR tides since the Harris 1981 report.



Note: HW = high water
HHW = higher high water
LW = low water
LLW = lower low water
MHW = mean high water
MHHW = mean higher high water
MLW = mean low water
MLLW = mean lower low water
MSL = mean sea level
σ = 1 standard deviation

Figure 3.15 Cumulative frequency density for tide parameters at Mayport (1963–81)
(Harris 1981, 201, Figure B-22b)

Table 3.16 Statistical parameters for water levels at Mayport (1963–81)

Parameter	Abbreviation	Absolute Feet (MLW)	Relative Feet (MSL)
Extreme high water	EHW	7.40	5.10
2 standard deviations	2 σ	5.62	3.32
Mean higher high water	MHHW	4.79	2.49
Mean high water	MHW	4.50	2.20
1 standard deviation	1 σ	3.96	1.66
Mean sea level	MSL	2.30	0.00
-1 standard deviation	-1 σ	0.64	-1.66
Mean low water	MLW	0.00	-2.30
Mean lower low water	MLLW	-0.08	-2.30
-2 standard deviations	-2 σ	-1.02	-3.32
Extreme low water	ELW	-3.20	-5.50

Datums based on 1941–59 tidal epoch

Source: Harris 1981, 47, Table 4

Predictions from the Tide Tables

The height ratios shown in Table D4 are multipliers that are to be applied to the daily values predicted in the tide tables for Mayport. The range of tide at each station can be calculated by multiplying both the high and low height ratios by one-half the mean range of tide at Mayport (2.25 ft) and then summing the results for each station. The variation of low- and high-water elevations in the LSJR, based on the older data in the 1991 tide tables, is shown in Table D4.

The time differences in Table D4 are the differences relative to high and low water at the south jetty, in units of hours and minutes. These differences describe the travel time of the tidal wave on flood and ebb. These data have been updated by the 1992 NOS analysis (Figure 3.16).

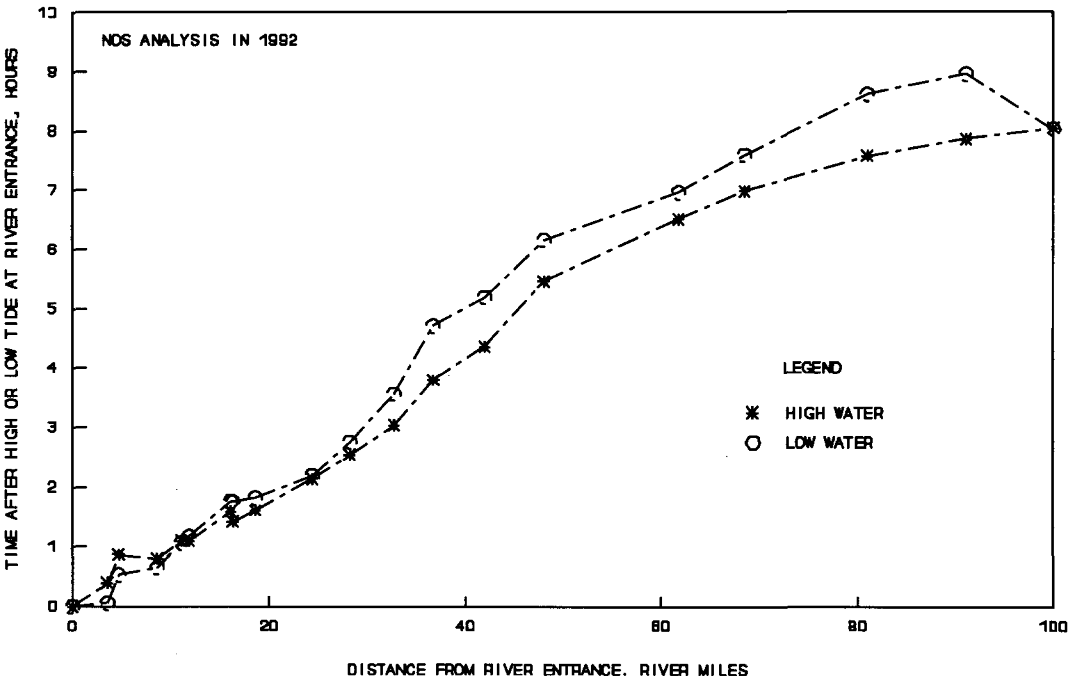


Figure 3.16 Variations in elapsed time following high or low water, from an analysis conducted in 1992 (USACE Jacksonville 1994b, 7, Figure 1)

SPATIAL VARIATION IN THE LSJR TIDE

It is important to recognize the difference between the height, amplitude, and range of tide. The *height* is the elevation of water surface relative to a datum; the *range* is the difference in height between low and high water; the *amplitude* is one-half the range.

Tide near the River Entrance

The reference station at Mayport was operated continually from 1928 to 1995. The elevation of local mean river surface relative to chart datum, MLLW, at Mayport is 2.46 ft (Figure 3.14).

The tide at the St. Johns River entrance is a mixed semidiurnal tide with alternating cycles of significantly higher and lower 12.42-hr variations. As the tide proceeds through an inlet, it is expected to undergo greater change with distance than in any other part of the river. This expectation was confirmed by NOS in its 1992 review of the tidal data for the LSJR.

The mean range of tide near the river entrance was first reported to be 4.9 ft (Haight 1938, 16; USACE 1986, 73) but has been updated to 5.49 ft (Table D5). The neap range for 1989 was 3.76 ft (NOS 1989.) The spring range was updated from 5.7 ft to 6.09 ft in the 1992 NOS tide tables (NOS 1991).

Available data for tides near the river entrance are summarized in Tables 3.17a and 3.17b. The values for the south jetty were derived from data taken over a 15-day period in 1909 and a 1-year period in 1923–24. No additional data have been taken at this site. In a recent investigation by BuSM/FDEP of the feasibility of an installation at this site, it was determined that it would not be practical either to install an instrument or to run a high-accuracy level line at this location.

The mean range of the tide for Mayport, as listed by NOS before 1992, was 0.4 ft below the ocean tide range, a value that was used in much of the reviewed literature for the river. The previously used ranges of tide at many intermediate locations in the LSJR are tabulated in the interim water quality management plan (USACE Jacksonville 1986, 3–9, Table 1).

Tide at Main Street Bridge

From March 1, 1954, to September 30, 1966, stage (water surface elevation) was measured by USGS at Main Street Bridge in Jacksonville, at NAS (8.2 mi upstream of the bridge) and at the USACE dredge depot (4.8 mi downstream). These data were used by USGS and others (Anderson and Goolsby 1973, 3–23) to determine some basic tidal means and ranges. MLW at Jacksonville was reported to be 0.6 ft below MSL (p. 10). The average tidal range at Mayport was reported to be 4.57 ft (p. 16). For this 13-year

Table 3.17a Tides in the vicinity of the river mouth, 1989

Station Index	Station Reference Number	Station Name	Mean Range (feet)	Spring Range (feet)	Mean Tide Level (feet)
N/A	8720194	Little Talbot Island	5.4	—	—
3349	—	South jetty	4.9	5.7	2.6
3351	8720220	Mayport	4.5	5.3	2.4

Note: Elevation datum is mean lower low water.
N/A = no index number assigned in Tide Tables
— = no data available

Source: Little Talbot Island: Brogdon & Parman 1979, 20
South jetty: NOS, n.d., Form 415
Mayport: NOS 1990b, 226

Table 3.17b Tides in the vicinity of the river mouth, 1992

Station Index	Station Reference Number	Station Name	Mean Range (feet)	Spring Range (feet)	Mean Tide Level (feet)
N/A	8720194	Little Talbot Island	5.49	6.09	0.53
3351	8720220	Mayport	4.51	4.92	0.31

Note: Elevation datum is mean lower low water.
A 1992 analysis of data justified values being given to two decimal places.
N/A = no index number assigned in Tide Tables
— = no data available

Source: USACE Jacksonville 1994b; Table D5, Appendix D period, the monthly means of the predicted tide at Mayport over a year varied from -3.5 to 3.5 ft (p. 23, Figure 12C). Part of this latter variation is due to the fluctuation in monthly MSL.

USGS stores each water surface elevation measurement (called "unit values") but only publishes the daily highs and lows. NOS has not measured the tide at Main Street Bridge.

Tide Upstream in the River

From a relatively short set of measurements in 1963, predicted departure of daily mean tide from the annual mean at NAS (RM 31) was found to range from -0.07 to 0.10 ft (Pyatt 1964, F43). This observation includes the effects of wind setup and freshwater inflows. Another investigator reported values of -0.07 to 0.50 ft for the same elevation difference at this station (Atlantis Scientific 1976, II-10).

In a USGS report, the MLW reference is given as 0.6 ft below MSL for tides measured from 1954 to 1966 by USGS (Anderson and Goolsby 1973, 10). In the same report, the difference between the highest and the lowest monthly mean height range was 0.027 ft. The corresponding monthly mean range of predicted tide at Mayport for the same period is shown in Anderson and Goolsby (p. 23). The range of tide versus distance from the river entrance (in nautical miles), as measured in 1933 and 1934, is shown in Figure 3.17 (Haight 1938, 23, Figure 11).

Haight's data indicated that, as the tide progresses up the river from the mouth, its amplitude gradually decreases to 1.51 ft at Main Street Bridge (RM 23.8) in Jacksonville and to 0.74 ft in Orange Park (RM 36). From this point, the amplitude of tide increases to 1.09 ft at Palatka (RM 79.5). Above Palatka, the tide becomes less noticeable until at Georgetown, approximately 109 mi upstream, it becomes negligible under normal conditions (Anderson and Goolsby 1973, 9; USACE Jacksonville 1986, 73). Under conditions of very low freshwater inflow and a northeast wind, upstream flow was observed at Lake Monroe (RM 161) (Anderson and Goolsby 1973, 9).

Tidal fluctuations can be discerned, at least according to the individual authors, greater than 161 mi upstream in Lake Monroe

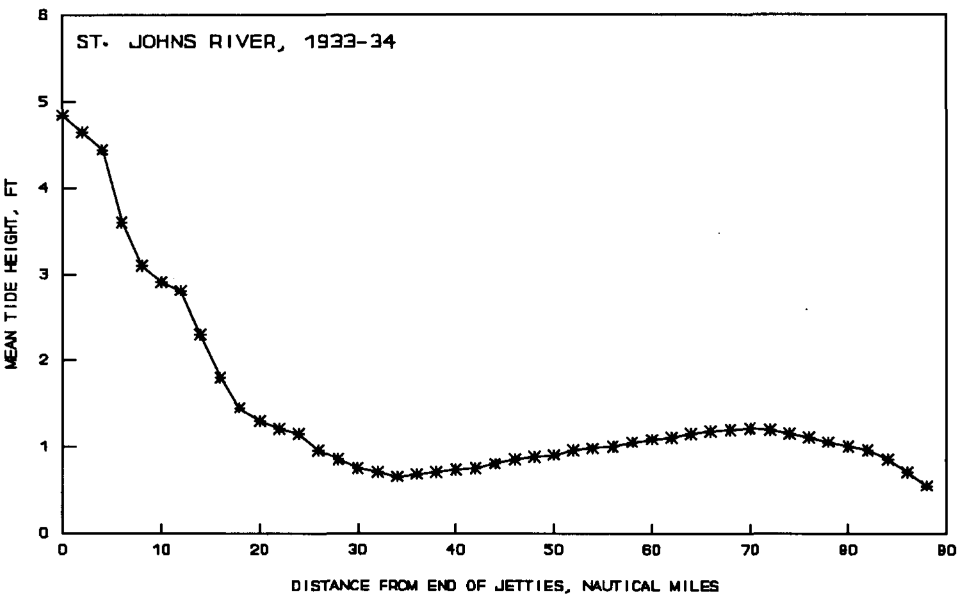


Figure 3.17 Monthly mean range of predicted tide versus distance from the river entrance (Haight 1938, 23)

near Sanford (USACE Jacksonville 1981, B-6). The USGS interim water quality report states that tidal influences are seen through most of the Middle St. Johns River Basin (Figure 1) to Lake Harney, RM 191 (USACE Jacksonville 1986, 2, 70). In an early study of the river, the extent of spring tide was reported to be as far as 283 mi upstream (Federal Security Agency 1951, quoted in Pyatt 1964, F27).

In 1968, USACE Jacksonville developed graphs showing the distribution of tides and extreme water surface elevations from the mouth of the St. Johns River to Lake George (Table D3). The estimated low tide (January 1942, 2 values), low tide of December

1956 (4 values), MLW (17 values), half-tide level (not shown; 6 values), mean high water (MHW) (16 values), minimum annual high water (9 values), and peak stage (Hurricane Dora, 5 values) in Figure 3.18.

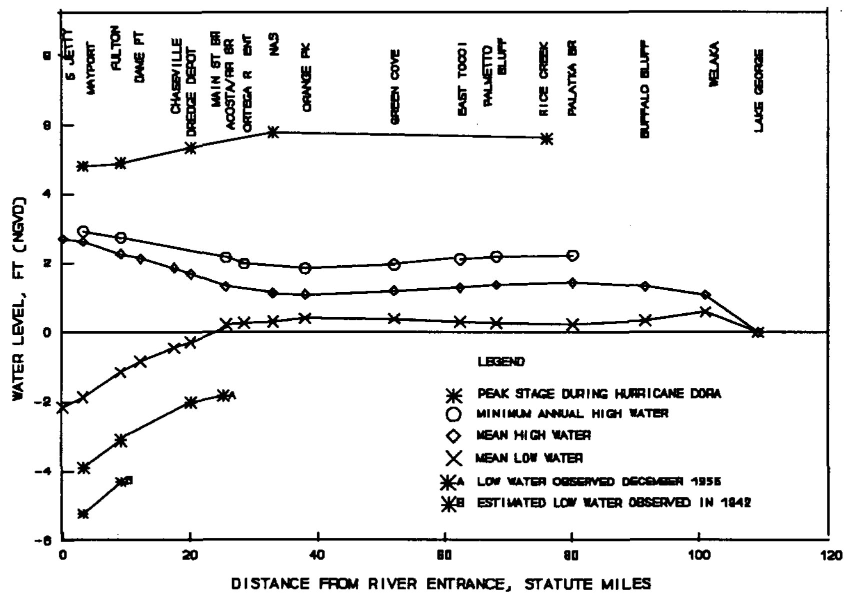


Figure 3.18 Tides and extreme water surface elevations from river entrance to Lake George (USACE Jacksonville 1968)

NOS 1992 Tidal Analyses and Statistics

In 1992, NOS analyzed all of the existing tidal data suitable for analysis and recovered as many tidal benchmarks as could be found. These tidal analyses and datum updates constitute a significant advance in understanding of the tidal characteristics of the river. NOS compared predicted and observed tidal heights and computed the associated variances at Mayport, the USACE dredge depot, Green Cove Springs, and Welaka. NOS calculated tidal datum relationships (MHW, MSL, and MLLW) at 22 stations and compared the long-term sea level variation at Mayport and the dredge depot with flow at De Land. Significant changes in descriptions of the range of MTL (Figure 3.19, part A) and the range in height of mean and diurnal tide (Figure 3.19, part B) are documented. Finally, a summary of tidal datums and vertical control was prepared (USACE Jacksonville 1994c).

MTL changes progressively upstream from the entrance (Figure 3.19, part A). From the entrance to Mayport (RM 2.4), it decreases by 0.23 ft from 0.54 ft (NGVD). From Mayport to Dames Point (RM 10.8), it regains almost half of its height (increases 0.12 to 0.45 ft), and by the time it has reached the Ortega River entrance (RM 28), it has increased to 0.85 ft. MTL then decreases to 0.68 ft at Orange Park (RM 36), rises to 0.81 ft at Julington Creek (RM 40.5), gradually decreases to 0.65 ft at Palatka (RM 79.5), and rises again to a maximum of 0.92 ft at Welaka (RM 100.4).

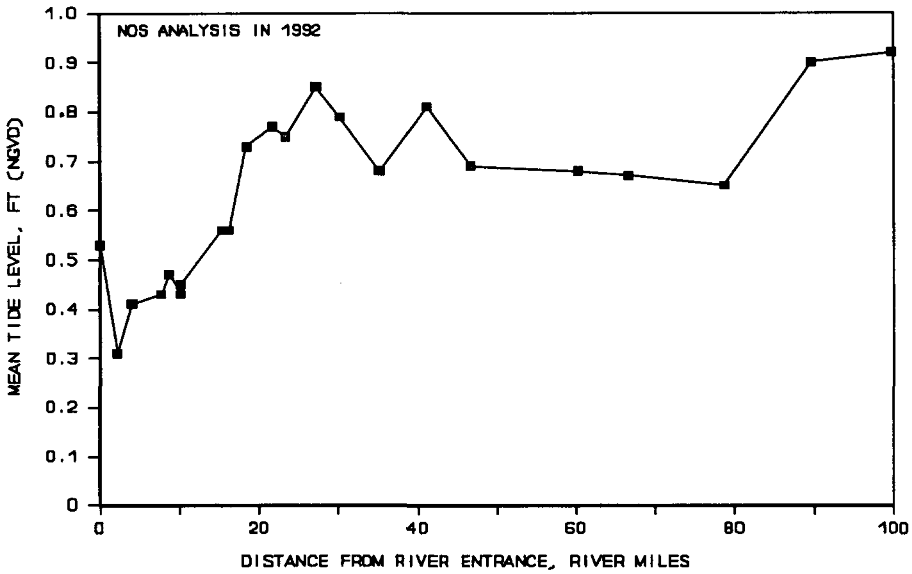
Both the mean and diurnal ranges of tide from Mayport to Welaka closely follow the values previously described by other researchers. The decrease of the mean range is relatively rapid, from 5.49 ft at Little Talbot Island, to 4.51 ft at Mayport (RM 2.4), to 3.9 ft at the Pablo Creek entrance (RM 5), to 1.51 ft at the Acosta Bridge (RM 24.0), then decreases more slowly, to a minimum of 0.71 ft at Julington Creek (RM 40.5). Tidal range then gradually increases to 1.09 ft at Palatka (RM 79.5) and slowly decreases to 0.93 ft at Buffalo Bluff (RM 90) and 0.35 ft at Welaka (RM 100.4) (Figure 3.19, part B).

Statistical Update on Mayport Tides

In 1992, NOS reviewed the existing water surface elevation data in the LSJR and, for those stations with at least 29 days of reliable data, confirmed or repeated the harmonic analyses that had been performed previously. One set of results from this review is the set of mean and extreme water surface elevations for Mayport which are reproduced in Table 3.18.

In addition to re-evaluating basic tidal statistics for Mayport, the 1992 NOS analysis provides times of high and low waters, mean ranges, mean diurnal ranges, and MTLs for each of 33 stations from

A



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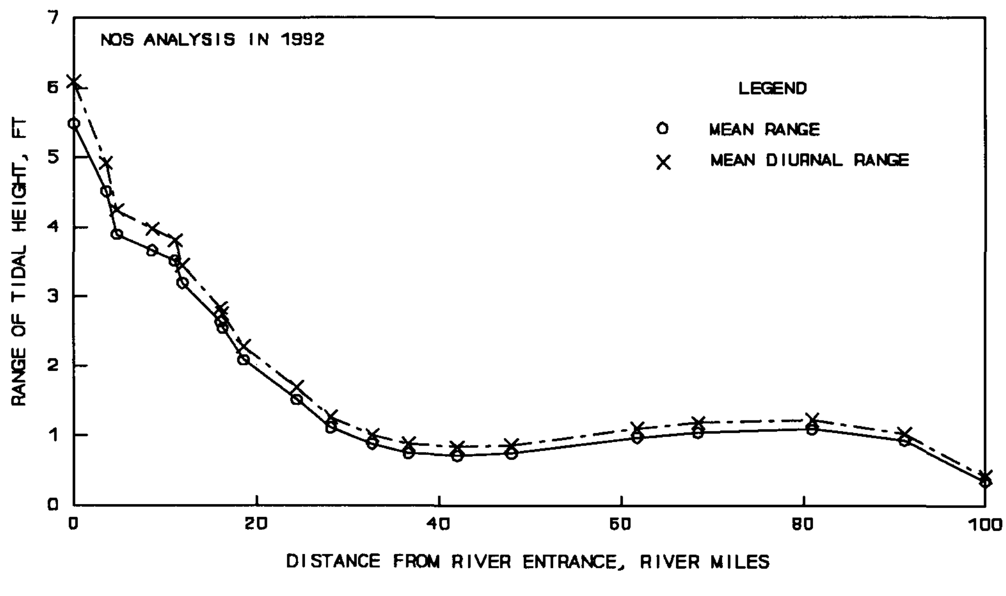


Figure 3.19 Updated variations in mean tide level (*A*) and mean and diurnal tide ranges (*B*) (USACE Jacksonville 1994b; Table D5, Appendix D)

Table 3.18 Reference elevations at Mayport, 1992

Elevation Designation	Abbreviation	Height Relative to Given Datum (feet)	
		Station Datum	NGVD Datum
Extreme high water	EHW	9.1	0.44
Mean higher high water (Sept 1964)	HHW	6.48	2.82
Mean high water	MHW	6.22	2.56
Diurnal tide level	DTL	4.02	0.36
Mean sea level (z_0)	MSL	4.02	0.36
Mean tide level	MTL	3.97	0.31
National Geodetic Vertical Datum	NGVD	3.66	0.00
Mean low water	MLW	1.71	-1.95
Mean lower low water	MLLW	1.56	-2.10
Station datum	(none)	0.00	-3.66
Extreme low water (June 1940)	ELW	-1.6	-5.26

The symbol z_0 is used by NOS to designate mean sea level.

The elevation of NGVD was changed from 3.62 to 3.66 feet in 1973 due to re-leveling of the geodetic network. The 3.66 value was first used by NOS in 1982.

EHW and ELW are given to one decimal place because they are estimates. All other values are calculated from the period of record.

Source: Steve Gill, NOS, pers. com. 1995

the inlet to Crescent City and Georgetown (Table D5). Table D5 contains information comparable to the information on the subordinate stations that is listed in the tide tables (reproduced as Table D4). Differences between Table D5 and Table D4 are that in Table D5, values are listed for a greater number of stations, time intervals are relative to Little Talbot Island, spring range is labeled mean diurnal range, and MTL is relative to NGVD, not MLLW, and in Table D4, heights of highs and lows are tabulated in terms of height ratios to be multiplied by predicted heights at the reference station.

Harmonic Analyses

Harmonic analyses were performed on data from many of the 23 stations listed in Table D7. A 29-day harmonic (Fourier) analysis was performed for stations with less than 6 months of hourly height data. This analysis produced the amplitudes and phases of 10 constituents and derived the equilibrium amplitudes and phases of 15 other constituents. The amplitudes and phases of the dominant eight harmonic constituents for 22 stations are found in Table D7, Appendix D, and USACE Jacksonville 1994b, 12, Table 3, along with the amplitudes and phases of three constituents for Georgetown. The six largest tidal constituents at 21 stations from Mayport to Welaka are shown in the chart in Figure 3.20 (USACE Jacksonville 1994b).

A full set of 37 tidal constituents for 40 different locations was obtained—by 29th day, 365th day, and intermediate-length analyses—by NOS as part of the 1992 study. The amplitudes and phases of these constituents are listed in Table D8.

Astronomic Coefficients. A plot of the changes in amplitudes of the largest constituents, with distance upstream, shows the dominance of M_2 (Figure 3.20). The phases of the largest constituents are grouped separately, one semidiurnal and the other diurnal (USACE Jacksonville 1994b, 14, Figure 4). The trends in phases are noted to be relatively linear until, in the vicinity of RM 36 (Orange Park near Station 374), the rate of change of phase with distance increases (p. 10).

Constituent Ratios. Ratios of various tidal constituents and combinations of constituents also partially explain the tidal characteristics of the river. The ratios of the shallow water overtides, M_4/M_2 and M_6/M_2, steadily increase and distort the sinusoidal shape of the total tidal curve with distance upstream (Figure 3.21). The $(K_1+O_1)/(M_2+S_2)$ ratio is less than 0.25 (semidiurnal) to RM 31 (Piney Point). Upstream of this point, the ratio increases slightly, indicating a greater diurnal effect, and returns to below 0.25 around RM 79.5 (Palatka) (Table D9; USACE Jacksonville 1994b, 6, Figure 6).

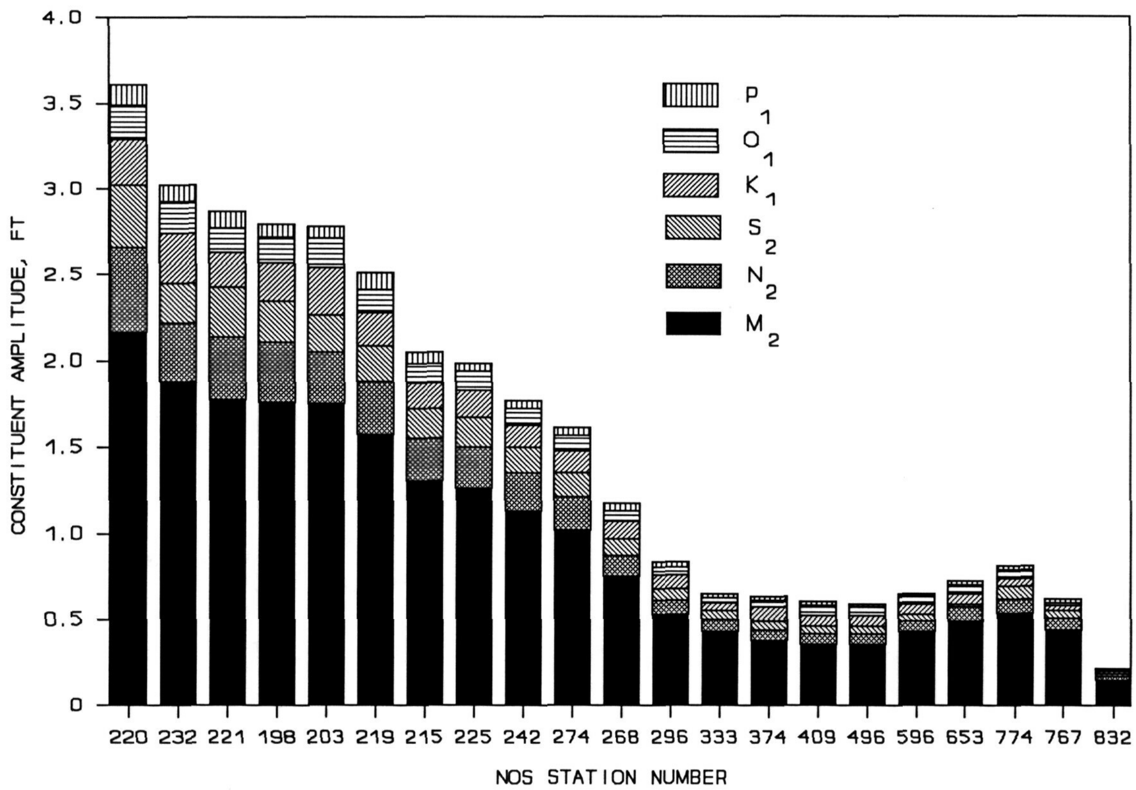


Figure 3.20 Amplitudes of the six largest tidal constituents at locations from Mayport to Welaka (see Figure 3.10 for location of stations and Table 3.14 for name of constituents) (Table D7, Appendix D)

Long-Term Constituents. Long-term data (time series longer than several years) are available only for Mayport and the USACE dredge depot. Therefore, only at these two stations could the long-period annual (S_a) and semiannual (S_{sa}) constituents be calculated. The amplitudes and phases are shown in Table 3.19.

These constituents are derived from the yearly and semi-yearly variations in the tide-producing forces but actually represent the annual and semiannual variation in MSL that is caused by seasonal variations in

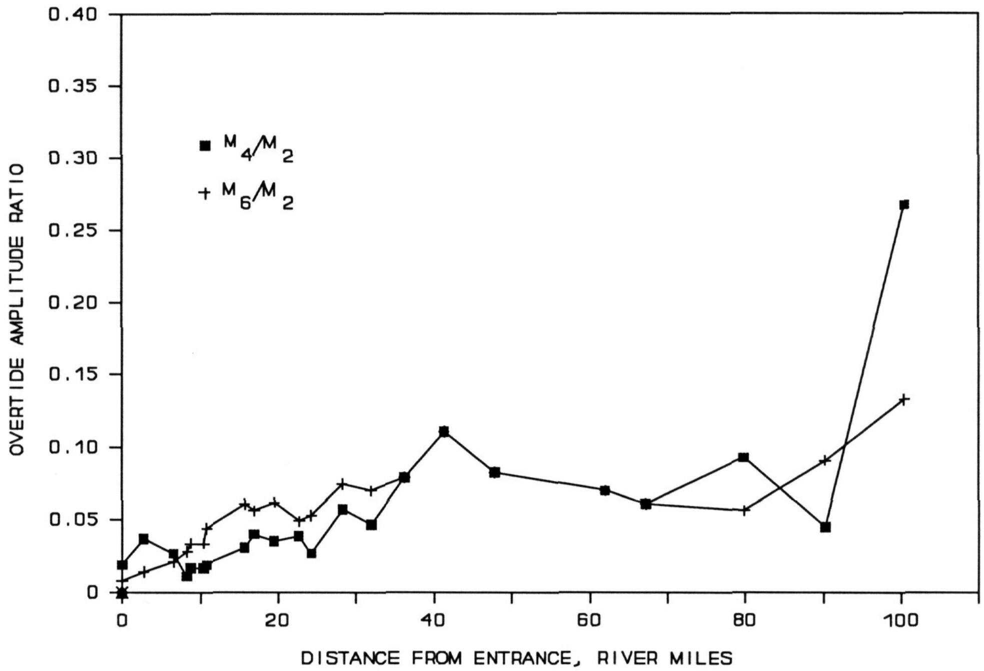


Figure 3.21 Ratios of the overtides M_4 and M_6 to the principal lunar constituent M_2 (Table D9, Appendix D)

Table 3.19 Long-period tidal constituents at Mayport and the USACE dredge depot

Constituent*	Mayport		USACE Dredge Depot	
	Amplitude (feet)	Phase (degrees)	Amplitude (feet)	Phase (degrees)
S_a	0.38	190	0.38	192
S_{sa}	0.25	55	0.24	47

*See Table 3.13 for name of constituent

Source: USACE Jacksonville 1994b, p. 10

rainfall, wind, barometric pressure, and river flow. Thus, each year the S_a and S_{sa} constituents provide a characterization of the wetness or dryness of the year (USACE Jacksonville 1994b, 10).

Comparisons of Predicted and Observed Tidal Elevations

Statistical uncertainty in predictions of tidal height is due to the natural variability of the river, which in turn is due to hydrologic and meteorologic changes, the limited amount of data available, and the lack of simultaneous observations. To attempt to quantify this uncertainty (i.e., the standard deviation) for the 1991 predicted tides, NOS compared the predictions with observations at Mayport and the dredge depot. It was found that predicted tides accounted for 93% of the total variability in Mayport tides and 81% of the variance in tides at the dredge depot (USACE Jacksonville 1994b, 17).

Farther upstream, the long-term constituents S_a and S_{sa} are not available. The analysis of variance at Green Cove Springs indicated that only 23% of the 13 weeks of observations of water elevation are due to tide. At Welaka, using an 8-month record of measurements, only 4% of water height observations were found to be tidal (USACE Jacksonville 1994b, 17–18).

The uncertainties of predicting hourly heights at these four stations are due to the shortness of the record of observations. NOS calculated the standard deviations shown in Table 3.20 for these stations (USACE Jacksonville 1994b, 18).

Nevertheless, NOS states that predictions of tides based on the harmonic constituents can be more precise than predictions based on the height and time corrections in the tide tables (USACE Jacksonville 1994b, 18).

Tidal Datum Relationships

The local values of MHW and MLLW are dependent on the tidal range and the elevation of MSL. In general, the differences between MHW and NGVD, between MSL and NGVD, and between MLLW and NGVD are greatest at Mayport and gradually decrease

Table 3.20 Uncertainties in tidal water surface elevation predictions, based on an NOS analysis of 1991 tides

Station	Mean Tidal Range (feet)	Standard Deviation (feet)
Mayport	4.51	0.49
USACE dredge depot	2.08	0.44
Green Cove Springs	0.74	0.50
Welaka	0.35	0.57

Source: USACE Jacksonville 1994b, p. 18

upstream. The values reported by NOS for these differences are only preliminary, pending final processing by NGS, but follow the typical relationships for tidal rivers. It is observed that the elevation of MLLW becomes greater than the elevation of NGVD near RM 24 (Acosta Bridge) (Table D10, Appendix D; USACE Jacksonville 1994b, 20).

Long-Term Sea Level Variation

Monthly means of simultaneous observations over the 14-year period of observations from 1954 through 1967 at Mayport and the dredge depot, together with USGS flow data at De Land, were used by NOS to describe generalized seasonal patterns and variability in MSL, the mean tidal range at Mayport and the dredge depot, and mean flow at De Land (USACE Jacksonville 1994b, 26–31, Figures 8–13). The mean ranges of tide at Mayport and the dredge depot have similar seasonal patterns: for most months the ranges are relatively constant (at 4.51 ft for Mayport and 2.08 ft for the dredge depot) and both increase slightly in July and have a minor minimum in September and October. The monthly MSL patterns are also very similar, with the largest maximum occurring in October and the second largest in May and June. The lowest MSL occurs in February. The monthly mean river flow at De Land is also maximum in October, with a secondary maximum in March and April and a minimum in May and June. There is significant variability from one year to the next in all of these statistical patterns.

The correlation between mean ranges and mean river flow and between MSL and mean river flow are poor as expected (USACE Jacksonville 1994b, 24). The MSL variations in tidal rivers are caused by a combination of effects in addition to those of the mean river flow. These effects are due to the response of the waters on the continental shelf to large-scale seasonal weather patterns, variations in wind and barometric pressure, and oceanic circulation patterns.

Long-term variations in MSL and mean range of tide were estimated from Mayport data (USACE Jacksonville 1994b, 24–25). The consistent upward trend in MSL is 0.007 ft/yr ±0.0009 ft/yr, with a standard deviation of 0.115 ft. This trend is relative because long-term variations in vertical land movement, global sea level change, and climate cannot be distinguished in the data.

Variation in Tidal Characteristics

The river may be divided into four different sections, based on its tidal characteristics. The divisions between sections are located at Mayport, the Acosta Bridge, and Palatka.

Outside the river entrance, the range of tide decreases by 0.3 ft from a location to the north of the entrance at Little Talbot Island to a location south of the entrance near Jacksonville Beach (USACE Jacksonville 1994b, 5). Over the distance upstream from the jetties to Mayport, the tidal characteristics are quite complex. Within a 2-mi distance, the tidal range decreases from 5.49 ft at the ocean to 4.51 ft at Mayport. Over the same reach, high water is delayed by 0.4 hr, although there is almost no delay in the occurrence of low water.

In the first section of the river, from the jetties to Mayport, the range and time of tide and geodetic datum relationships all change rapidly. These changes are probably not linear, and additional tidal datum information is needed in this region to describe the change in tidal characteristics through the inlet.

In the second section, from Mayport to the Acosta Bridge, changes in tidal characteristics are relatively uniform, and no additional data are needed.

From the second to the third sections, the Acosta Bridge to Palatka, changes occur in the rates of increase and relationships of the times of high and low water, the M_2 constituent amplitudes, and the harmonic constituent ratios. These changes are due in part to river shape and in part to the fact that the channel at Palatka acts as a partial reflector of tidal energy. The tides at Green Cove Springs and Palatka are fundamentally similar, and no additional stations are recommended for this section. However, additional longer datasets are needed at all of the historical stations to account for the annual variability.

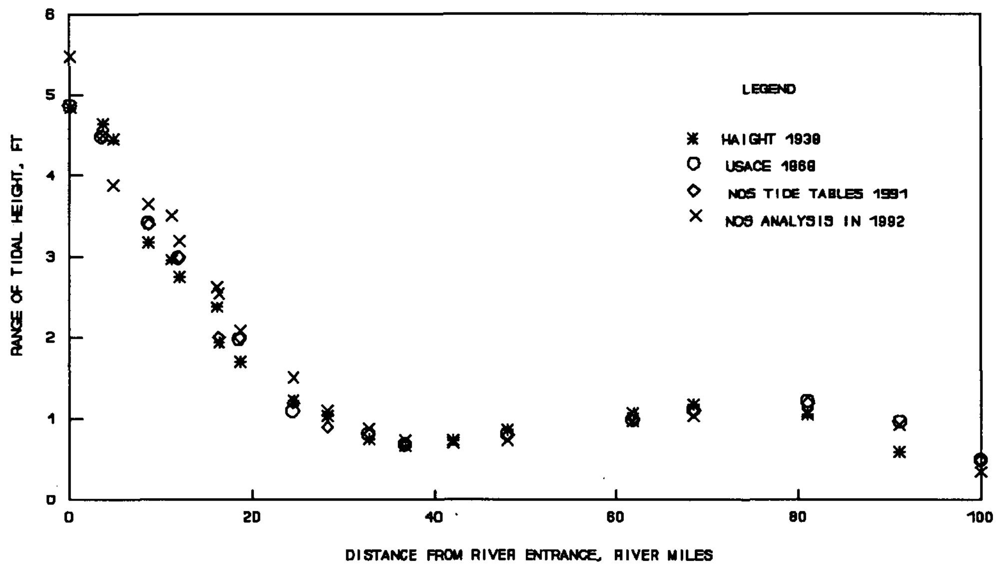
In the fourth section, upstream of Palatka, the tide becomes weak as it progresses toward the location of the head of tide. The tide range at Welaka is reduced and is more complex than it is downstream; the low water curve is flatter and may contain additional tidal components. If a head of tide study is planned, NOS recommends that additional measurements be made in this area.

NOS also recommends (1) that some of the historical stations be reoccupied simultaneously for a time period of from 1 to 5 years in order to update the tidal datums and (2) that new stations be established near the entrance to define the transition of tidal characteristics from the ocean to Mayport (USACE Jacksonville 1994b, 35).

Comparisons of Tidal Ranges and Times of Occurrence

Four distributions of ordinary mean tidal ranges are compared in part A of Figure 3.22 (Haight 1938; USACE Jacksonville 1968; NOS 1991; USACE Jacksonville 1994b). The updated values are presumed to be more accurate because they incorporate a few longer periods of record as well as harmonic analyses for each station.

A



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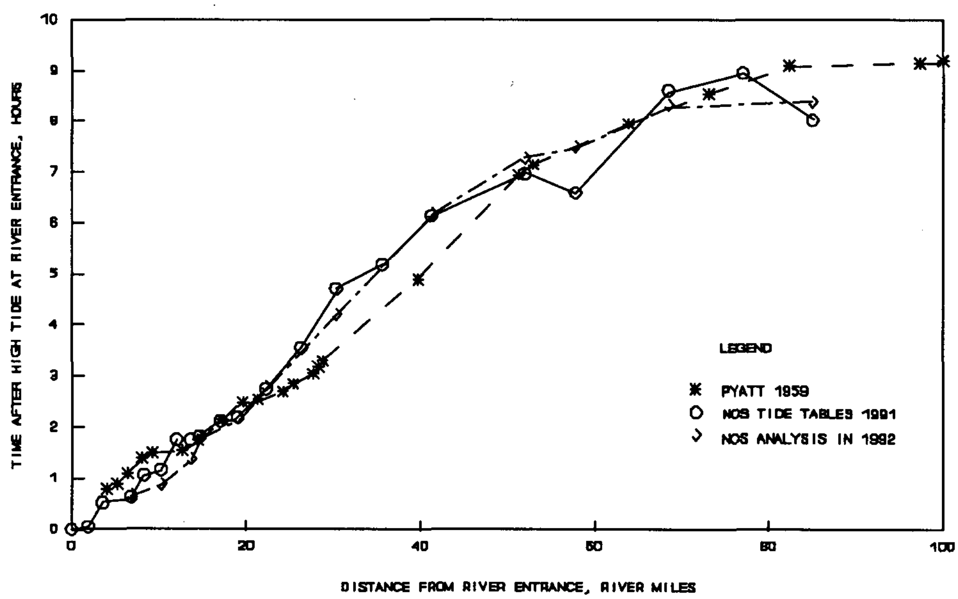


Figure 3.22 Comparison of variation in ordinary mean tidal range from four sources (*A*), high-water time interval from three sources (*B*), and low-water time interval from three sources (*C*)

C

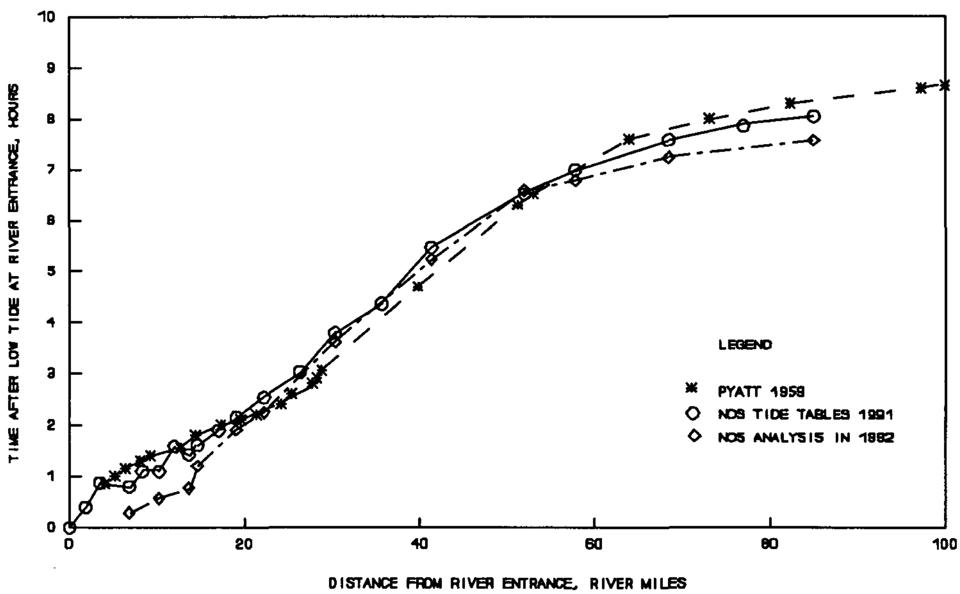


Figure 3.22—*Continued*

The progression of the tide as it moves upstream from the mouth of the river toward the head of tide is relatively smooth. This progression is measured by both the change in the range of the tide and the time interval of high or low water after the occurrence of the maximum or minimum water level at the mouth. The high water takes about 8 hr to progress 100 mi upstream after high tide at the mouth, and the low water takes about 9 hr to progress the same distance after low tide at the mouth. Welaka is the farthest upstream station with a persistent measured tide. The times of high tide relative to high water at the river entrance are 2.1 hr at Acosta Bridge (RM 24), 4.4 hr at Julington Creek (RM 38), 7.6 hr at Palatka (RM 76), and about 8 hr at Welaka (RM 100) (Figure 3.22 B and C). Near the river mouth, the high water time differences are greater than the low water time differences. However, near RM 10, this relationship reverses and the low water time differences become greater. This change is typical of many tidal rivers and is an indication that the tidal characteristics at some stations are not symmetrical. However, the individual station tidal characteristics have not yet been studied (USACE 1994b, 5).

The duration of tide at the ocean is 6.24 hr (one-half of the M_2 tidal period). Therefore, when the flood tide reaches a location north of East Tocoi (6.5 hr, RM 61), it is changing to an ebb tide at the river entrance. This phenomenon may lead to some interesting and complex tidal characteristics that have not yet been quantified.

SUMMARY OF TIDES IN THE LSJR

Water surface elevations have been measured by USGS at several bridges and selected upstream locations at various times since 1938. The spatial variation of tidal range was first described by Haight (1938) and later by USACE Jacksonville.

The tide at Mayport has been measured since 1928. It is classified as slightly mixed semidiurnal and has a mean range of 4.51 ft, a diurnal range of 4.92 ft, and a spring range of 5.3 ft. The range of tide decreases to about 0.8 ft at a distance of 40 mi upstream from the ocean and increases to about 1.2 ft near Palatka. Tide has been measured by NOS at 37 stations (Table D1). The ranges and high- and low-water intervals have been published for 31 of these stations (Table D5). The tide at Mayport has a small, but measurable, M_4 overtide which fluctuates, with an overall increasing trend, upstream, to a maximum value at Welaka. The M_6 overtide is also significant, although much smaller. Overtides, or shallow water constituents, indicate that there is distortion in the amplitude and phase of the tide wave, caused by changes in geometry and friction over the length of the river.

Water surface elevation statistics (including MSL, MHW, higher high water, and extreme high water and the corresponding lows) have been evaluated using all data available to 1992. Predicted times and heights of tides at 15 of the stations, 14 of which are calculated from the tide at Mayport, are published annually (Table D4). Maximum flood and ebb tidal currents at 16 stations are also predicted and published annually (Table D6). Tide elevation frequency distributions for Mayport tide were published in 1981 for 19 years of data (1963–81).

WATER STORAGE

WATER BALANCE IN THE RIVER

The balance of water in the LSJR—the hydrologic water balance or water budget—is an accounting of all of the inflows, outflows, and internal changes in storage over a certain period of time. USGS (1973) described eight basic factors that affect these volume changes. The five inflow factors were described as downstream flows from De Land and inflows from tributaries (the Middle St. Johns River Basin), upstream flow (from the ocean), inflow from intervening tributaries, inflow from ground water, and direct rainfall. The three outflow factors were upstream flows (into the Middle St. Johns River Basin), downstream flow from Jacksonville to the ocean, and direct evapotranspiration. The USGS report stated that if the interaction of these factors is such as to increase storage, the volumes and durations of downstream flows will be decreased and the volumes and durations of upstream flows at Jacksonville will be increased. Likewise, if these factors interact to decrease storage, downstream flows will be increased and upstream flows will be decreased (Anderson and Goolsby 1973, 18).

STORAGE VOLUMES

A significant part of the volume change in the LSJR is due to the amount of water pushed in by ocean tides. USGS concluded that much of the stored volume consists of ocean water and the mixed salinity waters already in the river, and much of this water flows out to the ocean on the ebb tide (Anderson and Goolsby 1973, 1).

The channel above Jacksonville is capable of storing large amounts of water (Anderson and Goolsby 1973, 1). USGS quantified the storage of water in the reach between Jacksonville and De Land using data from March 1954 to September 1966. For 6 of these 12 years, storage in the estuary increased, and for the other 6 years it decreased, but not in alternate years. The monthly change in storage and the estimated monthly difference between direct rainfall and evapotranspiration are shown in Figure 3.23a. The monthly change in MSL is shown in Figure 3.23b. Considered together, these figures show a relationship between MSL and storage.

From January through June, average storage increased as rainfall increased through the spring (Figure 3.23a). At the same time, average sea level at Mayport decreased to the lowest value in its annual cycle (Figure 3.23b). During this period, freshwater inflow and storage were so low that there was a tendency for ocean water to penetrate farther upstream. There was a minor peak in sea level in May or June, and after a low in July, there was a major peak in October. This annual cycle of rise in sea level tends to hold the river outflow back in proportion to the difference between freshwater head upstream and the ocean level. The average freshwater input was greater than the average freshwater output, due to the increased backwater effect of the ocean tide and the fact that average rainfall was greater than average evapotranspiration.

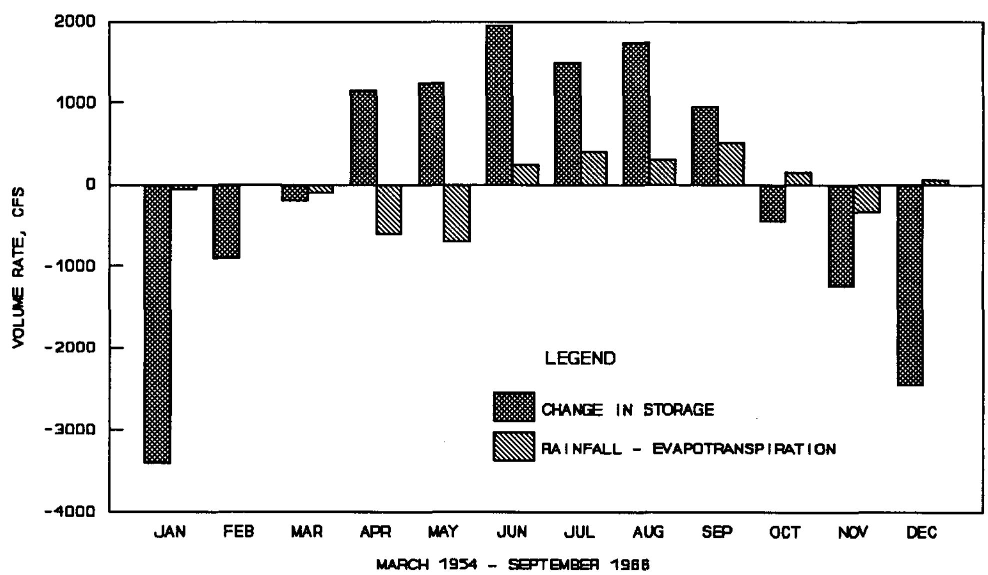


Figure 3.23a Average monthly volume storage rate of the main stem and rainfall minus evapotranspiration, March 1954–September 1966 (Anderson and Goolsby 1973, 19, Figure 10a)

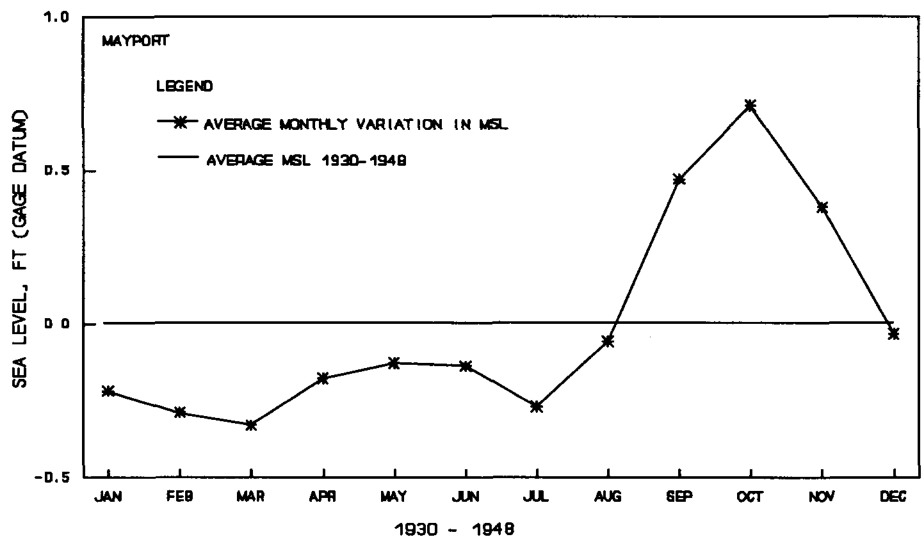


Figure 3.23b Corresponding average monthly variation in mean sea level (MSL) from average MSL for the period 1930–48 (Anderson and Goolsby 1973, 19, Figure 10b)

During July, freshwater inflow increased so rapidly that storage increased despite a small decrease in sea level. From October through March, freshwater input showed a general decline along with the annual decline in sea level, resulting in increased net discharge at Jacksonville. USGS found that in April and May the storage increased by about 1,250 cfs, even though evapotranspiration exceeded rainfall by about 700 cfs. On average, only three-fourths of the water coming into the river during April through September was discharged at Jacksonville. The remainder was stored and released from October through March (Anderson and Goolsby 1973, 20). USGS also stated that this backwater effect occurs in other months in very dry years, whenever the freshwater head is less than the ocean surface level, forcing seawater to flow upstream into storage (Anderson and Goolsby 1973, 18–21).

USGS (1973) concluded that most of the time during the study period (1954–66), storage in the estuary (and the net flow at Jacksonville) was affected more by freshwater inflow and outflow than by rainfall and evapotranspiration. USGS also concluded that the long periods (greater than 6 months) of average net upstream flow at Jacksonville were more a result of the coincidence of low storage and the start of annual rise in sea level than a result of evapotranspiration over rainfall (Anderson and Goolsby 1973, 20).

TIDAL PRISM

Intertidal storage in a river is frequently described in terms of the *tidal prism.* This term describes the volume of water exchanged with the ocean over a half tidal cycle and is always less than the total storage in the river. In situations where the type of tide is mixed, as in the St. Johns River, the tidal prism is different in each succeeding tidal cycle. In the NEI, the tidal prism of the St. Johns River is given as 1,880,000,000 cubic feet or 0.0128 mi^3. This value can be calculated from the NEI values by multiplying river length (123 mi) by mean width (2.3 mi) by a mean tidal range of 0.24 ft. However, a more accurate tidal prism can be calculated for 120 RM by dividing Connell's mean segment volume (Figure 3.2, part C) by mean segment depth (Figure 3.2, part B) and multiplying the result by tidal range (linearly interpolated for each channel from Table D5). This calculation results in a tidal prism of 0.036 mi^3, which is almost three times the volume given in the NEI.

A paper by Brun (1960, referenced in Atlantis Scientific 1976, II-7), estimated that the freshwater discharge is only 6% of the maximum value of tidal flow (i.e., maximum tidal flow is about 17 times the freshwater discharge), and the total freshwater discharge during half tidal periods amounts to about 9.2% of the tidal prism. A report by USACE gives the average tidal prism, or volume flow on flood or ebb, at approximately 44,000 ac-ft at Jacksonville and 90,000 ac-ft at the river entrance (USACE Jacksonville 1981, B-7). These values are equivalent to 22,000 and 45,000 cfs, respectively, for a half tidal cycle.

GROUND WATER EXCHANGE

Evidence exists of ground water seepage into and out of the LSJR. Conductivity, for example, is at a minimum between Black Creek (RM 45) and Shands Bridge (RM 50) and increases moderately upstream, indicating the likely presence of mineralized inflows from springs upstream. This discharge quantities and conductivity of several springs upstream of the LSJRB, as monitored by USGS, are significant. In addition, a substantial volume of ground water is pumped from the Floridan aquifer system for agricultural irrigation. This water is high in dissolved chlorides. Occasionally, river water can be exchanged to the surficial aquifer system if upland ground water tables are sufficiently depressed below normal levels. The variability in the amount of ground water exchange, unknown at present, is probably an important component of the LSJR water budget.

An estimate of the net upward leakance from ground water into the river was made by USGS for Phase 1 of the Feasibility Level Cost Share Agreement (USACE Jacksonville 1994d). USGS found that, for WY 1990 (a relatively dry year), the net (upward) leakance was 82 cfs. The net annual leakance was estimated to be about 127 cfs under more normal conditions.

SUMMARY OF STORAGE

It is sometimes simpler to describe the dynamics of the river in terms of changes in storage because this variable deals with overall volume changes and not with local changes. Note that there are two general causes for a change in storage in the LSJR: (1) increase or decrease in direct inflow or outflow and (2) the "backwater effect" caused by the tide or seasonal change in sea level at the entrance.

It would be useful to divide the river into segments and calculate a water budget for each of those segments. This calculation can be accomplished in the future when descriptions of the hydrology of each subbasin have been completed. Without such an effort, changes in volume are not particularly useful for describing river dynamics.

RIVER FLOW

River flow is described in two chapters in this report. This chapter focuses on general concepts, historical observations, measurements and calculations of flow, discharge and drainage area relationships, new estimates of the partial inflow at the upstream boundary, comparison of flow at Jacksonville and Palatka, differences among tidal, non-tidal, and total flows, and effects of wind and coriolis acceleration on flow. The next chapter, flow statistics, summarizes statistics calculated from the flow-related measurements.

INTRODUCTION

The magnitude of flow in the river is a measure of the rate at which volumes of water move. To answer questions that deal with overall river management issues, it is necessary to know the spatial and temporal variation of flow under a variety of circumstances and for the natural range of hydrologic events. Flow distributions are needed for describing the rate of mixing of fresh and salt water and the spreading and fate of pollutants.

The total flow in the river is the volume of water moving at a cross section in the river over a period of time (units of volume divided by time). The flow generally increases proceeding downstream as tributaries join the main stem. Flow can be treated as an instantaneous quantity, but more often it is expressed as a time-averaged quantity. The term "discharge" (units of velocity multiplied by cross-sectional area) has been used for quantifying the amount of water flowing into another flowing mass of water, but now it also is commonly used for volume flow in the downstream direction. "Current" is the horizontal movement of water at a point or in a confined area, with units of distance divided by time. "Speed of current" is the magnitude of the velocity of the flow; "strength of current" is the maximum velocity of a tidal flow.

In general, the movement of water in the river varies in all directions—longitudinally, laterally, and/or vertically—in response to local forces and antecedent conditions. The predominant forces determining the total flow in the St. Johns River are the volume of water stored upstream as a result of previous activity, the flow caused by tidal forces, the amount of inflow from tributaries, the amount of direct rainfall, and the effect of wind.

The term "circulation" implies flows that are not uni-directional, sometimes referring to flows that are circular, or eddying, caused by tidal or other forces. Circulation is sometimes used as an all-encompassing term for all of the flow over an entire water body. "Secondary" flows are any that are not the predominant flows, such as the lateral components of current in a bend or horizontal or vertical eddies.

There are several different ways to label the flow and the components of flow, in a tidal river: total discharge, net discharge, upstream and downstream flow, tidal flow, non-tidal flow, net flow, flow in different layers caused by local density gradients or wind, secondary flows, etc. Other types of flows, such as freshwater inflows from the basin and from the aquifer, also need to be quantified. Discharge, as well as flow, has units of volume divided by time; occasionally, constant flow is assumed and units of volume are used for discharge. The term "volume rate" is used sometimes to emphasize the time-dependent nature of flow. "Net" flow is the difference between flow in one direction and flow in the opposite direction.

The non-tidal flow in the river is that part of the flow not caused by tidal forces. The non-tidal flow is due principally to wind and freshwater inflows and outflows. Other non-tidal inflows of significance are large industrial and treatment plant discharges. The terms "net non-tidal flow" and "residual flow" are conventionally used to describe the difference between upstream flow and downstream flow averaged over a number of tidal cycles.

As stated in the chapter on tides, the St. Johns River is affected by tides and tidal currents at least to Crescent Lake (RM 95). Several reports have used 110 mi as the ordinary limit of tide (USACE Jacksonville 1975, 4) and the extent of the LSJRB (USACE

Jacksonville 1986, 2). A tidal influence has been reported as far upstream as Lake Monroe (RM 162), but this occurrence was more likely the result of wind.

The discharge of the river depends on the water balance. The monthly average net flow in a tidal river is upstream or downstream, depending on whether the sum of freshwater inflow and rainfall is less than or greater than evapotranspiration, respectively, plus or minus the change in storage.

The flow in the river depends on the amount of water in storage in the river and the relative magnitudes of inflows, outflows, and climatological forces (primarily wind and pressure). When the net freshwater inflow is positive, the duration and volume of downstream flows in the LSJR tend to increase, while the duration and volume of upstream flows tend to decrease (Anderson and Goolsby 1973, 15).

The reader should be careful to distinguish between net flow, tidal flow, total flow, and discharge in the literature on the St. Johns River. When the flow terminology is not explicitly stated, the source of data and the associated analysis usually provide the necessary information to indicate which term is being used.

HISTORICAL OBSERVATIONS

The first series of current measurements in the river was taken by the U.S. Army Engineers at various times "in connection with projects for improvement of the channel" and a few surveys by C&GS hydrographic parties reported in 1890, 1891, and 1910 (U.S. Army 1890 and 1891, as reported in Haight 1938, 17). During the winter of 1933–34, C&GS conducted an intense survey of currents consisting of (1) a set of 3-day observations at 35 locations and (2) a 15-day continuous set of measurements of currents between the jetties. Currents were measured using current poles (15-ft weighted sticks floating with 1 ft exposed above the surface) and Price current meters (Haight 1938, 17).

Some of the results of these measurements were as follows (statements have been reorganized here for emphasis):

> ...the time relation of current to local tide varies...along the river.
>
> In the lower portion...the strengths of flood and ebb occur near times of high and low water respectively.
>
> Above Jacksonville the current becomes rapidly earlier with respect to the local tide...
>
> ...fifty miles from the sea the strengths of these measurements of flood and ebb precede the high and low waters by about 3 hours, the slack waters occurring near the times of the highs and lows.
>
> Advancing up the river the current occurs later and later with respect to the tide, and at a distance of 85 miles from the sea the strengths again come at about the times of high and low tide, which is the same relation that exists at Jacksonville. (Haight 1938, 24)

In 1944, the City of Jacksonville and the Bureau of Sanitary Engineering, Florida State Board of Health, undertook a sampling program in the river which included water levels, currents, and water quality. The measurements were conducted in May and June 1945 in the main channel and from August 1945 to May 1946 in major tributaries. The results were reported in a dissertation by Pyatt (1959), which resulted in a USGS water supply paper which included data from a 1954–57 study by Wolman and Geyer (Pyatt 1964). The following results were reported:

- Current effects "were considerably more erratic than the variations in the tidal range" (p. F45).

- Looking "in the direction of prevailing flow, the higher velocities occur on the right and the current turns first on the left," an indication, to the author, of a significant Coriolis acceleration (p. F44).

- "From Mayport...to Jacksonville...the current ranged from 1 to 3 kn [knot] and was generally less than 1 kn and affected by wind above Jacksonville" (p. F45).

FLOW MEASUREMENTS

The total flow in a channel is difficult both to measure and to calculate. The traditional method for calculating uni-directional (non-tidal) flow in rivers is to measure the velocity components on a cross section, multiply these velocities over each area element, and sum the resulting unit flows. In a reversing tidal flow, this method is very difficult to use because of limitations on positioning the instruments on the cross section, the threshold of low-flow detection, and the difficulty in indicating the direction of flow. Attempts to simplify the process by continually measuring velocity at the location of the mean flow are even more difficult, because the location of the mean flow tends to migrate during the tidal period. The results of other methods, such as the USGS moving-boat method and experiments using acoustic or Doppler transducers that integrate the flow over the entire cross section, have not been reported in the literature for the St. Johns River. For these reasons, discharge volumes cannot be assessed as accurately as other variables that can be directly measured. Some investigators, such as Pyatt and Anderson and Goolsby, developed approaches for estimating bi-directional flow from changes in water level slopes between two neighboring cross sections. These measurements were limited by the accuracy of the water level instruments, because small changes in water surface elevation are associated with large changes in flow. Such measurements are marginal, at best.

Velocity Data

The first measurements of current velocity in the river were collected by USED in 1890–91 and C&GS survey teams. These efforts involved relatively short-term observations, and results were limited (Haight 1938, 17). In 1909, USED collected data on surface-current slack times and flood and ebb durations at ten stations on the St. Johns River. No velocities were reported. These data are summarized by Haight (1938, 25, Table 1).

During the winter of 1933–34, measurements of tide and velocity in the St. Johns River were conducted by C&GS at four depths at each of 35 stations (Haight 1938, 25–27, Table 1) (Figure 3.24). These

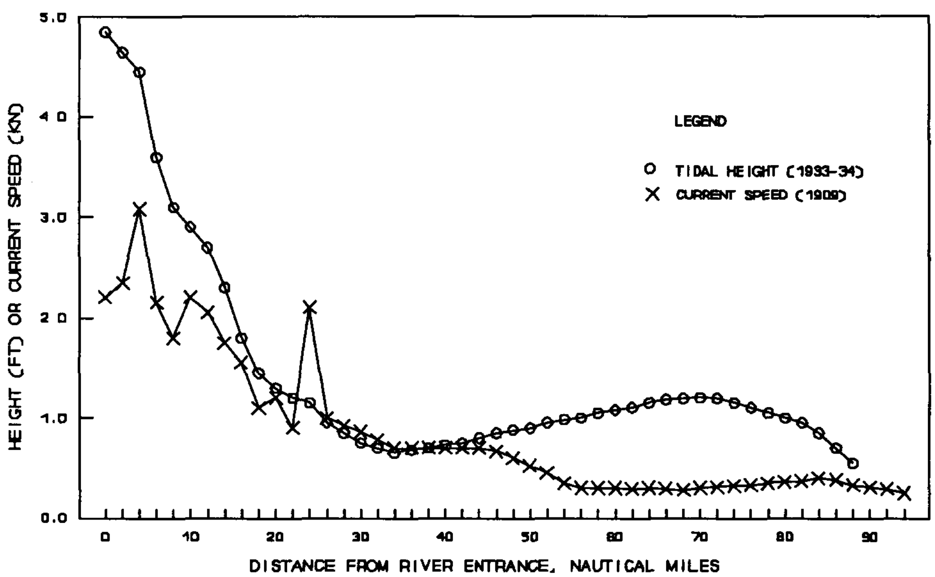


Figure 3.24 Range of tide and vertical-mean speed of current (Haight 1938)

surveys resulted in the first published report on currents in the LSJR, which concluded that "Currents in the...river are...modified considerably by winds and freshet conditions" (a freshet is a rush of fresh water) (p. 17). Haight reported that north and northeast winds increase the velocity and duration of flood current and decrease the ebb; south and southeast winds have the opposite effect. Freshets, occurring usually in autumn, increase ebb and decrease flood current (p. 17). The current velocities decreased from a high of over 3 knots near the river entrance to a relatively constant low of 0.3 knots upstream of Tocoi (60 nm from river entrance) (p. 23). Haight notes the general decrease in tidal height range and current from the entrance to Mandarin (37 nm from river entrance), followed by a decrease with increasing tidal range farther upstream and a small increase in velocity with decreasing tidal range still farther upstream.

Pyatt described a comprehensive stage, velocity, and discharge measurement program conducted by USGS in 1945 involving "continuous velocity traverses" (Pyatt 1959, 14). These are most likely the same measurements reported by the USACE Waterways Experiment Station (WES), Vicksburg, Mississippi. These neap, mean, and spring tide data were needed for calibration and verification of the WES physical model of the St. Johns River, which extended from the river mouth to Welaka. The strengths of flood and ebb currents at three depths at ten stations from south of Palatka to Mayport were measured (WES 1947, 7, Figure 2) and summarized at four stations by Pyatt (1959, 127). After extensive measurements of currents and salinity had been evaluated, variations of flow data were judged inadequate, and a mean freshwater discharge of 17,000 cfs was used for model verification (WES 1947, 18).

Pyatt described a subsequent project using correlation between three continuous stage recorders in the Jacksonville area and five intensive tidal cycle surveys in 1954–55. No velocities are given in the published reports on these projects (Pyatt 1959, 15–17).

The University of Florida Coastal Engineering Laboratory (CEL) measured currents in the vicinity of Baptist Memorial Hospital (near RM 25), using floats, during two ebb and two flood tidal cycles (CEL 1959). These currents, summarized in figures in the CEL report, were used to calibrate and verify a small physical model.

USGS reported that the observed time of maximum velocity at Main Street Bridge was equal to the predicted time plus or minus 2 hr, depending on non-tidal factors (Anderson and Goolsby 1973, 7, 14).

Data for Flow Calculations

Historical Flow Network. The measurement network that existed in 1977 to provide data for calculations of flow in the main stem downstream of Lake George consisted only of gages at Palatka and Jacksonville (SJRWMD 1977, D-25, Figure D-7). Tributary discharge stations, also included in Figure D-7, are described in Bergman (1992). All stations that have been used to collect data for flow calculations in the main stem, up to 1994, are shown in Figures 3.25a–d. In 1990, an AVM (acoustic velocity meter) was installed at Buffalo Bluff, near the mouth of Dunns Creek; other AVMs were installed between 1990 and 1994.

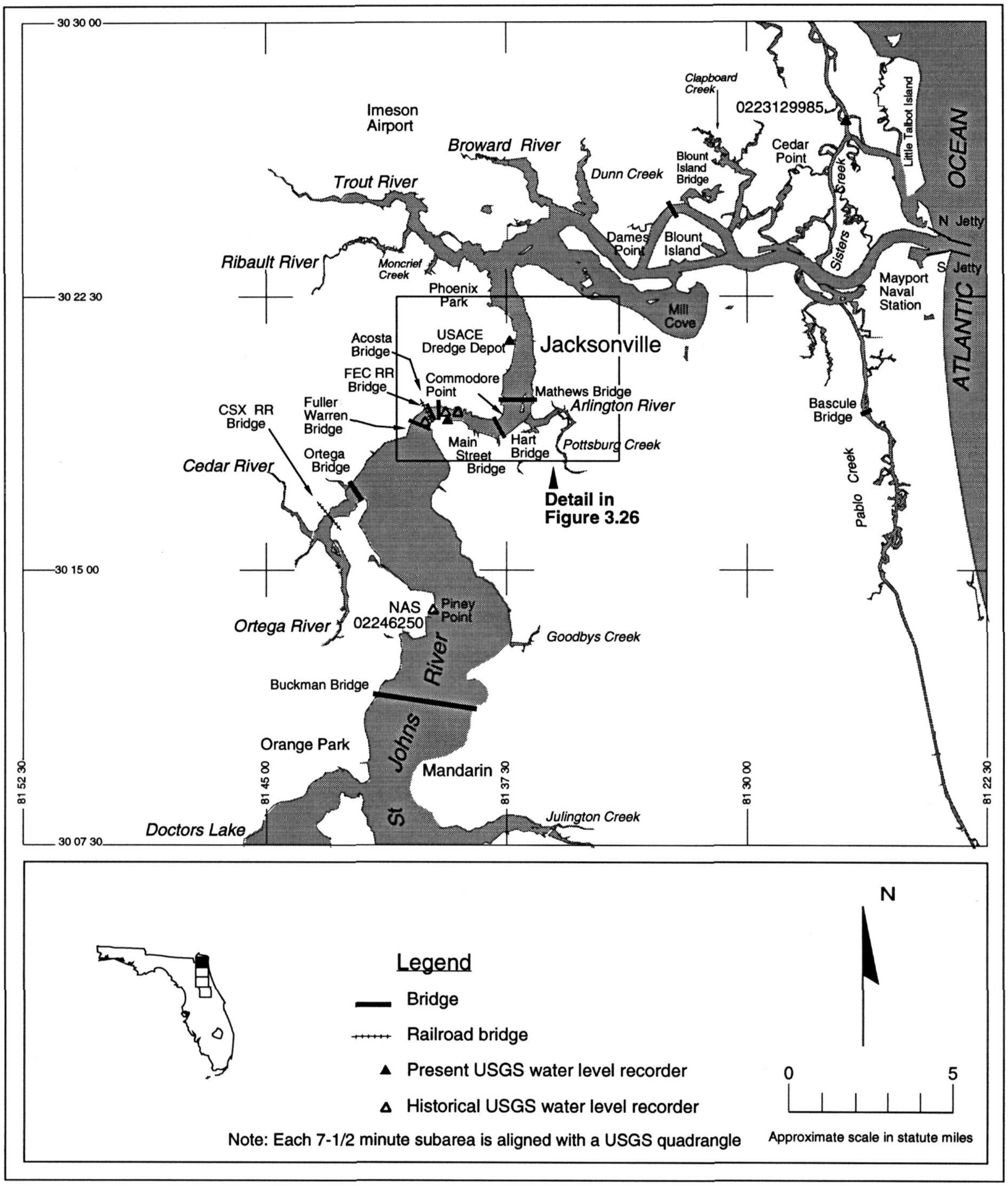


Figure 3.25a Locations of stations used for flow calculations between the mouth of the St. Johns River and Julington Creek

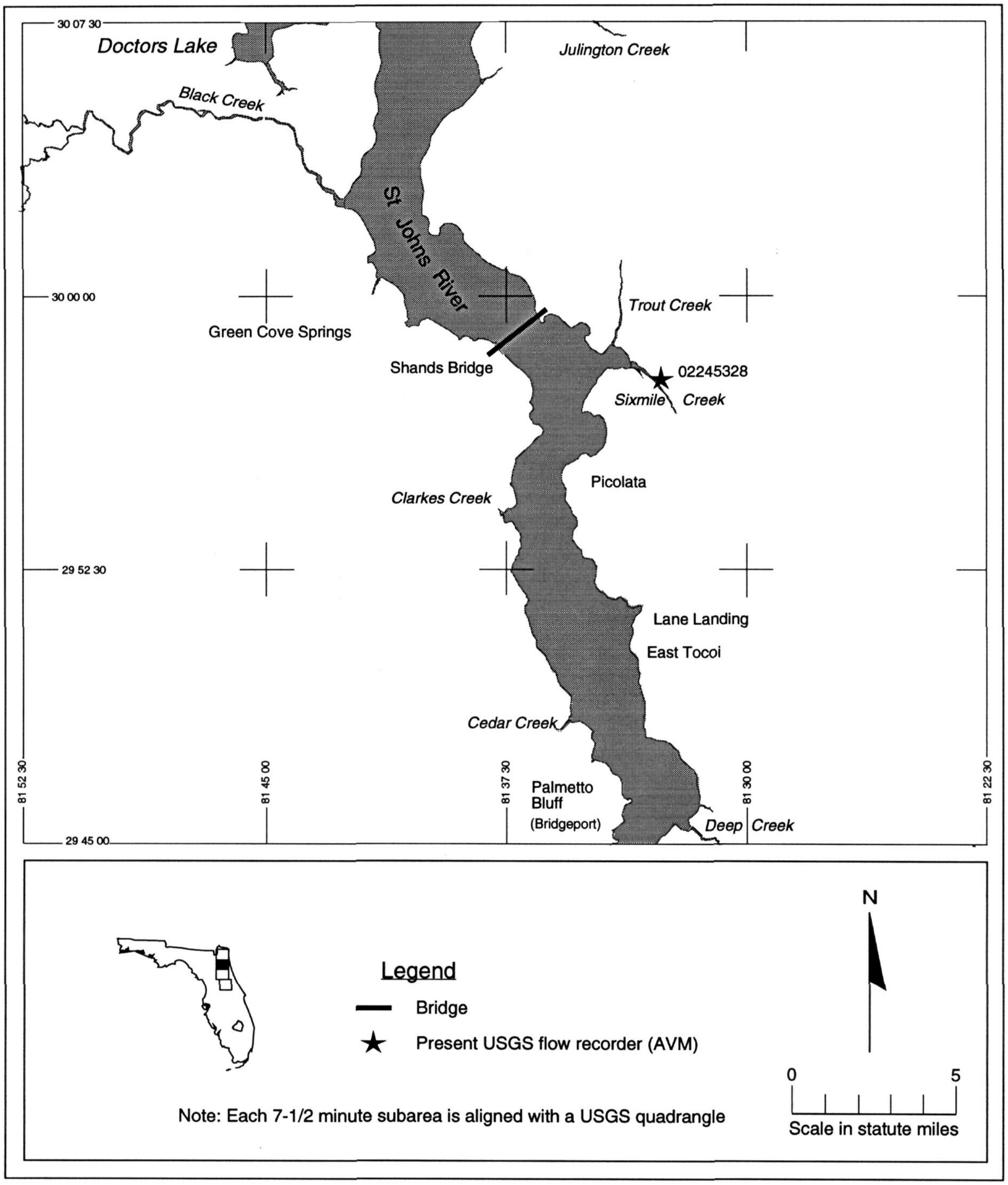


Figure 3.25b Locations of stations used for flow calculations between Julington Creek and Deep Creek

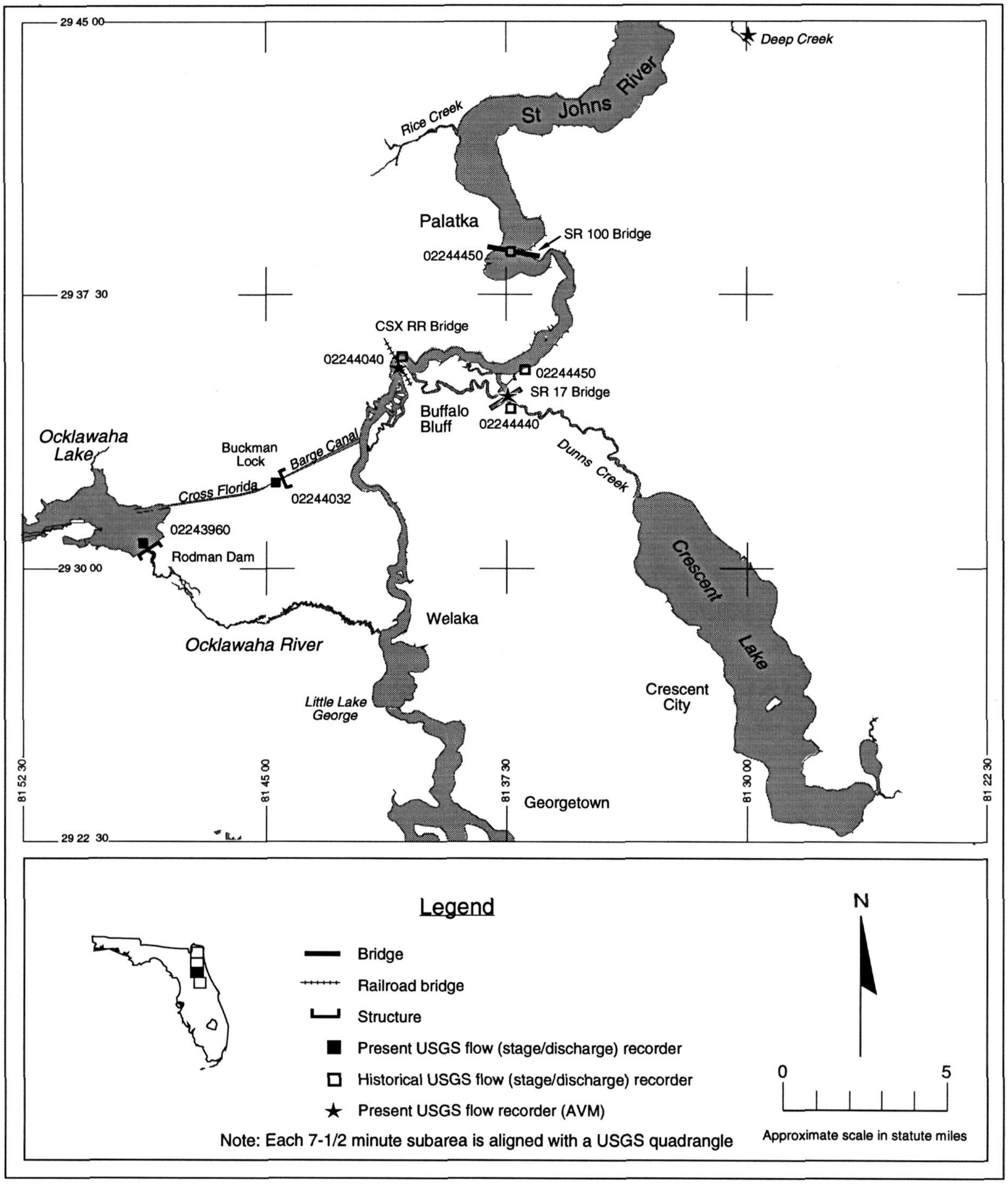


Figure 3.25c Locations of stations used for flow calculations between a location north of Rice Creek and Georgetown

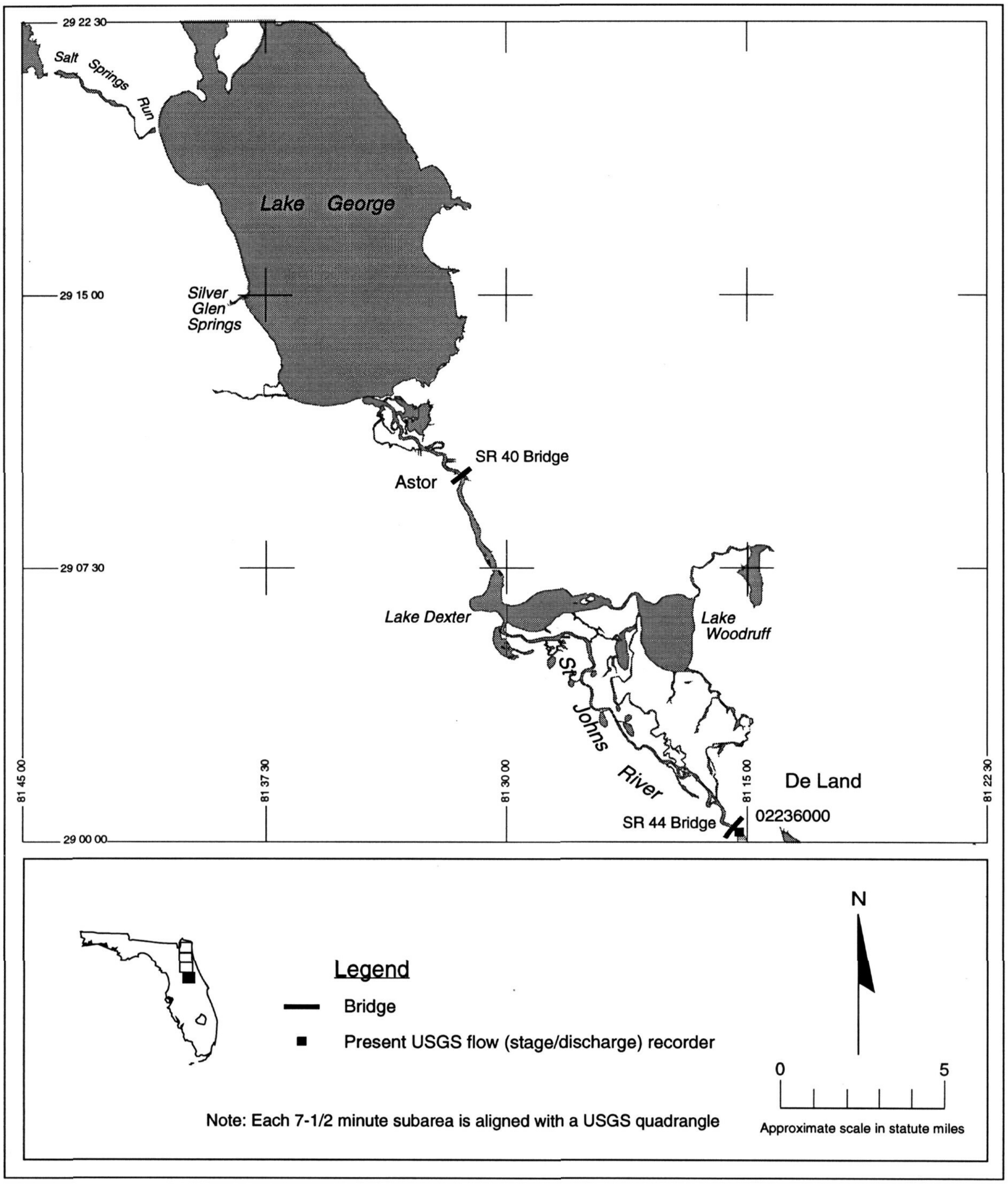


Figure 3.25d Locations of stations used for flow calculations from Lake George to De Land

The stations that have been established, either on the main stem or on tributaries close to the confluence with the Ocklawaha River, are described in Table 3.21. The three tributary stations are included because their data were used to calculate the summation of flow at the upstream end of the LSJRB (see "Flow at the Upstream Boundary of the Basin" in this chapter).

Flow Measurements at De Land. Until the USGS station at Buffalo Bluff was established, the farthest downstream, long-term station above Jacksonville was the USGS gaging station on the main stem near De Land. Published data are available for De Land from October 1933 to September 1994. As of September 1994, the mean annual flow at this site was 3,028 cfs over 61 years of record (USGS 1994). The extremes of stage were −0.59 ft (April) and 6.06 ft (October), and the extremes of flow were 3,030 cfs upstream (August) and 17,100 cfs downstream (October) (USGS 1994, 60).

Flow Measurements at Rodman Dam and Buckman Lock (tributaries). Flow gages began operation at Rodman Dam in January 1969 and at Buckman Lock in January 1970. Discharges from these structures are controlled and have been relatively small and intermittent. Means and extremes of these discharges are tabulated in Appendix E.

Flow Measurements at Dunns Creek (tributary). Data for Dunns Creek are intermittently available from January 1978 to September 1986, when the stage/discharge gage and electromagnetic current meter were removed following significant data losses. In April 1989, an AVM was installed on the downstream side of the west pier of the U.S. 17 bridge; the meter was calibrated in 1992–93. Updates of some missing flow data for October 1990 through September 1993 were published in WY 1993 surface water report by USGS. During this period, the meter was modified to an AVM.

Flow Measurements at Buffalo Bluff. USGS installed a stage/discharge recorder on a dock on the north bank downstream of the Seaboard Coast Line Railroad (CSX RR) bridge at Buffalo Bluff and operated it from September 1943 to July 1948. In October 1989,

Table 3.21 Periods of record for reliable data and locations of stations used in calculations of mainstem flows

Station and USGS ID Number	Published Period of Record	Reporting Interval	Gage Type	Location Description
De Land USGS 02236000	Oct 1933–Feb 1934	Month	Non-recording stage recorder	Near site of former Crows Bluff Bridge, about 1,000 feet downstream
	Feb 1934–May 1936	Day	Stage/discharge	(same as 1933–34)
	Jun 1936–Jul 1970	Day	Stage/discharge	0.4 miles downstream of above station
	Jul 1970–Sep 1994	Day	Stage/discharge	Near west bank, downstream of Whitehead Bridge at State Road 44, 5 miles west of De Land
Rodman Dam USGS 02243960	Jan 1969–Sep 1994	Day	Stage/discharge	Upstream of structure
Buckman Lock USGS 02244032	Jan 1970–Sep 1994	Day	Stage/discharge	Upstream and downstream of structure
Buffalo Bluff USGS 02244040	Oct 1993–Sep 1994*	15 minutes	AVM	300 feet upstream of CSX RR bridge
Dunns Creek USGS 02244440	Jan 1978–Sep 1986*	Day	Stage/discharge ECM	Under U.S. 17 bridge, downstream side, on west pier
	Oct 1986–Apr 1989[†]	Day	Stage/discharge	
	Oct 1990–Sep 1994*	15 minutes	AVM	
Palatka USGS 02244450	Jan 1968–Feb 1976	Day	Stage/discharge and deflection meter	Under U.S. 100 bridge, near center span
	Jul 1976–Sep 1979	Day	Stage/discharge and deflection meter; velocity meter	6 miles upstream of U.S. 17 bridge, near east bank at Edgewater Light 13, 1.4 miles downstream from Dunns Creek
	Oct 1980–Sep 1982	Day	Stage/discharge and velocity meter	(same as 1976–79)

Table 3.21—*Continued*

Station and USGS ID Number	Published Period of Record	Reporting Interval	Gage Type	Location Description
Jacksonville, vicinity of Main Street Bridge—USGS 02246500				
(a) Florida East Coast RR bridge	Dec 1970–Oct 1986 Jan 1979–Sep 1986	Day	Stage Stage and deflection meter	Near center of RR bridge, 0.3 miles upstream of Main Street Bridge
(b) Main Street Bridge pier	Feb 1954–Apr 1966	Day	Stage recorder	Downstream side on pier, near east bank
(c) Main Street Bridge, downstream side	Oct 1986–Sep 1994	Day	Stage recorder	Downstream side, on walkway, near east bank of river, for use in the BRANCH model
(d) Fireboat dock	Apr 1966–Sep 1970	Day	Stage recorder	Southeast corner of dock, on west bank of river, 0.3 miles downstream of Main Street Bridge
(e) Jacksonville USGS 02246530 USACE dredge depot	Oct 1972–Jun 1973 Jul 1984–Sep 1994 Jul 1984–Sep 1986	Day	Stage recorder Stage recorder, then moved to Main Street Bridge	USACE dock (dredge depot), west bank, 1.2 miles downstream of Deer Creek, 5.1 miles downstream of Main Street Bridge, for use in the BRANCH model

Note: CSX RR = Seaboard Coast Line Railroad
AVM = acoustic velocity meter (with rating measurements)
ECM = electromagnetic current meter

*Data are not available for all months in some of these intervals. See table in Appendix E for actual months in which data are available.
†Data collected during this period were determined to be poor and not adequate for publishing.

Source: USGS 1966, 1987, 1990

a stage recorder with shaft encoder was installed on a bridge pier on the south side of the "draw" section under the CSX RR bridge, but this station did not produce reliable data either. All of these attempts to measure flow at this site were not successful because a rating could not be developed. In the early 1990s, an AVM was installed 300 ft upstream of the bridge at RM 91.5. USGS conducted tests and modifications on this gage for several years, but reliable data from this station were not published until WY 1994.

Flow Measurements at Palatka. Palatka area data are available from January 1968 to September 1982 except for WY 1980. A stage/ discharge gage and a deflection meter were installed near the center span under the U.S. 17 bridge at Palatka in 1967. In February 1976, the stage recorder was moved 6 mi upstream to a location near the south bank at Edgewater Light 13, 1.4 mi downstream of Dunns Creek, and data are available from this site beginning in July 1976. By October 1980, a velocity meter had been installed. However, the data collected at both of these locations were rated poor, and the upriver site was discontinued in September 1982.

Flow Measurements at Jacksonville. One location at which measurements for calculating discharges may be collected is Main Street Bridge in downtown Jacksonville (Figure 3.26). In this part of the river, some of the narrowest and deepest parts of the river are found. However, stage and velocity measurements have proven to be very difficult to translate into flows, particularly at this location. In the 1980s, one of the more promising approaches appeared to be the use of stage measurements in conjunction with the BRANCH computer model. The BRANCH, or inference, model is a branched-network, unsteady, numerical flow model that computes flow from differences in water level at locations separated by several miles of the river (Schaffranek et al. 1981). In 1993, the Doppler current system appeared to be the best method for future calculations of the distribution of flow over a cross section. When positioned by a boat at successive locations on a transect across the river, this system produces successive vertical profiles of velocity and vertically integrated flow at each measurement location, as well as an integrated value of flow across the entire cross section. With the Doppler system, an entire cross section can be completed in a relatively short period of time, overcoming some of the difficulties of boat measurements associated with tidal flows in the past.

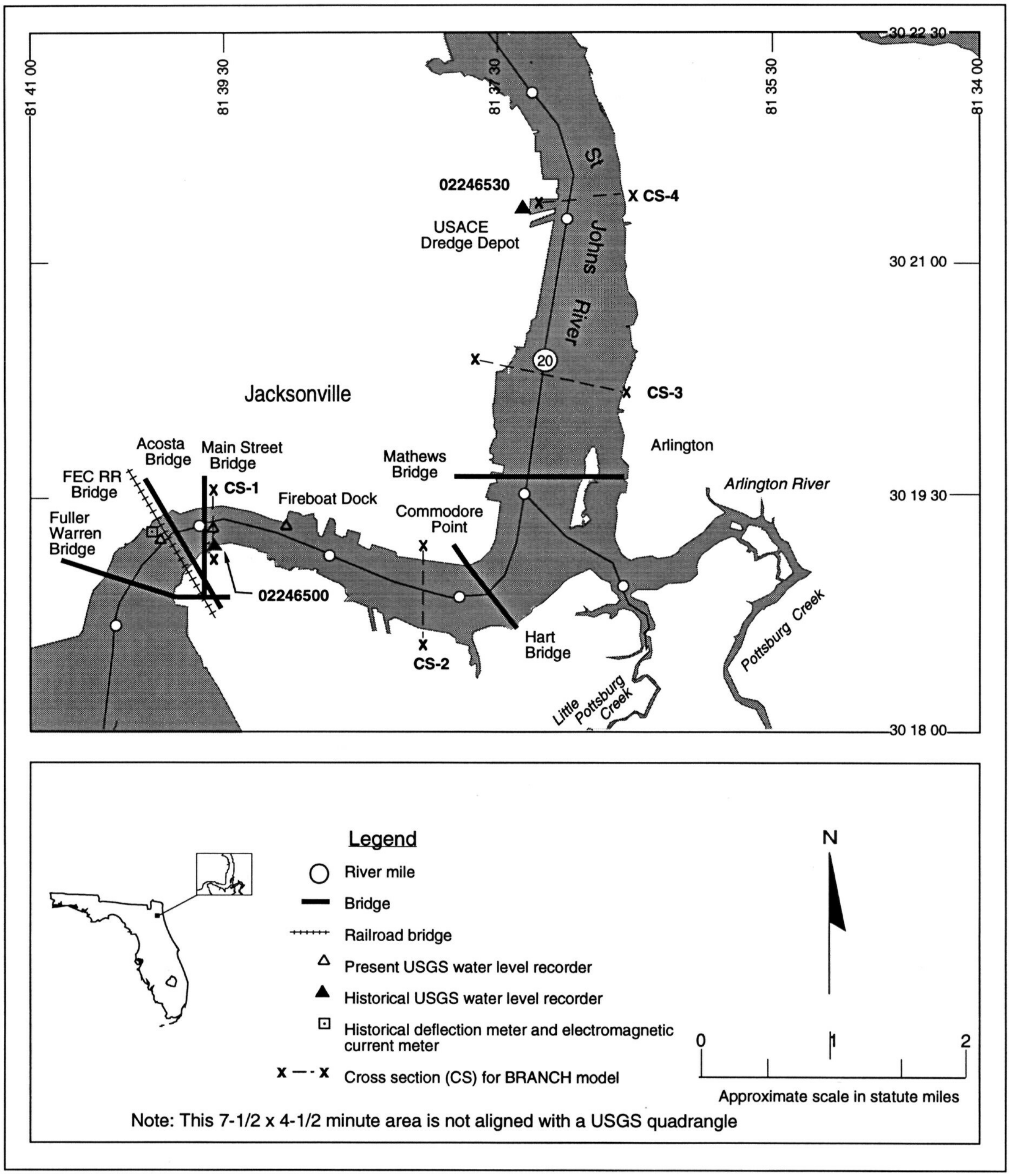


Figure 3.26 Detailed map of locations of gages installed in the vicinity of Main Street Bridge for measurements related to the calculation of flow

The first stage recorder established by USGS was on a downstream pier of Main Street Bridge, near the south bank of the river, in February 1954. In April 1966, the recorder was moved 0.3 mi downstream to the fireboat dock on the west bank. Until September 1970, total ebb and flood volumes were estimated from the data taken from these gages and auxiliary gages at Jacksonville NAS and the USACE dock (dredge depot). Initially, the lobe-area method of flow calculation was used, but this method was abandoned in 1970 because it could provide only net half-tidal flows, not hourly flows, and because it was relatively inaccurate (Hampson 1989, 31). The stage recorder was moved again in December 1970, this time to the FEC RR bridge.

A mechanical vane (deflection) meter was installed approximately at the center span on the west side of the FEC RR bridge, from which data were reported along with stage, beginning in October 1971. Vane response was rated to mean cross-sectional velocity measured at Main Street Bridge, but by 1974 it was apparent that the calculated discharges were underestimates of actual flow. An electromagnetic velocity probe was installed in January 1979, but flow was also underestimated by this device (Hampson 1989, 31). Data collection was discontinued at this location in September 1986.

In October 1972, a stage recorder was installed on the west side of the river at the USACE dredge depot to collect input data for the BRANCH model. The water level recorder located at the NAS crash boat dock, 7.9 mi upstream of Main Street Bridge, provided the other stage data for operation of the BRANCH model.

In January 1979, an electromagnetic two-axis velocity meter was installed near the deflection meter—and operated simultaneously with it—on the FEC RR bridge. Data were collected from this meter until September 1986, but no data were produced that could be used for computing discharges.

Partially as a consequence of the lack of success in calculating discharges from velocity data, an auxiliary stage recorder was installed at the USACE dredge depot in July 1984 for use with the inference model. In 1985, using the BRANCH model, USGS began to calculate discharges over the reach from Main Street Bridge to the dredge depot. The stage recorder was moved from the FEC RR bridge to a location slightly inland of the shoreline at the base of the southeast corner of Main Street Bridge in October 1986. Data have been collected from this location from October 15, 1986, to September 1994. The two cross sections in the center of the reach—about one-third mile west of Hart Bridge (CS-2) and one-half mile north of Mathews Bridge (CS-3)—were used only to represent cross sections in the BRANCH model and did not have stage recorders installed (Figure 3.26).

From October 1986 to September 1994, the only instrument installed at Main Street Bridge was a stage recorder. On November 3 and 4, 1986, the first actual discharge measurements in the LSJR were recorded, using the moving-boat method, about 100 ft downstream of Main Street Bridge (Hampson 1989, 33). In conjunction with these measurements, vertical current profiles were taken with a Neil Brown directional AVM at the mid-channel section of Main Street Bridge. Preliminary results showed that discharges computed from the electromagnetic velocity recordings were slightly shifted, temporally, relative to the results of the BRANCH model. Also, the flows from the electromagnetic probe underestimated ebb flow volume and overestimated flood flow volume relative to the BRANCH model results (Hampson 1989, 31, 33).

The published flow data for Main Street Bridge cover three separate periods: October 1971 through September 1974, October 1980 through September 1981, and July 1987 through September 1992. All of these data are considered of poor quality. Due to equipment failure, Jacksonville daily flows are not reportable from October 1974 through June 1987, except for the WY October 1980 through September 1981. Daily flows were again reported from July 1987 through October 29, 1988; December 7, 1988, through December 18, 1989; and January 25 through September 30, 1990. Inconsistencies between the various methods were apparently resolved with the publication of daily flows for WY 1991 in the USGS 1992 data report. However, as of 1994, these data were still rated "poor" by USGS.

1994 Flow Gaging Network. Supplementing the flow into the LSJR at De Land, major flows enter downstream of De Land from springs, the Ocklawaha River (downstream of Rodman Dam), the Cross Florida Barge Canal (downstream of Buckman Lock), Dunns Creek (Crescent Lake), and various smaller tributaries (Figure 3.27). As of 1994, only the stage/discharge recorder at De Land, the AVM at Buffalo Bluff, and stage recorders for inference modeling in the vicinity of Main Street Bridge were being maintained on the main stem.

HISTORICAL CALCULATIONS OF FLOW

Measurements of velocity at a station can be integrated to calculate total instantaneous discharge, which includes tidal flow, freshwater discharge, wind effects, and other non-tidal components. Instantaneous discharges can be summed separately over the periods of flood and ebb to obtain the total volumes of flow upstream and downstream over each half tidal cycle. If there were no net freshwater inflow or outflow, the volume of tidal flow would be the difference between the upstream and downstream volumes. If the freshwater inflow exceeds evapotranspiration, the downstream flow should increase and the upstream flow should decrease due to increasing net non-tidal downstream flow. Thus, some investigators have expected that a relationship exists in the LSJR between net flow and tidal flow.

USGS summarized the monthly mean total flows at Jacksonville, calculated from data collected between March 1954 and September 1966 (Anderson and Goolsby 1973). The graphs depicted in Figure 3.28 illustrate the analyses.

The upper plot (graph A) shows the monthly means of the total flow volume upstream (the composite of both tidal and non-tidal influences) and the same downstream, in million cubic feet. On graph A, consecutive months with net upstream flows are indicated by a filled-in area on the two lines, where the lower line crosses and lies above the upper line, while consecutive months with consecutive net downstream flow are not filled in. The second plot, graph B, shows the monthly averages of the monthly mean upstream and

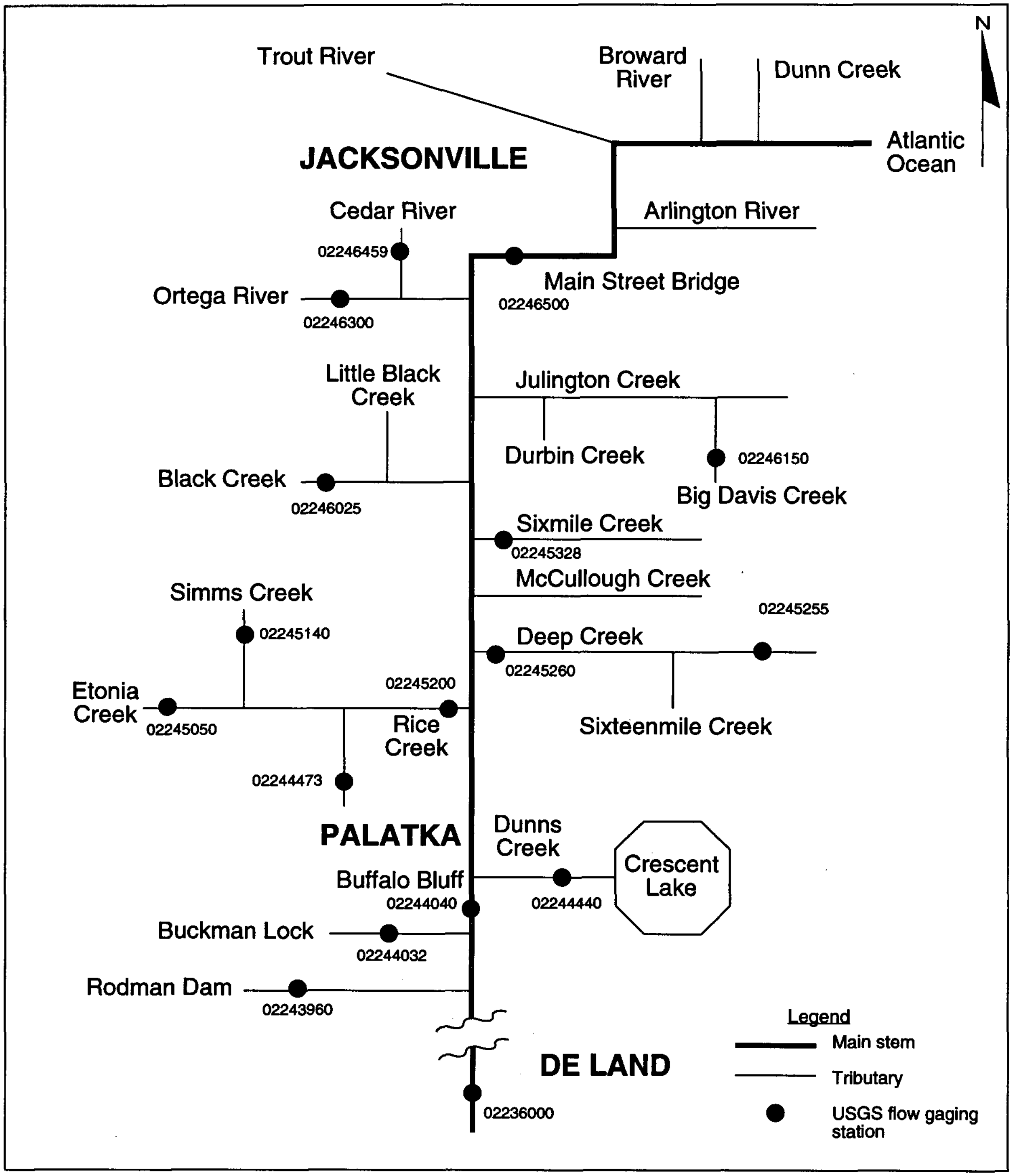


Figure 3.27 Relative locations of major tributaries and flow gaging stations in the flow gaging network of the St. Johns River

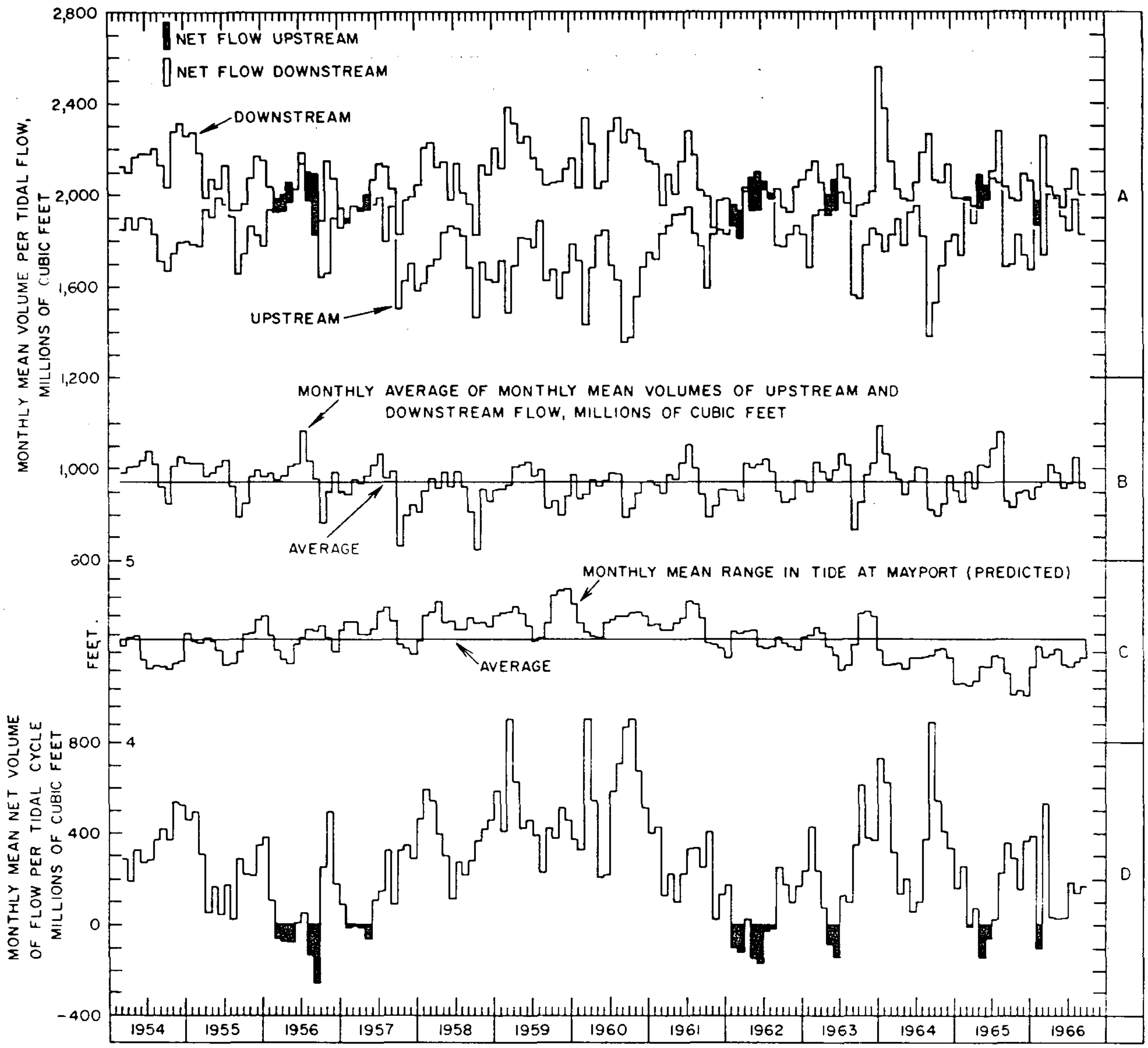


Figure 3.28 **Hydrographs of monthly mean flow volumes, average monthly mean flow volumes, and net volumes at Jacksonville and the predicted tidal range at Mayport** (Anderson and Goolsby 1973, 23, Figure 12)

downstream flow volumes in the first graph, which represents the tidal part of the flow because non-tidal effects tend to cancel over a full tidal cycle. The lower graph, D, summarizes the monthly mean net volume of flow (the averages of the differences in the monthly mean volume of upstream flow and the monthly mean volume of downstream flow) at Jacksonville, which represents the net non-tidal flow because the effects of the tide are approximately canceled. The months with net upstream flow on graph D (negative values of flow) are filled in with solid black (Anderson and Goolsby 1973, 23–24). Graph C shows the corresponding monthly mean predicted tidal range at Mayport. This analysis had not been updated in the literature as of 1994.

Historical Discharge Estimates

Freshwater inflow to the river is the sum of direct runoff from the land (both point and nonpoint), inflows from springs and other ground water sources, and direct rainfall. Freshwater outflows from the river are due principally to evapotranspiration (Anderson and Goolsby 1973, 15), but other outflows include some of the fresh water that is mixed with ebb tide and, although not mentioned in any of the reviewed reports, occasional seepage to the surficial aquifer when the level of the ground water table is lower than river level.

If the sum of freshwater inflow and rain is less than the evapotranspiration plus or minus the change in storage in a month, the average net flow per tidal cycle will be upstream (Anderson and Goolsby 1973, 24).

The average non-tidal flow at the river mouth for data from March 1954 to September 1966 was 5,883 cfs (Anderson and Goolsby 1973, 22, Table 1). The long-term range has been reported elsewhere as 6,000 to 8,300 cfs (attributed to USGS, quoted in RSH 1974, 5).

Recent USGS Total Flow Data

Each year, USGS publishes the daily values of flow at stations on the main stem and in major tributaries in the Water Resources Data reports (USGS, various years). These values are calculated from hourly or more frequent samples. The first published analysis of flow data in the LSJR is the USGS summary of the monthly means and extremes of net discharge at Jacksonville from data collected between March 1954 and September 1966 at Main Street Bridge. A summary of the published extremes of USGS-calculated flow, for data to September 1994, is given in Table 3.22.

Table 3.22 Published extremes of USGS-calculated daily values in some tributaries and the main stem

Station Location and Period of Record	Maximum Daily Discharge		Minimum Daily Discharge	
	Date	cfs	Date	cfs*
De Land, WYs 1934–94	10/15/53	17,100	08/23/57	-3,030
Rodman Dam, WYs 1969–94	02/05/70	9,560	03/09/69	(unknown leakage)
Buckman Lock, WYs 1970–94	05/09/92	202	(no flow for many days)	
Buffalo Bluff, WY 1993–94	03/13/93	14,200	03/19/93	-14,900
Dunns Creek, WYs 1978–94**	02/19/83	6,650	03/19/93	-6,400
Palatka, WYs 1968–82**	11/05/70	31,300	06/06/68	-20,400
Jacksonville WYs 1954–70†	09/10/64	61,137	09/09/64	-51,064
WYs 1972–94**	06/20/72	64,000	10/20/72	-62,700

*Negative values indicate upstream flows.
**Refers to periods in which there are missing data
†Older daily values are no longer available on the USGS data base; daily values for Jacksonville begin in 1972.

Data are made available from USGS in Water Year@ groups. Data in Appendix E are arranged by calendar year for the convenience of the user. Periods of record in this table are in Water Years to delineate availability from USGS.

Note: cfs = cubic feet per second
WY = Water Year (@October through September)

Data from Appendix E for all stations except the Buffalo Bluff station. Data for this station came from USGS WY 1993–94.

The daily flows are the means of the hourly samples. Although the daily flow may be considered to be indicative of the net flow for the day, the daily flow calculations are not very accurate because they do not attempt to resolve ebb and flood volumes and are not synchronized with the beginnings and ends of tidal cycles. The hourly data from Palatka and Jacksonville are not available for analysis because USGS considers the data to be of poor quality.

DRAINAGE AREAS

In a 1976 report, the drainage area above De Land was given as 3,120 mi^2, the "topographic drainage area" (assumed to be above Jacksonville) was given as 9,430 mi^2, and the tabulated drainage area at Jacksonville was given as 9,040 mi^2 (Atlantis Scientific 1976, II-1–2). USGS estimated the drainage area of the St. Johns River at Jacksonville to be 8,104 mi^2 (excluding the drainage area of Paynes Prairie, 650 mi^2, because this area does not contribute to the basin discharge) (USGS 1990, 140). An estimate of the drainage area at the upstream boundary of the LSJRB has not been found in the literature. However, it is reasonable to substitute an estimate of 6,580 mi^2 for the drainage area above Buffalo Bluff, just a few miles downstream of the upstream boundary of the LSJRB (Scott Gain, pers. com., USGS 1993).

DISCHARGE/DRAINAGE AREA RELATIONSHIP

Historical Relationship of Drainage Area to Freshwater Inflow

A method that has often been used to estimate total flows in the St. Johns River uses a comparison of the mean total flow at each gaging station to its contributing drainage area, for each major tributary on the river. Such a comparison yields a discharge-to-drainage area relationship (or runoff rate) that increases, irregularly, from upstream to downstream because rainfall and runoff are not uniform from one basin to the next. However, as would be expected, the runoff rate increases toward the mouth of the river. Total flow at the mouth of the river may be estimated from the slope of a straight regression line through the discharge-to-drainage area relationship.

The first published calculation of total discharge in the LSJR from a discharge-to-drainage basin area relationship was by USGS (Snell and Anderson 1970, 37 Figure 18). Runoff rates calculated for this relationship varied from 0.93 cfs/mi^2 between Melbourne and Sanford to 1.5 cfs/mi^2 near the headwaters south of Melbourne. Using an (assumed weighted) average of the runoff rates, Snell and Anderson extrapolated this discharge-to-drainage relationship and estimated the average discharge at Jacksonville to be about 8,300 cfs.

Connell Associates tabulated 20-day mean net flows (from data for July 1–20, 1970), using 2,681 cfs at De Land. They calculated runoff rates varying from 0.52 cfs/mi^2 at Rice Creek to 1.37 cfs/mi^2 at Jacksonville (1974, 4-54, Table 4-5). Recognizing that this runoff rate for Jacksonville was high, they used an estimated increase in flow from Palatka to Jacksonville of 0.98 cfs/mi^2 (the average of the values for Palatka and Black Creek), linearly extrapolated the relationship to Jacksonville, and calculated a net flow at Jacksonville of 7,200 cfs (pp. 4-51, 4-53).

The work of Snell and Anderson was modified by Reynolds, Smith and Hills (RSH) using a mean annual discharge of 3,200 cfs at De Land and an overestimate (according to RSH) of flow between Palatka and Jacksonville of 7,900 cfs attributed to Anderson. RSH determined the average stream yield, or runoff, for the St. Johns River basins to be in the range of 0.175 to 1.53 cfs/mi^2, based on updated data (RSH 1974, 17, Exhibit 6).

SJRWMD recalculated the total discharge of the river for the WRMP (1977). A mean annual discharge of about 3,000 cfs at De Land and the drainage areas given by RSH were used to develop a modified discharge per unit drainage area of 1.08 cfs/mi^2. This relationship was plotted for Melbourne, Cocoa, a location near Christmas, a location near De Land, Palatka, and Jacksonville. When extrapolated to the Atlantic Ocean, the average annual non-tidal discharge of the river exceeded 10,000 cfs (pp. D-24 and D-26, Figure D-8).

Revised Relationship of Discharge-to-Drainage Area

The relationship of drainage area to mean discharge approaches linearity if the drainage characteristics of the basins used for developing the relationship are similar. The regression line through the points spatially averages all of the discharge/drainage relationships in the basin, and the extrapolation of this line to the mouth of the river provides an estimate of the total freshwater flow in the river, as shown in the examples above. A new discharge/drainage area relationship is developed for this report using recent USGS flow data in the main stem and all gaged primary tributaries (Figure 3.29). The discharge areas for Rodman Dam,

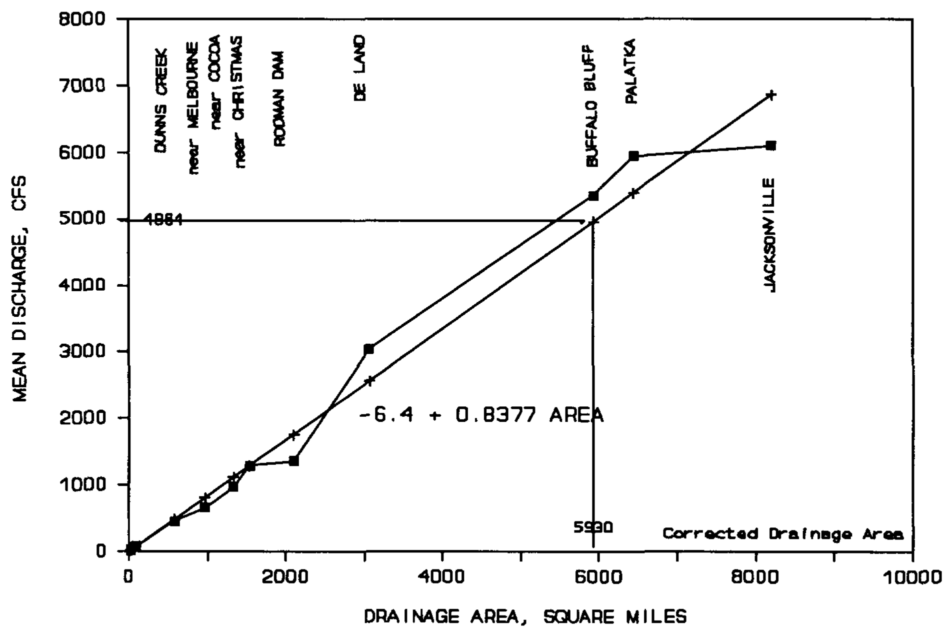


Figure 3.29 Discharge-to-drainage area relationship for flows in the Lower St. Johns River Basin

Palatka, and Jacksonville are decreased by the area of Paynes Prairie (650 mi^2) (Table E1, Appendix E). The 1994 mean gaged flow at Buffalo Bluff was 5,360 cfs (S. Gain, USGS, pers. com. April 24, 1995).

Flows at Astor and Lake Monroe are not published. The expression for the regression line in Figure 3.29 is

$$\textit{Mean flow} = -6.4 + 0.8377 \times \textit{upstream drainage area} \tag{2}$$

The mean discharge of the river at its mouth, for an estimated upstream drainage area of 8,200 mi^2, obtained from the extrapolation of the regression, is 6,863 cfs. The mean discharge of the river at Buffalo Bluff, obtained from the intersection of a corrected drainage area of 5,930 mi^2, is 4,961 cfs.

FLOW AT THE UPSTREAM BOUNDARY OF THE BASIN

An approximation to the total flow into the main stem at the upstream limit of the LSJRB has been derived for this report by summing the monthly total flows at De Land, Rodman Dam, Buckman Lock, and Dunns Creek. The summation, which may be called the partial flow at the upstream boundary of the LSJRB, includes available data from WYs 1969 through 1992, including intervals of missing data at Dunns Creek and Buckman Lock. The missing values result in some inconsistencies from one year to another during this period of record. Monthly mean, minimum, and maximum values of this combined flow, representing the runoff from the ungaged drainage area downstream of De Land, are listed in Appendix E. The mean value of the ungaged flow is 1,163 cfs.

The mean of the calculated monthly mean flows at the upstream boundary is 4,165 cfs; the mean of the means of annual flows is 4,144 cfs (Table E13). Thus, a reasonable estimate of the mean flow at the upstream boundary is the average of these two values, or about 4,150 cfs.

These flow estimates should be used with caution. The measured mean total flow at Buffalo Bluff, downstream of the confluence, is 5,360 cfs. The discharge-to-drainage relationship provides a freshwater flow of 4,961 cfs at this location. However, these data represent only 1 year of data collection and thus may not be representative of the long-term mean flow at the upstream boundary of the LSJRB.

FLOW AT JACKSONVILLE VERSUS FLOW AT PALATKA

A comparative study of flow in the river for the Florida Department of Pollution Control noted "the approximate 6,000 cfs increase for flow from Palatka to Jacksonville" (Connell Associates 1974, 4–51). However, a subsequent study of the surface water resources of the river found that "there are sufficient data to indicate a net loss in stream flow from Palatka to Jacksonville" (RSH 1974, 20). This conclusion was based on the annual means and 3- and 4-year average flows for 1969–72, which indicated a difference between the annual flows at the two stations of 1,000 cfs or less.

The WRMP (SJRWMD 1977) summarized USGS flow data at Palatka and Jacksonville through 1975. This report stated that "net downstream flow was greater at Palatka than at Jacksonville," referring to the graph of discharge versus drainage area. This could be a suspect conclusion because it is based on annual means and poor data, or it could be indicative of large losses of water due to evaporation or leakage to the aquifer. The relation between drainage area and average discharge at principal gaging stations was used to extrapolate the average discharge at the mouth, which was estimated by this method to exceed 10,000 cfs (SJRWMD 1977, D-27 and D-24, Figure D-8).

The mean total flow at Palatka exceeds that of Jacksonville during the period from November through March. The uncertainty in flow calculations can only be resolved by more accurate flow measurements at both sites.

In summary, the non-tidal discharge of the river is estimated to increase from 6,000 cfs at De Land to about 8,000 cfs at Jacksonville to over 15,000 cfs at the mouth. The total discharge of the river is an order-of-magnitude greater.

TIDAL FLOW

Measurements of flow provide values of total (instantaneous) flow. The tidal component of the total river flow must be calculated because it is part of the total flow and cannot be measured separately. The non-tidal component, caused by all forces except the tide, including tributary inflows and wind, is the difference between the total flow and the tidal flow.

The first estimate of the relationship of freshwater flow to tidal flow was published in 1976:

> In regard to the influence of fresh-water flow...in the St. Johns River...it should be mentioned that...the fresh-water discharge per second is only 6% of the maximum value of the tidal flow and the total fresh-water discharge during one-half tidal period amounts to about 9.2 percent of the tidal prism (Brun 1960, as referenced in Atlantis Scientific 1976, II-7)

Tidal Wave

In general, the tide acts as a long period wave, which can have the characteristics of a *stationary* wave, a *progressive* wave, or a combination of the two, depending on river geometry and the balance of forces. A progressive wave is characterized by a crest that advances up and down the river; the times of high and low water progress from the mouth to an upstream location and back to the mouth. The maximum or strength of tidal current occurs at the same time as the maximum water level, and slack current occurs at the time of the turn of tide between high and low water in a progressive wave.

In contrast, a stationary, or standing wave, is one in which the water surface oscillates vertically between fixed locations (called nodes) without progression. At the nodes, there is no vertical water motion, but there is maximum horizontal movement. The locations of maximum vertical rise and fall of the water surface are called the antinodes; here, the water theoretically has no horizontal motion and has maximum vertical motion. In a uniform channel, the time of slack water occurs at the times of high and low water, that is, the current has zero velocity when water level reaches a maximum or minimum. Also, the current in a standing wave is maximum when water level reaches its mean value (Haight 1938, 5).

In most tidal rivers, including the St. Johns River, the theoretical progressive and standing wave relationships between tidal water level and current are modified considerably by the non-uniform geometry of the channel. Other forces affect the strength of tidal current about half as much as they affect the water level.

Current measurements taken in the LSJR in 1933 and 1934 were interpreted by Haight to show the existence of a combination of a stationary wave and a progressive wave (1938). Likewise, time relations in the Jacksonville area and between Palatka and Welaka seemed to approximate those of a progressive wave. According to Haight (1938), the time relation in the region about midway between Palatka and Welaka is that of a stationary wave:

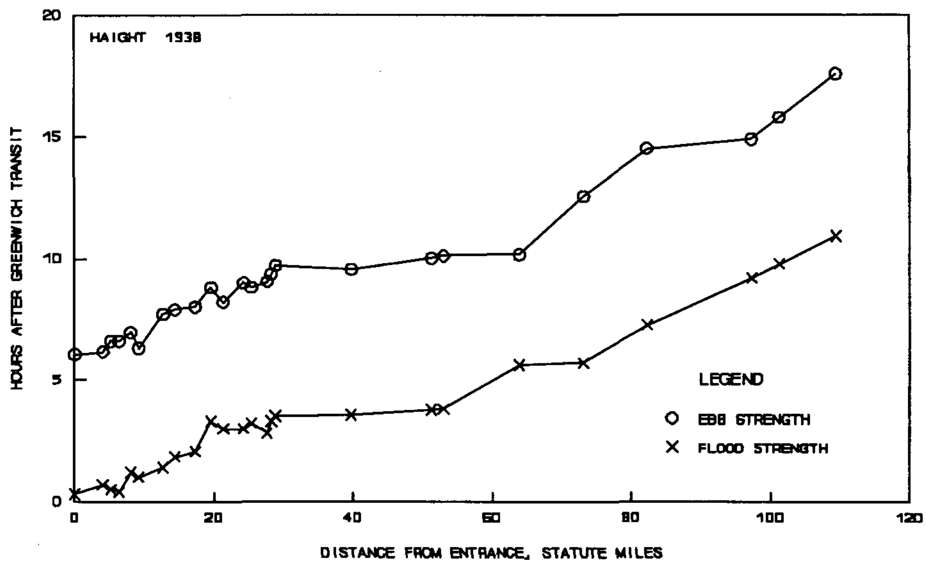
> ...the time relation of current to local tide varies from place to place along the river. In the lower portion ... the strengths of flood and ebb occur near the times of low and high water respectively. Above Jacksonville the current becomes rapidly earlier with respect to the local tide and 50 mi from the sea the strengths of flood and ebb precede the high and low waters by about 3 hours, the slack waters occurring near the times of the highs and lows.
>
> Advancing up the river, the current occurs later and later with respect to the tide and at a distance of 85 mi from the sea the strengths again come at about the times of high and low tide, which is the same relation as exists at Jacksonville (Haight 1938, 24).

This analysis suggested that the tidal wave has progressive characteristics below Jacksonville and above Palatka and stationary characteristics in the reaches between these locations. The variation of tidal range observed by Haight along the river is shown in Figure 3.24; the corresponding observed variations in the times of occurrence of maximum ebb and flood current, high and low water, and slack before ebb and flood are shown in Figure 3.30.

As local water elevation varies over a tidal cycle, the water depth at the crest of the tidal wave is significantly greater than at the trough. Because the velocity of the tidal wave at any location is proportional to the depth of water, the crest moves more quickly and may tend to overtake the trough, resulting in a shorter flood, a longer ebb, and highest velocity currents during the flood. In a long estuary, such as the St. Johns, this relationship may be complicated by mixing of successive tides.

Both the speed and direction of the tidal current in a channel also can vary laterally. In a uniform channel with a rectangular cross section, the velocity is greater near the center of the channel and

A



B

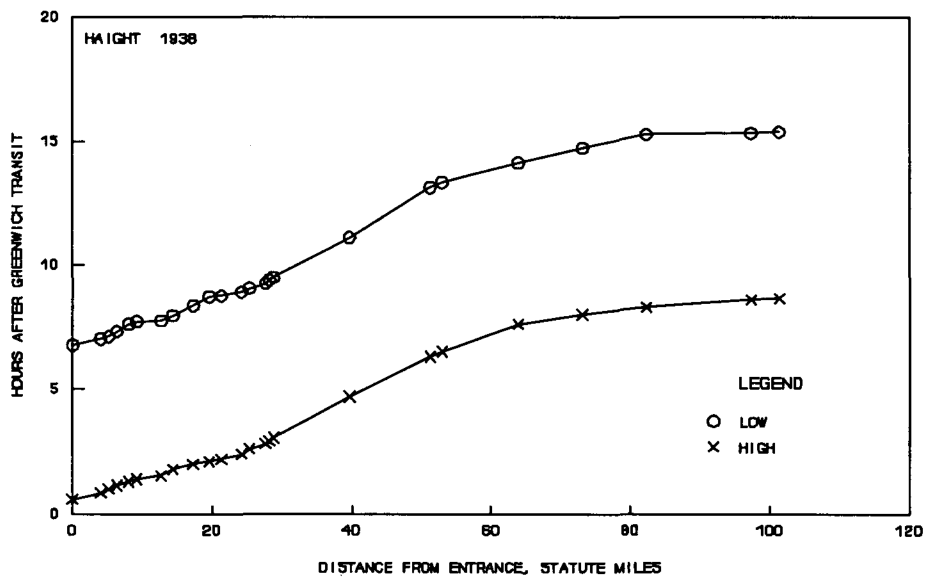


Figure 3.30 Lag of strength of flood and ebb current (*A*), lag of high and low water levels (*B*), and lag of slack before ebb and flood (*C*) (Haight 1938)

C

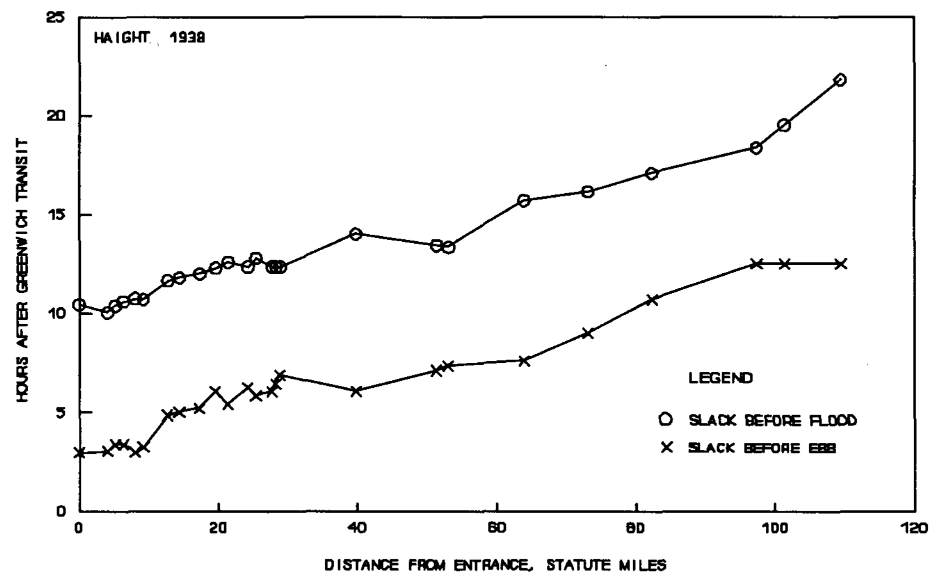


Figure 3.30—***Continued***

decreases towards the banks. In some tidal rivers, the ebb flow may be strongest closer to one bank and the flood strongest nearer the opposite bank.

Flood- and Ebb-Dominance Effect on Flow

Recall that flood dominance is characterized by stronger flood currents and longer falling tide; conversely, ebb-dominated systems have stronger ebb currents and a longer period of rising water. The direction of this asymmetry has significant implications for sediment transport, dispersion of pollutants in the water column, and stability of shorelines (Speer and Aubrey 1985, 208). Speer and Aubrey reference other studies indicating that a shallow estuary will be flood dominated unless it has extensive tidal flats (p. 223). The St. Johns River has deep and narrow channels, as well as some wide shallow areas, and tidal flats near the mouths of tributaries, so the dominance conditions are likely to be complex.

The type of tidal distortion may be quantified by the relative phase of either the astronomic elevation coefficients or the astronomic current coefficients (Speer and Aubrey 1985, 208). The astronomic coefficients are quantified by means of a harmonic analysis of either level or current data, which produces an amplitude and a phase for each component. Although the values of the coefficients are different for sea-surface elevation as compared to current, the designations of the components are the same. As described above, the largest fundamental coefficient is the lunar M_2, and the largest significant overtide is its M_4 harmonic.

An undistorted tide has sea-surface and velocity amplitude ratios, M_4/M_2 (either elevation or velocity), of zero. The larger the amplitude ratio M_4/M_2, the stronger will be the distortion. A flood-dominant tide is characterized by (1) an amplitude ratio M_4/M_2 greater than zero, (2) velocity phase of M_4 between -90 and +90 degrees relative to the velocity phase of M_2, and (3), assuming a linear relationship, a sea-surface phase between 180 and 360 degrees. An ebb-dominant tide has (1) an M_4/M_2 ratio greater than zero, (2) velocity phase of M_4 between 90 and 270 degrees relative to the phase of M_2, and (3), assuming a linear relationship, a sea-surface phase of 180 to 360 degrees (Friedrichs and Aubrey 1988, 522–524).

The sea-surface height and velocity amplitude ratios, both designated M_4/M_2, are defined by the expressions [$sa(M_4)/sa(M_2)$] and [$va(M_4)/va(M_2)$], respectively. The sea-surface phase of M_4 relative to M_2 is designated by the expression "$2M_2$-M_4", which is [2 multiplied by (sea-surface phase of M_2) minus (sea-surface phase of M_4)]. The velocity phase of M_4 relative to M_2 also is designated by the expression "$2M_2$-M_4", which is [2 multiplied by (velocity phase of M_2) minus (velocity phase M_4)].

Results of studies on many estuaries indicate that there will be a net flood sediment transport for a relative elevation phase within 90 degrees of zero and net ebb transport for other values of relative elevation phases (Friedrichs and Aubrey 1988, 525). Water level, flow, intertidal storage, and other relationships can be derived from the harmonic constants at any station for which there are adequate data. With these ratios, the changes in tidal characteristics can be described not only in terms of both depth and flow but also in terms of sediment transport. Numerical models can be effectively used for such analyses (p. 539).

In a study of 26 estuaries on the east coast of the United States, Friedrichs and Aubrey (1988) found that at Fort George (located just north of the St. Johns Inlet), for tidal data up to 1984, the amplitude ratio was 0.032 and the relative phase was 147 degrees, which indicated flood dominance (p. 531). NOS tidal data for Georgetown, Florida, show that the amplitude ratio is 0.114 and the relative phase is 120 degrees, indicating that in this area the river is even more strongly flood dominated.

Tidal Current

Tidal currents are the horizontal movements of water caused by, or associated with, the tide. They are a periodic component of the net or resultant current that is caused by all the other major forces in the estuary, including freshwater inflow and outflow, wind, and differences in temperature and density. Currents in the St. Johns River are normally predominantly tidal. In general, in a restricted channel such as the LSJR, the tidal current reverses direction; it runs in the flood direction for about 6 hr and the ebb direction for about 6 hr, separated by relatively short slack periods.

Harmonic constants for currents between the jetties at the river entrance were calculated by Haight (1938, 30, Table 2). Annual tidal current tables giving predicted times of occurrence of slack water, flood and ebb strength, and the magnitudes of flood and ebb strengths at the St. Johns River entrance are published by NOS (first referenced by Anderson and Goolsby 1973, 10) in the annual tidal current tables (Table D6).

Other Effects on Flow

Wind Component of Flow

As described in the section on water level, wind has the effect of moving water in the direction in which it is blowing. The depth to which this force has effect is dependent on the strength of the wind relative to the magnitude of the prevailing flow. The expected effect of wind is to move water faster if the water movement at various depths is in the same direction as the wind or to move a surface layer opposite to, or at an angle to, the prevailing direction of flow if the wind and water directions are opposed. Vertical variations of flow are complicated by the counterbalancing effects of conservation of mass and momentum throughout the water body.

Wind Effect on Flow in the St. Johns River

Winds have considerable effect on water levels and velocities in the St. Johns River. Occasionally the wind effect is greater than the tide effect. Wind from the north quadrants in the St. Johns River causes upstream flow, and wind from the opposite directions causes downstream flow, at least at the surface. The greatest effects on the river are from winds blowing from the northeast or southwest (Anderson and Goolsby 1973, 15). Strong north and northeast winds can raise the water level about 2 ft at Jacksonville. Wind from opposite directions can lower the water level about 1 ft, thereby increasing the velocity of ebb currents or retarding the flood flow (USACE Jacksonville 1981, B-7).

Tide normally dominates the flow but can be substantially affected by wind, especially sustained winds. Flow can be completely offset or accentuated by strong winds, especially by the powerful winds brought by a hurricane such as Dora, which occurred in September 1964, with "hurricane-force winds of 82 mph from the north" (Frederic R. Harris 1973, IV-5). Winds can indirectly cause salinity to range from relatively fresh (a few parts per thousand [ppt]) to 60% of ocean salinity (22 ppt) (Anderson and Goolsby 1973, 9).

Upstream wind setup in 1974 caused a 7-day low flow of −17,504 cfs at Jacksonville and 7,881 cfs flow at Palatka from March 3–9. This event coincided with the normal antecedent winds that occur in February, which blow from north to northeast at over 10 mph (Atlantis Scientific 1976, II-6).

Coriolis Acceleration

The Coriolis force or acceleration causes moving particles of water to deflect clockwise from the direction of motion in the Northern Hemisphere. The magnitude of the deflection is proportional to the speed of the particle and the latitude of the location. This effect is usually negligible except in wide bays and the open ocean.

In a wide section of a river or bay, the Coriolis acceleration may be large enough to cause lateral flow asymmetries. In the northern hemisphere, looking in the direction of prevailing flow, this effect causes higher velocities to occur on the right and the current to turn first on the left. Observations of this type by Haight (1938) suggested to him the presence of a significant Coriolis acceleration and indicated that a strong lateral salinity gradient might occur frequently (Pyatt 1959, 128; 1964, F44). There is no further discussion of this phenomenon in later literature on the St. Johns River, although Edge (1973) mentions in passing that no Coriolis effect is included in his model "due to the dimensions of the St. Johns River" (p. 4).

SUMMARY OF RIVER FLOW

Of interest to managers is the total flow and the net non-tidal flow, in terms of the effects on movement and mixing and pollutant transport. Locally, flow is caused by differences in water levels, which can be caused by the tide, winds, or inflows and outflows.

Measurements of stage and current velocity provide values for calculations of the total flow. The non-tidal component is difficult to separate from the total flow because the components cannot be directly measured. The non-tidal component has been estimated by assuming that the upstream and downstream tidal flow is the same, calculating the upstream and downstream flow volumes over a half tidal cycle, and subtracting upstream from downstream flow. The non-tidal flow is estimated to be about one-seventh of the total flow.

Wind has a significant effect on local flow in the river, although this effect has not yet been adequately quantified.

Flows have been measured at several locations in the river. The longest record is at De Land. Other locations are Rodman Dam, Buckman Lock, Dunns Creek, Palatka, and Jacksonville. Except for the De Land site, these locations have not produced reliable results.

Flow at the upstream boundary of the LSJRB has been calculated by summing the monthly mean flows at De Land, Rodman Dam, Buckman Lock, and Dunns Creek over the common period of record of the USGS data, WYs 1969–92. The long-term mean of these combined flows is 4,144 cfs. The linear regression of mean discharge/drainage area results in a discharge of 4,961 cfs for a corrected drainage area of 5,930 mi^2 (the drainage area attributed to Buffalo Bluff by USGS).

The average annual non-tidal discharge of the river ranges from about 6,000 cfs at De Land to 15,000 cfs at the river mouth.

FLOW STATISTICS

In this chapter, the statistics of three different components of St. Johns River flow are described: total flow, tidal flow, non-tidal flow, and flow distribution and frequency. Total flow is defined as the sum of tidal and non-tidal flow. Within each of these categories, the mean and range of flow are quantified, to the extent permitted by available data. Where possible, the long-term, annual, seasonal, monthly, and daily flows are summarized.

These statistics were compiled in 1993 for the period of record at each station through WY 1992. For Rodman Dam and Jacksonville, the 1992 data were not available. The period of record for Palatka and Dunns Creek ended in 1982 and 1986, respectively.

TOTAL FLOW

Change in Elevation and Velocity at De Land

The average change in elevation, or fall, from the St. Johns Marsh at the headwaters of the St. Johns River to the river mouth is 0.08 feet per mile (ft/mi) (about 25 ft over 300 mi). The average velocity of the river at State Road 44 (142 mi upstream of the mouth, near De Land) is reported to be 0.3 mph, the lowest at any of the flow measuring sites on the 13 major coastal rivers along the Florida coastline (Heath and Conover 1981, 109–110, Figure 44).

Estimated Total Flow at the Upstream Boundary of the Basin

An estimate of mean total flow at the upper boundary of the LSJRB, based on an assumption of a uniform ratio of long-term mean total flow to discharge area over the upstream basins, is about 5,300 cfs. The method for obtaining this result was described in the previous chapter.

Total Flow over the Period of Record

A recent summary of daily mean flows at Jacksonville, calculated from hourly stage-discharge measurements, provides a mean average discharge of 6,105 cfs over 23 years and a range of daily discharges from 64,000 cfs downstream to 62,700 cfs upstream, as of September 1993 (USGS 1994, 154).

Peak Flows

Peak total flows to 150,000 cfs are common, according to USGS. A maximum total flow of 170,000 cfs was measured at Main Street Bridge between 1954 and 1964 (Anderson and Goolsby 1973, 1 and 14, Figure 7B). Extremes of these magnitudes are not shown, however, in any of the USGS daily data. The maximum of the daily measured maximums at Jacksonville was 64,000 cfs in June 1972.

Extremes of Flow in the Main Stem

The published maximum and minimum flows calculated from stage/velocity measurements at USGS gages during the period of record are summarized in Table 3.23. Flow at De Land is included, even though it is not in the LSJRB, because it is useful for comparisons with flows at other locations. These flows are assumed to be total flows.

Historical Annual Means of Total Flow

Annual total flow for a particular year is the mean of the monthly mean flows for that year. Annual flow is, therefore, close to the mean of the daily flows, although the different lengths of the various months are not weighted in the averaging process. In its 1973 report, USGS designated the flows calculated from stage/discharge measurements as "tidal flows," but by the definition used in that report, it is apparent that these flows are total flows driven by the tides and other forces.

Flow readings have been taken since 1934 at De Land, at intervals during a period of about 13 years at Palatka, and intermittently for

Table 3.23 Minimums, means, and maximums of mean monthly total flows in the main stem from annual summaries over the periods of record, to 1992 (where available)

Station	Number of Years	St. Johns River Monthly Total Flow (cfs)			Month of Occurrence	
		Minimum*	Mean	Maximum	Minimum	Maximum
De Land	67	62	3,016	15,800	May	October
Upstream boundary of the LSJRB	22	870	4,165	12,913	October	October
Palatka	15	-2,092	5,937	20,115	August	October
Jacksonville	9	-10,428	6,952	25,515	May	August

Note: cfs = cubic feet per second
LSJRB = Lower St. Johns River Basin

*Negative values indicate upstream flows.
Flows are derived from USGS daily flows.
Data compiled from Tables E9 and E13–15, Appendix E

about 20 years at Jacksonville. The mean annual flow at De Land held reasonably constant until 1982, when it began to decline. The maximum values of annual flow at that location have decreased since 1960. The mean annual flow at Palatka decreased slightly over the period of measurement (to 1982). The record at Jacksonville is not complete enough for a comparative general analysis.

Tidal Flow/Tidal Range Relationship

A relatively linear relationship between the average volume of upstream and downstream tidal flows at Jacksonville and the range of tide at Mayport for measurements taken between 1955 and 1966 was given in a 1973 USGS report (Anderson and Goolsby 1973, 17, Figure 9). The predicted range of tide at Mayport varied from 2.45 to 6.83 ft, and the corresponding average volume of tidal flow ranged from 1,175 to 2,650 million cubic feet (mcf) (26,279 to 59,268 cfs per tidal cycle [/tc]) from a linear fit to these values and the ratio of average volume of tidal flow (1,941 mcf/tc) to the average range of the tide (4.57 ft), the following relationship may be written:

$$\textit{average volume of tidal flow (mcf/tc)} = \frac{1{,}941\ (mcf/tc)}{4.5\ (ft)} \times \textit{tide range (ft)} \quad (3)$$

Converting units of mcf/tc to cfs/tc:

$$\textit{average volume of tidal flow (cfs/tc)} = 425\left(\frac{mcf/tc}{ft}\right) \times 22.365\left(\frac{cfs/tc}{mcf/tc}\right) \times \textit{tide range (ft)} \quad (4)$$

Because these relationships were developed from annual averages, the relationships are only approximate for tidal cycle calculations.

Flow/Velocity Relationship

The 1973 USGS study developed the following relationships between maximum flow at Main Street Bridge and maximum velocity at the tidal entrance (Anderson and Goolsby 1973, 14, Figure 7B):

$$\textit{upstream flow} = 67 \times \textit{velocity} \pm 50 \times 1{,}000\ \textit{cfs} \quad (5)$$

$$\textit{downstream flow} = 59 \times \textit{velocity} \pm 35 \times 1{,}000\ \textit{cfs} \quad (6)$$

Derived Annual Total Flow

When enough data are available for an individual station, it is appropriate to compare annual means and the extreme values and to expect that the data are at least somewhat representative of current conditions at the site. All of the mean daily flows monitored in the reaches of the St. Johns River at or above Dunns Creek (De Land, Rodman Dam, and Buckman Lock stations) have at least 10 years of data which are available from USGS.

The annual mean, minimum, and maximum total (monthly) flows at De Land, the upstream boundary of the LSJR, Palatka, and Jacksonville are plotted in Figure 3.31.

A

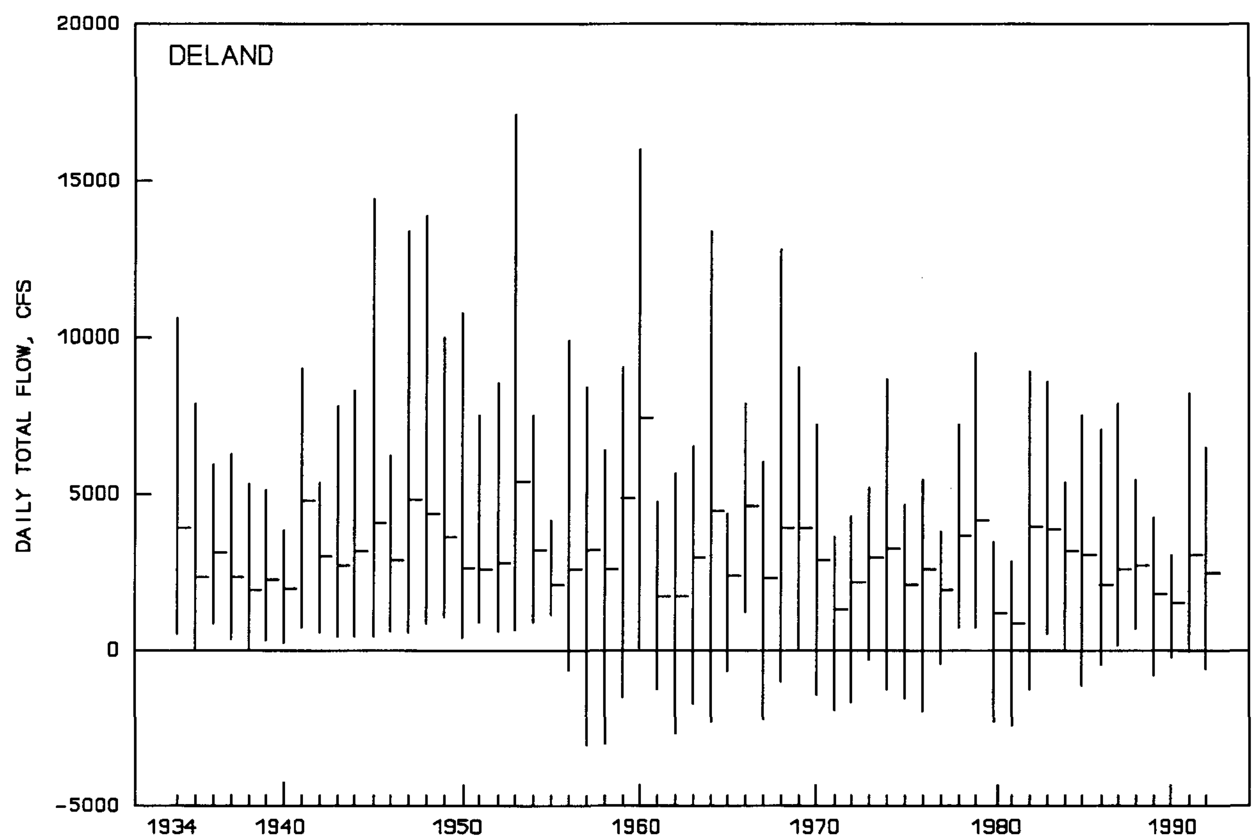


Figure 3.31 Annual mean and range of monthly flows at De Land (*A*), the upstream boundary of the Lower St. Johns River Basin (*B*), Palatka (*C*), and Jacksonville (*D*)

B

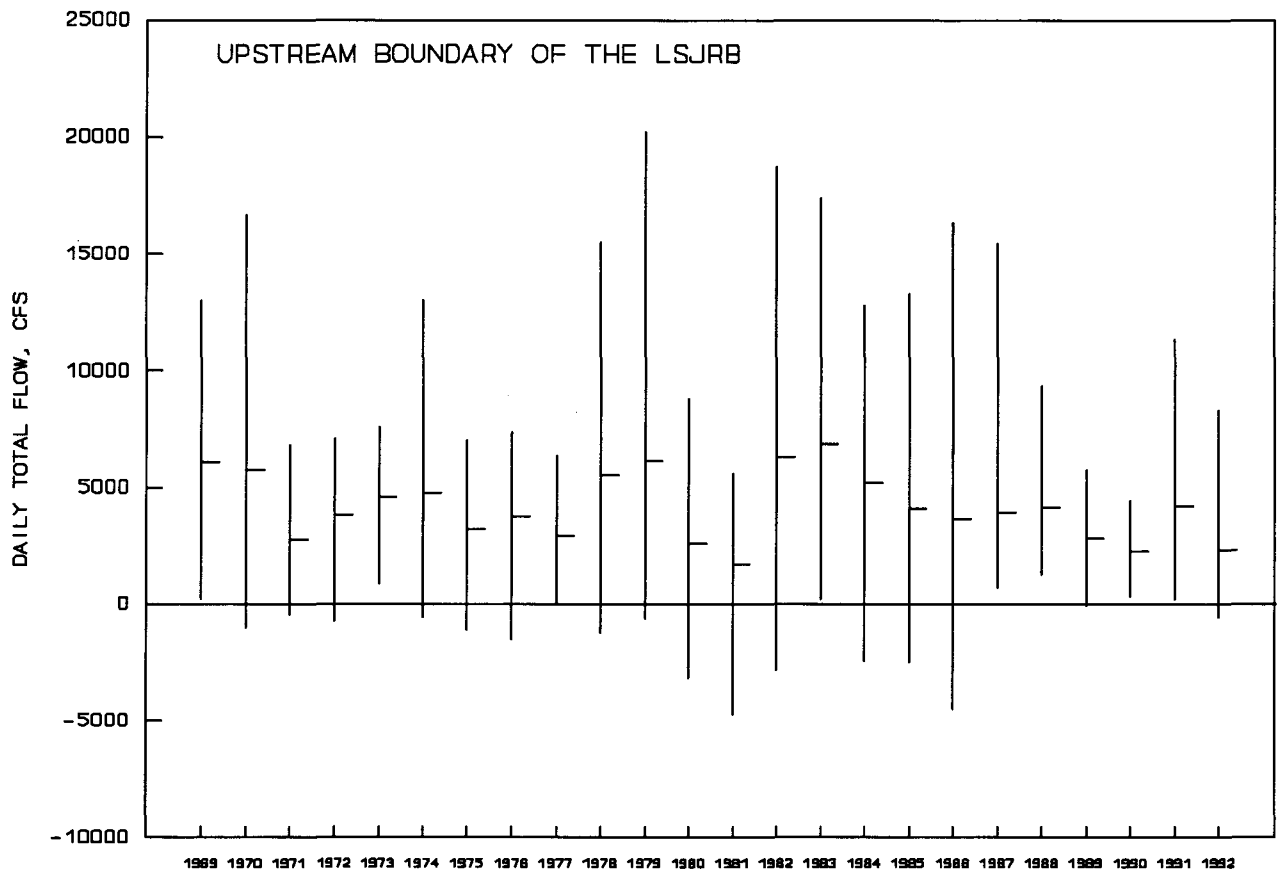


Figure 3.31—*Continued*

C

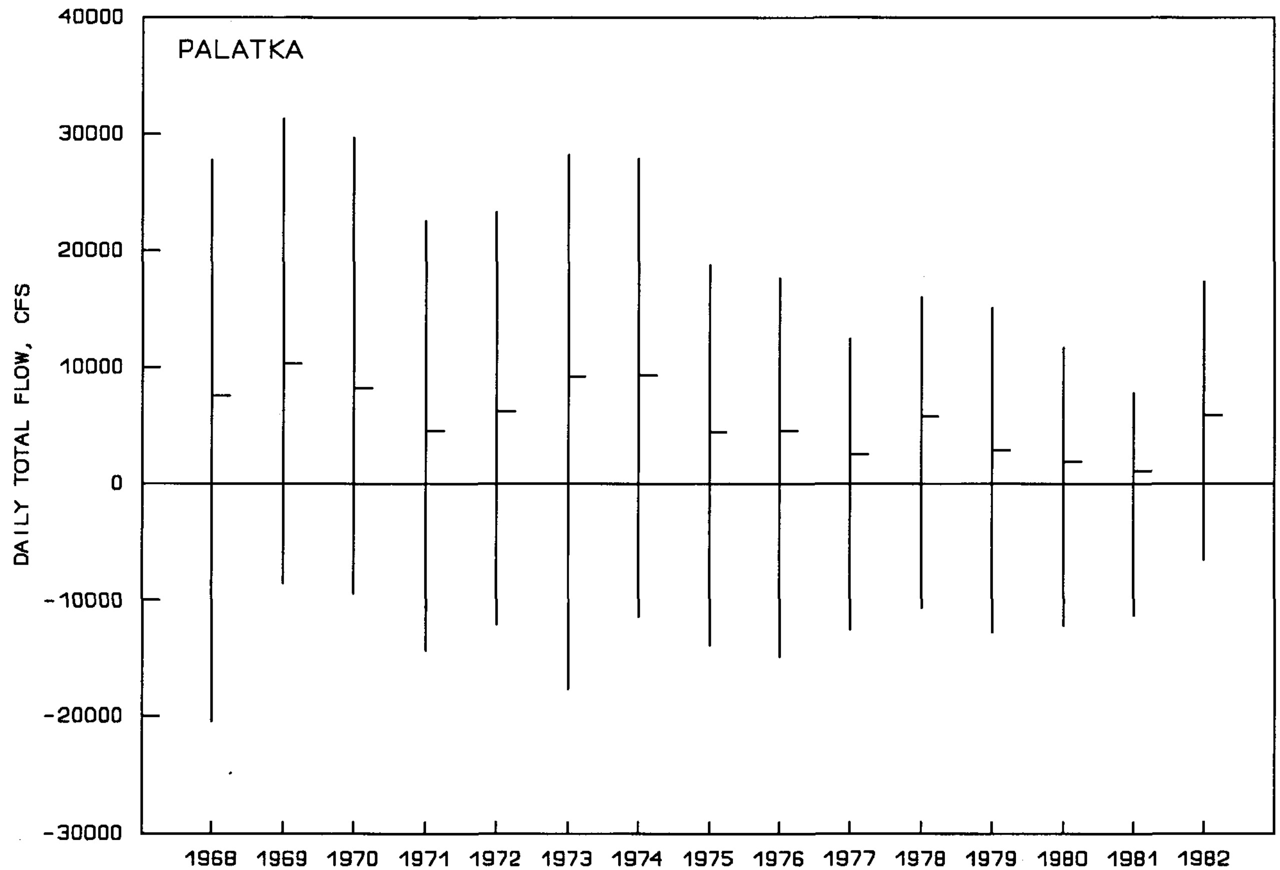


Figure 3.31—*Continued*

D

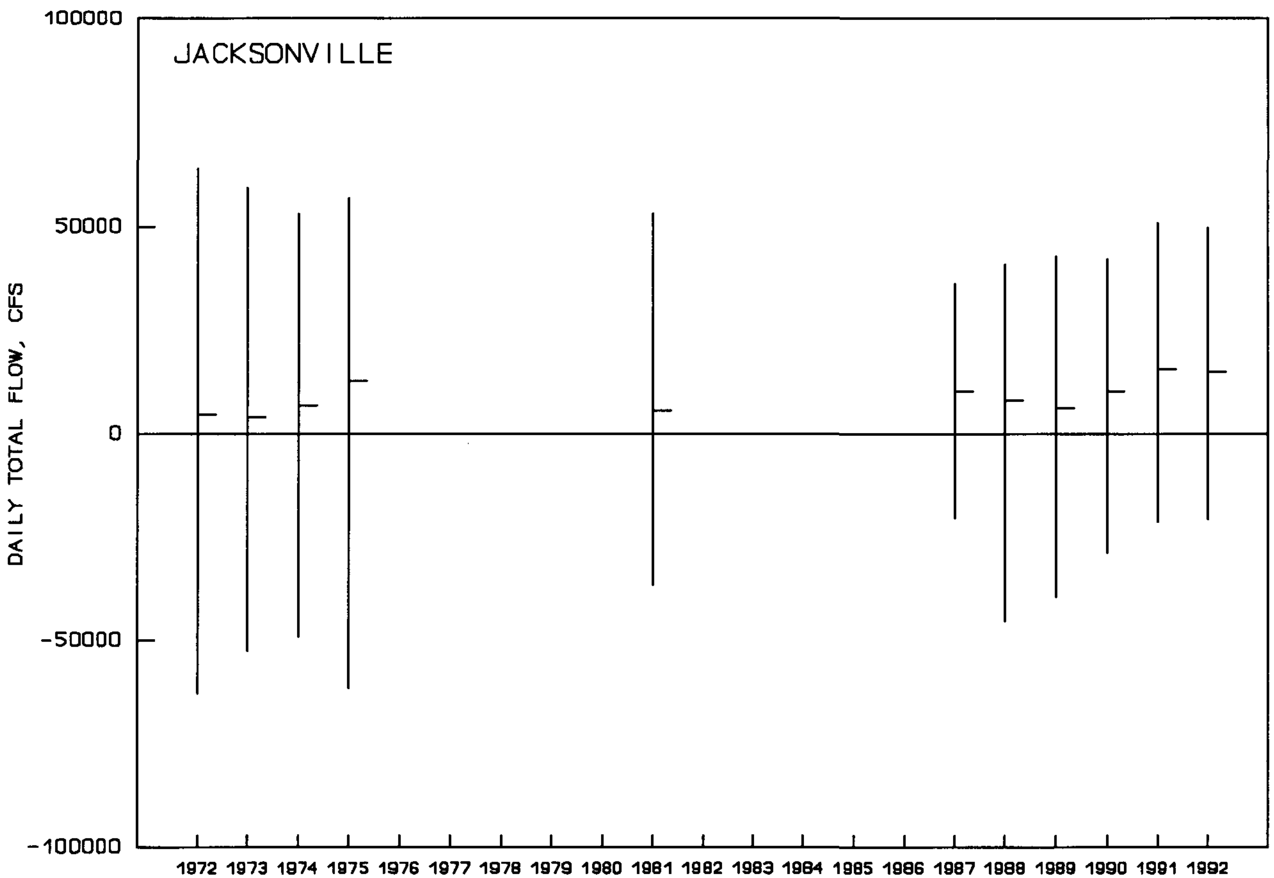


Figure 3.31—*Continued*

The mean, minimum, and maximum values of mean monthly total flows derived from the annual summaries over the period of recordfor each station (to 1992, where available) are shown in Table 3.23. Note that these values represent the variability of the monthly mean flow; these values do not reflect the daily or monthly ranges, but only the ranges of the monthly means over the period of record. Thus, these values do not include the effects of daily fluctuations.

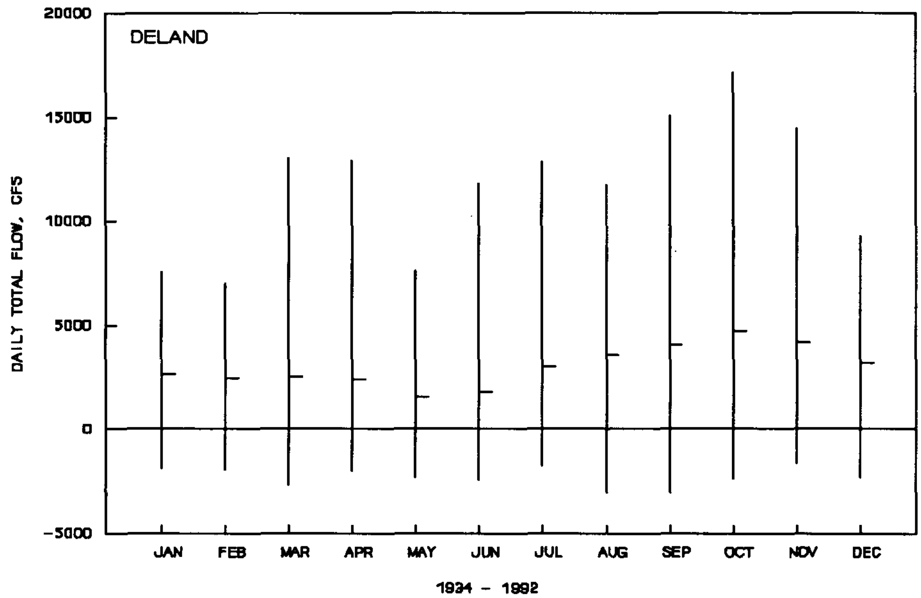
Derived Monthly Total Flow

The monthly total flow in the river is the mean of the daily values of total flow for the month (Figure 3.32, based on the published USGS flow data). During the common period of record (1978–86) for the four locations that were summed to obtain partial flow at the upstream boundary of the LSJRB, the mean of the monthly mean flows was 4,144 cfs. At Palatka, over the shorter 15-year period of record (1968–82), the mean was 5,931 cfs, and at Jacksonville over the 9-year period (i.e., three intermittent periods totaling 9 years: 1972–75, 1980–81, 1987–92) it was 7,305 cfs.

A summary of the monthly means of total flow at the three monitoring stations, together with the monthly means of a summation of the total flow into the upstream boundary of the LSJRB, for the particular periods of record of each station, is provided in Table 3.24. It is noted, as first observed by RSH (1974, 20, and discussion in the chapter on river flow), that the total flow at Jacksonville is less than it is upstream at Palatka from November through March, which are the first 5 months of the dry season.

During the common 9-year period of record (1978–86) for the partial summation of flow at the upstream boundary of the LSJRB, the monthly mean flows ranged from 870 to 12,913 cfs (Table E13). This common period of record may be extended back to begin in 1969, provided that intervals with missing data at some stations are disregarded; the minimum and maximum monthly mean flows in the St. Johns River do not change. Both the lowest and the highest total monthly mean flows in this 18-year period of record occurred in October.

A



B

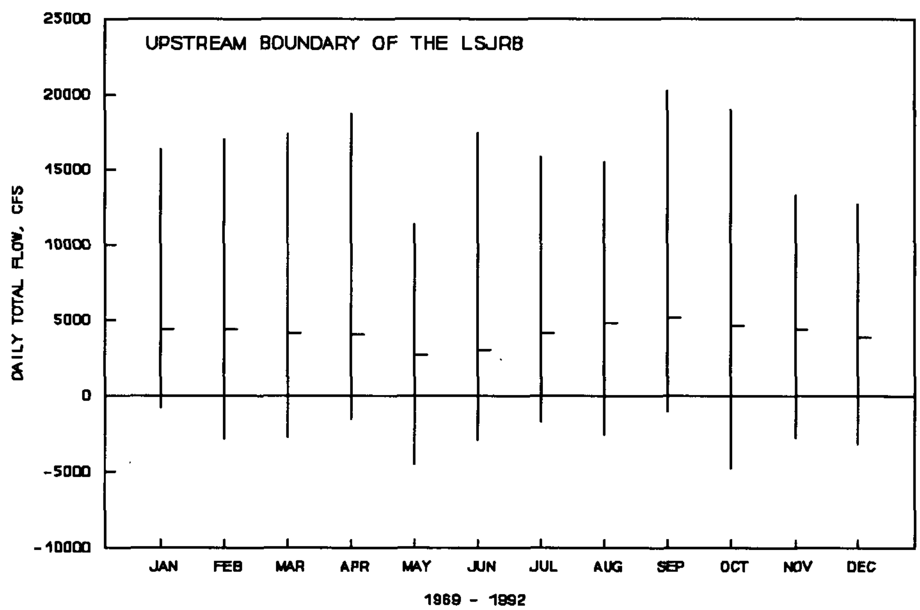
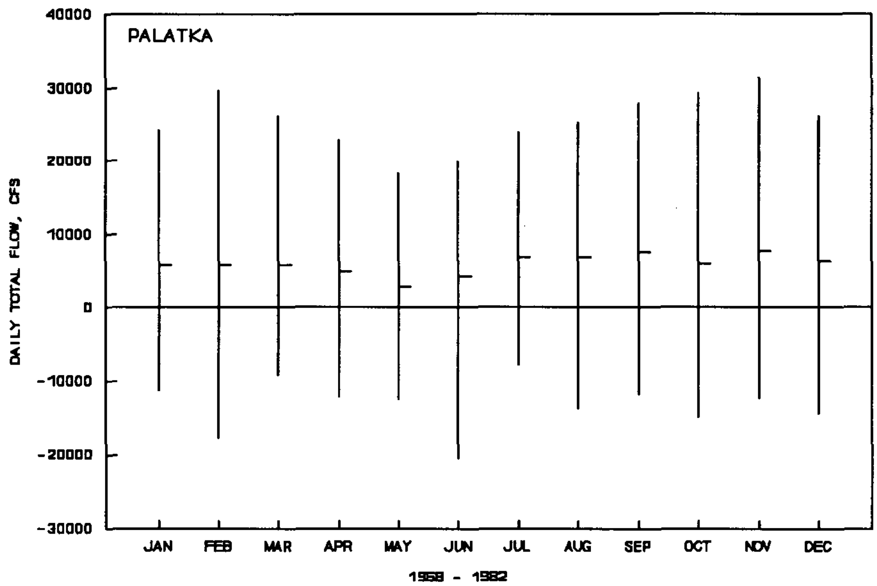


Figure 3.32 Monthly mean and extreme daily total flows at De Land (*A*), calculated daily total flow for the upstream boundary of the Lower St. Johns River Basin (*B*), monthly mean and extreme daily total flow at Palatka (*C*), monthly mean and extreme and daily total flow at Jacksonville (*D*)

C



D

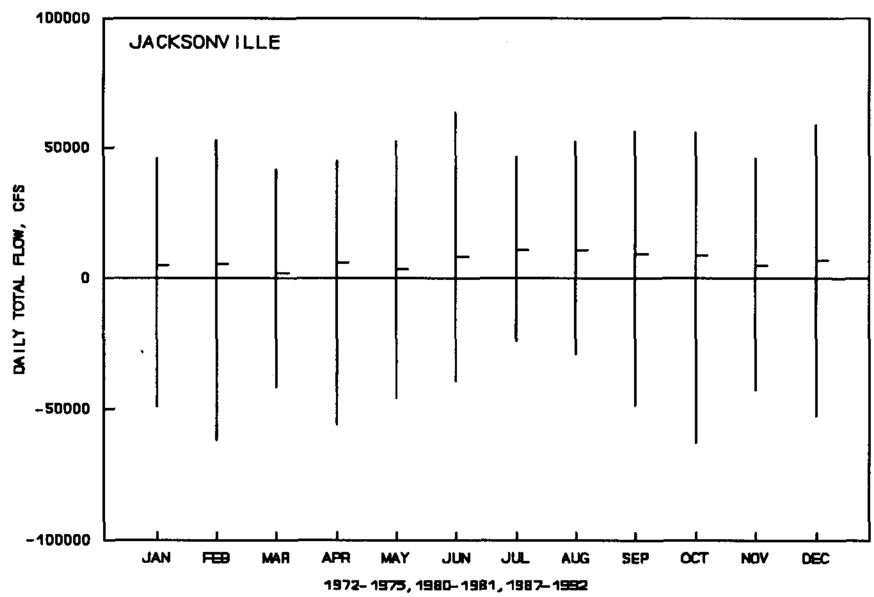


Figure 3.32—*Continued*

Table 3.24 Means of monthly mean total flows over associated periods of record to 1992 (where available)

Month	Mean Total Flow (thousands of cfs)			
	De Land Monitoring Station	Calculated Flow at the Upstream Boundary of the LSJRB	Palatka Monitoring Station	Jacksonville Monitoring Station
January	2,664	4,383	5,792	4,829
February	2,470	4,411	5,762	5,358
March	2,530	4,154	5,880	1,923
April	2,407	4,061	4,935	6,024
May	1,556	2,699	2,879	3,438
June	1,800	3,032	4,236	8,606
July	3,003	4,173	6,763	10,917
August	3,545	4,826	6,859	10,787
September	4,052	5,217	7,499	9,368
October	4,746	4,686	6,428	10,566
November	4,207	4,386	7,770	5,354
December	3,213	3,949	6,425	6,253

Note: cfs = cubic feet per second
LSJRB = Lower St. Johns River Basin

An estimated correction of 1,163 cfs (see p. 145) may be added to the values at the upstream boundary (column 3) to account for discharges from the ungaged area north of De Land.

Data compiled from Tables E9 and E13–15, Appendix E

Over the shorter 15-year period of record at Palatka, monthly mean flow varied from 2,092 cfs upstream in August to 20,115 cfs in October. Over the interrupted period of record (7 years) at Jacksonville, monthly mean flow varied from 10,428 cfs upstream (May) to 25,515 cfs (August). The individual monthly values and mean annual total flows for the periods of record for De Land, Rodman Dam, Buckman Lock, Dunns Creek, Palatka, and Jacksonville are in Appendix E.

Derived Daily Total Flow

Mean daily flow data are available from USGS for each of the stations listed in Table 3.24. When summarizing annual changes, monthly statistics are appropriate, but the daily variability is lost. For some more detailed analyses of flows, the daily fluctuations may be summarized, as has been done in Appendix E. Again, it is important to note that these datasets are incomplete except at De Land, and therefore the partial flow at the upper boundary of the tidal portion of the LSJR may not be consistent from one month to the next.

The summaries of daily flows were tabulated in a spreadsheet on a monthly basis by listing the minimum, mean, and maximum daily flows in each month over the period of record. Then the minimum, mean, and maximum values for each month and for each year were tabulated along with the daily values. Because the spreadsheets were too large to include in this report, the daily values were deleted and the statistics were reorganized so that the minimum, mean, and maximum values of the monthly minimums, means, and maximums could be tabulated. The mean and extreme daily values are shown in Figure 3.31 for De Land, for the upper boundary of the LSJRB, for Palatka, and for Jacksonville.

TIDAL FLOW

Tidal flow is the volume of water moving, either into or out of the river, due to tidal forces. Conceptually, non-tidal flow is the part of the total flow that is due to winds, freshwater discharges, and other causes. A particular analysis of the "volume of upstream and downstream flows" may be focused on total flows or only on the non-tidal component. Therefore, the context of any description of such flows should be examined closely.

Upstream and Downstream Flows

USGS analyzed the water elevation and point velocity data that were collected in the vicinity of Main Street Bridge in the early 1970s. Stage data were obtained at Main Street Bridge, 8.2 mi upstream at

NAS, and 4.8 mi downstream at the USACE dredge depot. Point velocity data were obtained at the downstream (east) side of Main Street Bridge. "Rapid discharge measurements" (a standard USGS technique) using four current meters supplemented these readings. Discharges and point velocities, plotted for each direction of flow, were found to be linear (with small scatter) and were used to obtain discharge during each tidal cycle. The volumes of flow for each tidal cycle were computed from the areas under the graph of discharge and plotted against the area between the superimposed stage graphs at NAS and the dredge depot. The volume of each upstream and downstream flow was then derived from the stage records using the linear fit relation of tidal flow to the product of the elevation difference multiplied by time. This process, while complex, provided a means for separating non-tidal from tidal flow (Anderson and Goolsby 1973, 3–7). An update of this type of study has not been published since 1973.

Historical Annual Tidal Flows

Annual average upstream and downstream tidal flow per tidal cycle, as a function of yearly average net flow per tidal cycle, was calculated by USGS using data from WYs 1955–66. The mean tidal flow (adjusted for annual average tidal range) was 1,940 mcf (43,165 cfs per half tidal cycle [/htc]) and ranged from 1,620 to 2,215 mcf (36,046 to 49,284 cfs/htc). The annual average upstream flow was 1,806 mcf during the 12-year period, while the annual average downstream flow was 2,076 mcf. The annual average net flow per tidal cycle ranged from 20 to 510 mcf (445 to 11,348 cfs/htc) (Anderson and Goolsby 1973, 16, Figure 8).

Annual Tidal Flow

From the data collected between March 1955 and September 1966, USGS reported that the average volume of downstream flows was 2,076 mcf (46,191 cfs/htc) and that the average volume of upstream flows was 1,806 mcf (40,184 cfs/htc); the difference, 270 mcf (6,007 cfs/htc), was considered to be the average net flow and, therefore, the average freshwater flow. If the net, or freshwater flow, had not been superimposed on the tidal flow, the average tidal volume would have been the average of the computed upstream and downstream flows, or 87 mcf/tc (1,941 cfs) (Anderson and Goolsby 1973, 15). The relationships of annual average tidal flows to annual average net flows, adjusted for variations in annual tidal range, are summarized in Figure 8 in Anderson and Goolsby (p. 16). The scatter about the linear relationship is attributed to errors in calculating the volumes of flow.

The relationships between the adjusted annual average downstream and upstream tidal flow per tidal cycle and yearly average net flow per tidal cycle also were calculated. Yearly average flow per half tidal cycle ranged from 1,780 mcf (39,605 cfs/htc) upstream to 2,220 mcf (49,395 cfs/htc) downstream; the yearly average net flow per tidal cycle ranged from 35 to 510 mcf (778 to 11,348 cfs/htc) (Anderson and Goolsby 1973, 16, Figure 8).

Average Tidal Flow

The average tidal flow, based on data from February 1954 to September 1966, was calculated to be 87,000 cfs. This is about seven times the average net or freshwater flow (Anderson and Goolsby 1973, 1, 5).

Tidal Volume

Based on data from 1954 to 1966, the difference between highest and lowest monthly mean tidal volume flow was 235 mcf, ranging from 7.4% less than to 4.7% greater than the mean tidal flow (Anderson and Goolsby 1973, 46–48).

Long-Term Extremes in Tidal Flow

The maximum upstream and downstream total flow at Main Street Bridge, obtained from the calculations described above on data collected from March 1954 through September 1966, is 170,000 cfs and 175,000 cfs, respectively. The monthly averages of the monthly mean tidal flow volumes and monthly mean net tidal flow volumes per tidal cycle are given by USGS (Anderson and Goolsby 1973, 14, Figure 7B).

For the period 1954–66, the net flow at Main Street Bridge was downstream for about 70% of the days of record and upstream for about 29%. Zero net flow was observed on 13 of the 4,597 days (about 0.3%). The greatest number of consecutive days of upstream flow was 14 (Atlantis Scientific 1976, II-6–7).

Selected statistics for flow at Jacksonville, based on data from March 1954 to September 1966, are summarized for the downstream and upstream directions of flow in Table 3.25. This analysis was carried out by Anderson and Goolsby for 8,813 tidal cycles (91 months) of data.

Table 3.25 Selected total flow statistics at Jacksonville (data from March 1954 to September 1966)

Flow Statistic	Downstream Flow		Upstream Flow	
	mcf/tc	cfs	mcf/tc	cfs
Average discharge	2,075	*46,419	1,812	*40,536
Average net discharge	263	*5,883	NA	NA
Maximum daily net flow	3,890	*87,000	NA	NA
Minimum daily net flow	NA	NA	2,303	*51,500
Average volume/tc	*2,075.5	46,419	*1,812.4	40,535
Average net volume/tc	*263.1	5,884	NA	NA
Maximum volume/tc	*5,280	118,089	*4,410	98,631
Minimum volume/tc	*0	0	*0	0

Note: mcf/tc = million cubic feet per tidal cycle
cfs = cubic feet per second

*Value is source table (tidal cycle is given as 12.42 hours)

Values of mcf/tc given in source are converted to cfs by first multiplying by 22.36536 (cfs/tc)/(mcf/tc) and rounding result to nearest whole number.

Values of cfs given in source are converted to mcf/tc by first multiplying by 0.044712 (mcg/tc)/(cfs/tc) and rounding result to nearest whole number.

Source: Anderson and Goolsby 1973, 22, Table 1

USGS performed extensive analyses, some using the BRANCH model, on the water elevation and point velocity data that were collected in the vicinity of Main Street Bridge in the 1970s and 1980s. Upstream and downstream flows were reported for several years (WYs 1972–74, 1981, and 1987–90) but the data were considered to be generally poor. The reported maximum monthly mean upstream flow was 10,428 cfs, and the maximum monthly mean downstream flow was 25,515 cfs (Table E15).

NON-TIDAL FLOW

Seasonal Non-Tidal Flow

The 1973 USGS study, as previously described and based on data collected during WYs 1955–66, proposed that, by subtracting the average volume of the upstream flows from the average volume of the downstream flows, the computed average flow would represent the net or freshwater flow for that period. The resulting flow was 270 mcf (6,007 cfs/htc) downstream (Anderson and Goolsby 1973, 15). The corresponding average and extreme monthly mean net discharges at Jacksonville are given in Figure 3.32, part D. This figure shows the seasonal net flow regime. The seasonal flow periods, which correspond to the hydrologic seasons, are low net discharge in May through June, increased net discharge from July through September, high net discharge from October through January, and decreasing net discharge from February through April (Anderson and Goolsby 1973, 48 and 49, Figure 31).

Monthly Non-Tidal Flow

Monthly Mean Flow Volumes. Monthly mean flow volumes derived by USGS for the 1973 report are summarized in that report and described in the previous chapter (Figure 3.28). The upper plot (Anderson and Goolsby 1973, 23, Figure 12, graph A) shows the monthly means of the total flow volume (the composite of both tidal and non-tidal influences) upstream and the same downstream, in millions of cubic feet.

Recent Calculations of Monthly Mean Freshwater Inflows. Monthly mean inflows, as given in the NEI, are summarized in the last column in Table 3.26. These values are compared with total

Table 3.26 Comparison of long-term monthly mean freshwater inflows to the St. Johns River (to Jacksonville) to total flows at the upstream boundary of the Lower St. Johns River Basin

Month	Calculated Partial Flow at Upstream Boundary of the LSJRB (Total Flow, cfs)	Estimated with Addition of Ungaged Flow (cfs)	National Estuarine Inventory (Freshwater Inflow, cfs)
January	4,383	5,546	6,800
February	4,411	5,574	6,800
March	4,154	5,317	7,000
April	4,061	5,224	6,300
May	2,699	3,862	4,300
June	3,032	4,195	5,200
July	4,173	5,336	7,900
August	4,826	5,989	9,500
September	5,217	6,380	10,600
October	4,686	5,849	11,600
November	4,386	5,549	9,600
December	3,949	5,112	7,700

Note: cfs = cubic feet per second
LSJRB = Lower St. Johns River Boundary

Data for upstream flows (column 2) from Appendix E, Table E13.
Estimated flows (column 3) are obtained by adding 1,163 cfs (see p. 145) to values at the upstream boundary (column 2).

Source (column 4): NOAA 1985, 2.16

flows at the upstream boundary of the LSJRB; the total flows are the calculated sums of the USGS flow data at four locations. The freshwater inflows listed in the NEI are substantially larger than the calculated total flows at the upstream boundary. The difference between the two includes the unmonitored inflows above the upstream boundary as well as the inflows along the 100 mi of the St. Johns River below the upstream boundary of the LSJRB. Although the methodology for development of the tabulated flows is not specifically indicated in the NEI, the flows were probably calculated with the assistance of the screening model for estuarine assessment (chapter on hydrodynamic and water quality models; Klein and Galt 1986).

Daily Non-Tidal Flow

The long-term daily average freshwater inflow to the St. Johns River, as stated in the NEI, is 7,800 cfs for the 1950–82 period of record (NOAA 1985, 2.16). More recent analyses and summaries of freshwater inflow are not available.

Wind-Induced Flow

Statistics of wind-induced flow have not yet been developed for the St. Johns River.

FLOW DISTRIBUTION AND FREQUENCY

Flow distribution and frequency statistics are based on the duration of flow. Because tidal flow reverses, the duration of flow in one direction can only be described in terms of the total number of tidal flows during which flow was in that direction. The volume of a tidal flow is a function of both the duration of the flow and the average discharge during that time. Cumulative flow-distribution curves show the percentage of the total number of tidal flows during which specific volumes were equaled or exceeded.

USGS published the results of a flow distribution and frequency analysis based on data taken between March 1, 1954 and September 30, 1966 (Anderson and Goolsby 1973, 26–36) (Table 3.27).

Table 3.27 Types of analyses performed by USGS on March 1954–September 1966 data

Type of Analysis	Source Report Figure Number
Percentage of the total number of tidal flows during which specific volumes were equaled or exceeded during downstream flow at Main Street Bridge (cumulative flow distribution)	13
Percentage of the total number of days of record during which specific total daily volumes of downstream flow were equaled or exceeded at Main Street Bridge	13
Percentage of the total number of days of record during which daily net flow was equaled or exceeded at Main Street Bridge (cumulative flow distribution)	14
Percentage of the total number of tidal flows during which specific volumes were equaled or exceeded during upstream flow at Main Street Bridge (cumulative flow distribution)	15
Percentage of the total number of days of record during which specific total daily volumes of upstream flow were equaled or exceeded at Main Street Bridge	15
Average recurrence intervals of downstream tidal flow volumes that occur as monthly and yearly maximums. For example, a monthly maximum downstream tidal flow of 4,000 mcf or more occurs on the average of every 60 months. Also, a yearly maximum downstream tidal flow of 4,000 mcf or more occurs on the average of every 6.7 years	16
Average recurrence intervals of upstream tidal flow volumes that occur as monthly and yearly minimums	17
Average recurrence intervals of downstream tidal flow volumes that occur as monthly and yearly minimums	18
Average recurrence intervals of upstream tidal flow volumes that occur as monthly and yearly minimums	19
Average recurrence intervals of daily net flows that occur as monthly and yearly maximums. For example, the average recurrence interval of monthly maximum net flows of 5,000 mcf or more is 120 months	20
Average recurrence intervals of daily net flows that occur as monthly and yearly minimums	21
Maximum periods of flow deficiency or the maximum number of consecutive days that daily net flow was less than specified amounts	22

Note: mcf = million cubic feet

Source: Anderson and Goolsby 1973, 26–36

Because these distributions were calculated for a limited period several decades ago, only the types of analyses are listed; the reader is referred to the Anderson and Goolsby report for details.

Cumulative Flow Frequency

Cumulative flow frequency relationships are shown by flow-duration curves. The flow-duration curves may be used for direct determination of water supply potential, but because these curves do not show the chronologic sequence of flows, their use is limited in flood studies or for estimating the storage needed to assure any selected flow. Of course, such curves depend on basic flow data, which is very limited for the St. Johns River. Flow-duration characteristics for tributaries above and at the USGS station at De Land are given in the WRMP (SJRWMD 1977, D-33–34).

The river discharge equaled or exceeded for different percentages of time over a year at De Land is given in Table D-5 in the WRMP (SJRWMD 1977). Available low-flow characteristics are restricted to the Upper St. Johns River Basin (SJRWMD 1977, D-35–36).

Flow in the reach downstream of Lake George is described as reversing with each tidal change, except under conditions of high freshwater inflow or strong winds. About 75% of the time, the net flow is toward the ocean, but at other times it may be upstream for several consecutive days. The maximum number of days during which net flow is likely to be equal to or less than a specific amount at Palatka and at Jacksonville is shown in Figure D-14 in the WRMP (SJRWMD 1977, D-41, attributed to Snell and Anderson 1970). Periods of upstream or negative net flow usually occur during periods of low freshwater discharge, high evapotranspiration, and increased tidal range (SJRWMD 1977, D-36).

Annual exceedence plots of the annual data through 1991 of partial flows at the upstream boundary of the LSJRB and the flows at Palatka and Jacksonville show the probabilities that daily mean discharge will exceed specific values within certain periods of time. For example, in a 10-year period, the total flow at the upstream boundary may be expected to exceed 17,500 cfs; at Palatka, 31,000 cfs; and at Jacksonville, 60,000 cfs. These exceedence probabilities are summarized in Figure 3.33.

Duration of Flow

In a report written for the Florida Power and Light Company, RSH reviewed the hydrology of the entire St. Johns River in order to quantify water availability. The results were to be presented in terms of estimated quantities of excess water for diversion (RSH 1974, 1, 20).

Flow duration is the percentage of time during which specific quantities of discharge are likely to be equaled or exceeded. At De Land, zero flow occurs about 1% of the time, indicating that tides and/or wind can cause net upstream flows at times of low freshwater inflow over short periods of time. Flow durations are also listed for the upstream boundary of the LSJRB and for Palatka and Jacksonville (Table 3.28) (RSH 1974, 21–23; USGS Surface Water WY 1992).

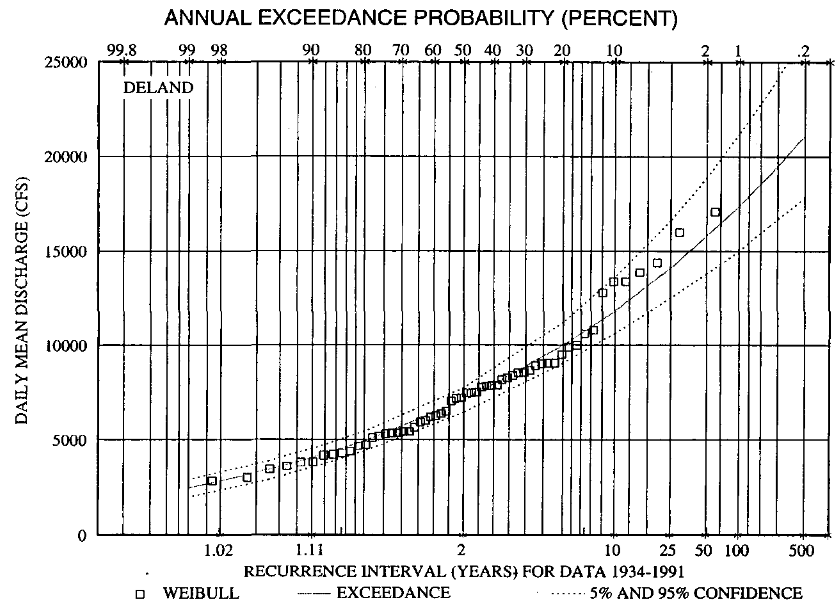
In the same study, the number of consecutive days a flow could be expected to be equal to particular values during a specific recurrence interval was extracted from frequency curves at De Land (Table 3.29). This type of analysis would not be appropriate in parts of the river where there are tidal flow reversals (RSH 1974, 23–25).

A flow duration curve, showing the percentage of time that specific flows at the station near De Land were equaled or exceeded during a given period, was developed for the WRMP (SJRWMD 1977, D-32, Figure D-10). Similarly, the low-flow characteristics, considered representative of the amount of ground water flow into the LSJRB, are described by frequency curves of annual minimum flows at Palatka and Jacksonville (p. D-41, Figure D-14).

Design Flow for Water Quality Modeling

A water quality modeling study required an estimate of the 7-day, 10-year flow conditions in the main stem. The contractor, Atlantis Scientific, determined that flows developed by Connell Associates

A



B

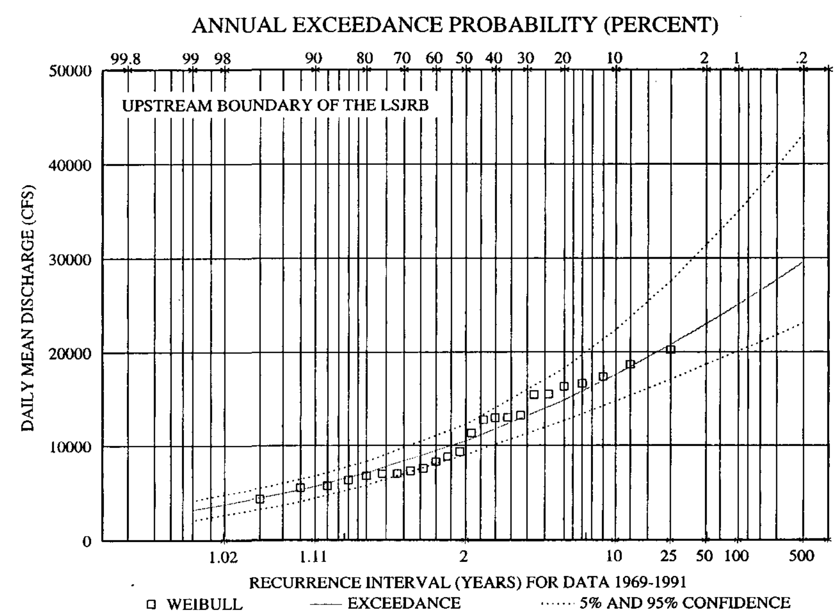
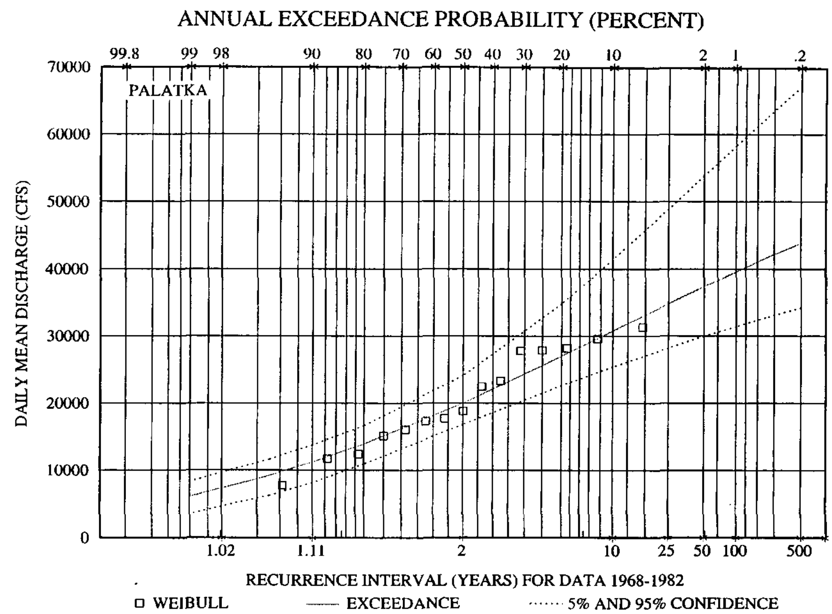


Figure 3.33 Annual exceedence for flows at De Land (*A*), for partial flows at the upstream boundary of the Lower St. Johns River Basin (*B*), flows at Palatka (*C*), and flows at Jacksonville (*D*)

C



D

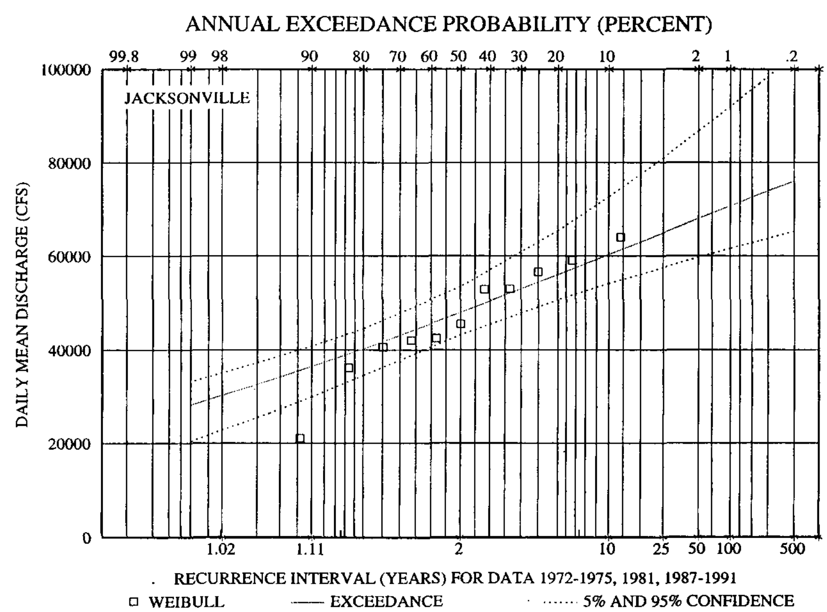


Figure 3.33—*Continued*

Table 3.28 Flow duration for three USGS stations on the main stem, plus calculations for flow at the upstream boundary of the Lower St. Johns River Basin (LSJRB)

Station	Percentage of Time Discharge Amount (cfs) Was Equaled or Exceeded					
	1%	10%	50%	90%	95%	99%
De Land						
Oct 1935–Sep 1965	10,000	7,000	2,800	1,100	800	0
Jan 1934–Sep 1992	11,800	6,160	2,480	948	700	289
Upstream boundary of the LSJRB*	11,703	8,034	3,530	1,594	1,323	1,050
Palatka	24,200	15,500	6,440	1,530	834	228
Jacksonville	46,300	28,200	11,950	2,591	1,220	245

Note: cfs = cubic feet per second

*1,163 cfs (see p. 145) may be added for ungaged inflows.

Data for De Land, October 1935–September 1965 from RSH 1974, 22, Table 5
Data for De Land, January 1934–September 1992 from USGS 1991
Data for upstream boundary, Palatka, and Jacksonville from calculations on USGS data to 1992

(1974) were slightly higher than the average and that flows described by Edge (1973) were low and did not take into account the reverse flows that have been frequently observed. The design flows that were needed had to represent typical seasonal downstream flows and a conservative reverse flow (Atlantis Scientific 1976, V-1).

A 19-year dataset for Jacksonville was available for analysis. Atlantis Scientific determined that flows for the months of October, February, June, and August represented the seasonal extremes. The lowest quartile (fifth lowest) mean annual flow for Jacksonville occurred in 1971. This flow, and the two mean annual flows ranked closest, both lower and higher, are summarized in Table 3.30.

Atlantis Scientific determined that design flows should be selected from data for 1968 because supporting water quality data were more available for 1968 than for 1971. Representative seasonal low flows

Table 3.29 High- and low-flow frequency data for De Land (1935–65)

Recurrence Interval (years)	Consecutive Days of Flow and Flow Amounts (cfs)		
	1 Day	29 Days	274 Days
5-year high	12,000	10,000	4,700
10-year high	15,000	13,000	5,500
25-year high	19,000	17,000	6,500
5-year low	275	550	1,800
10-year low	60	500	1,500
25-year low	10	480	1,000

Note: cfs = cubic feet per second

Source: RSH 1974, 23–25, Table 6

Table 3.30 Ranking of average annual flows at Jacksonville for the year with the lowest quartile flow (1971) and the 4 years with adjacent ranked flows (for 19 years of data, 1958–76)

Year	Rank (out of 19)	Flow (cfs)
1967	3	1,640
1968	4	2,849
1971	5	2,910
1957	6	3,150
1958	7	3,152

Note: cfs = cubic feet per second

A ranking of 1 indicates lowest flow; a ranking of 19 indicates highest flow.

Source: Atlantis Scientific 1976, V-2

for Jacksonville and Palatka, estimated to approximate the 7-day, 10-year low flows, are summarized in Table 3.31.

Table 3.31 Representative seasonal low flows at Palatka and Jacksonville (data to 1976)

Year of Occurrence	Month	Season	Description of Season	Total Low Flow (cfs)	
				Palatka	Jacksonville
1968	June	May–June	Low flow	8,035	1,610
1968	February	February–April	Decreasing storage	2,322	2,730
1968	August	July–September	Increasing storage	8,954	4,470
1967	October	October–January	High flow/storage	3,213	5,768

Note: cfs = cubic feet per second

Source: Atlantis Scientific 1976, V-3

Duration of Reversed Flow

Anderson estimated the number of consecutive days between 1954 and 1965 when stream flow was reversed at Jacksonville and Palatka (reported in RSH 1974, 6). During this period of time, the mean daily flow was upstream for 18 days at Palatka and 22 days at Jacksonville (p. 23).

Recent Flow Frequency Analysis

The NEI lists the 7-day, 10-year low flow; 50- and 100-year flood flows; and average, high-, and low-flow ratios for data from 1950 to 1982 (NOAA 1985). Flow ratios are the proportion of the volume of fresh water entering the river during one tidal cycle to the tidal prism volume. The flow ratios provide an indication as to whether freshwater inflow or tidal inflow is the dominant factor for average, high-, and low-flow periods. High-flow ratios indicate that freshwater inflows predominate. The flow ratios listed for the St. Johns River are all relatively small (Table 3.32).

Table 3.32 Flow statistics and ratios for the St. Johns River (data from 1950 to 1982)

Flow Statistics (cfs)	
Period	Flow (cfs)
7-day, 10-year low flow	600
50-year flood	38,500
100-year flood	44,900
Flow Ratio	
Period	Ratio
Average annual	0.185
High-flow period	0.252
Low-flow period	0.125

Note: cfs = cubic feet per second

*Flow ratio is the proportion of the volume of fresh water entering a coastal system during a tidal cycle to the volume of the tidal prism.

Source: NOAA 1985, 2.16

SUMMARY OF FLOW STATISTICS

The means and extremes of available USGS daily total flow data have been summarized by year and by month. The annual means and extremes of monthly mean flows at De Land, the upstream boundary of the LSJRB, Palatka, and Jacksonville are shown in Figure 3.31. The seasonal trends in the monthly means that were first observed in data collected by USGS (Anderson and Goolsby 1973, 49, Figure 31) have been confirmed in these data. Means of monthly mean total flow are summarized for De Land, the upstream boundary of the LSJRB, Palatka, and Jacksonville in Table 3.24. The monthly means and extremes of daily flows for the same locations are shown in Figure 3.32. The mean values in these figures are tabulated in Appendix E.

Flow exceedences, calculated from annual mean flows at the four locations on the main stem over the respective periods of record, are shown in Figure 3.33. Flow durations—the percentages of time that flows were equaled or exceeded at these sites—are summarized in Table 3.28.

The total discharge of the river is normally greater than 50,000 cfs and can exceed 150,000 cfs.

RIVER SALINITY

Salinity is considered to be part of the hydrodynamics of a river because it is indicative of the density of different water masses, and density differences can affect flows. Water masses may or may not mix, depending on their relative density, local dispersion, and the state of turbulence in the flow. In the extreme, a relatively fresh, less dense layer of water can flow over a more dense layer in the opposite direction with only a relatively small amount of mixing at the interface. Thus, salinity is considered to be a physical parameter of river and estuarine dynamics.

Traditionally, salinity has been measured indirectly through the specific conductivity of a water sample. The concentration of chlorides, or chlorinity, is related directly to the conductivity and temperature of the sample, and salinity can be calculated from the chlorinity. Now, field instruments with a built-in processor convert conductivity and temperature directly to salinity.

CLASSIFICATION BASED ON SALINITY

The classification of an estuary is important to managers. It provides a summary of the relative circulation and mixing processes, allows a better understanding of the effect of movement and dispersion of pollutants, and can lead to better estimates of the impacts caused by waste loads, channel dredging, fresh water inflow alterations, and other influences (NOAA 1985).

A variety of classification schemes have been devised for estuaries, which are useful for comparing individual features, combinations of features, and the overall functioning of the estuaries on a numerical scale. One of the first schemes was that of Stommel and Farmer, who divided estuaries into four different types (Stommel and Farmer 1952a, as referenced by Pyatt 1959, 25). The St. Johns River is classified by this system as varying between type 2 (slightly stratified) and type 3 (highly stratified).

Another classification scheme, devised by Pritchard (1952), describes types A (highly stratified), B (moderately stratified), C (vertically homogeneous with lateral salinity gradients often due to Coriolis effects), and D (both vertically and laterally homogeneous). The classification of a particular estuary under this scheme depends primarily on the magnitudes of river flow, tidal flow, width, and depth. According to Pritchard's scheme for estuary typing, the St. Johns River fluctuates between types A and B (Pyatt 1959, 105; 1964, F42).

A later classification is based on the stratification-circulation diagram developed by Hansen and Rattray (1966). On this diagram, the tidal mean salinity difference (surface to bottom) divided by tidal mean salinity is plotted against the net circulation velocity at the surface divided by the tidal mean velocity. Because surface velocity and salinity data are not available for the St. Johns River, this classification cannot be accurately determined.

Classification of an estuary varies with the amounts of freshwater inflow and tidal prism volumes, which change monthly. To account for this variability, salinity classifications for "the three-month period of highest fresh water inflow and the three-month period of lowest fresh water inflow" are described in the NEI (NOAA 1985). The NEI provides the results of an analysis of long-term mean flows. Based on data from 1950 to 1982, the stratification classification of the St. Johns River is given as vertically homogeneous (i.e., no significant stratification) under conditions of both 3-month low flow and 3-month high flow. Vertical homogeneity implies that stratified conditions fluctuate over much shorter periods than 3 months and that there is no persistent stratification during either of these extremes; these conditions do not relate to the transient effects of freshwater inflows (NOAA 1985, 2.16), nor do these conditions describe the condition of the river between these extremes. Thus, the NEI classification may be considered to be an incomplete description of salinity stratification of the river.

SEGMENTATION BASED ON SALINITY

An estuary may be segmented for comparing spatial differences in any basic parameter. A water quality model study of the river, for example, divided the lower 120.5 mi distance from Lake George to the mouth into 69 segments to represent changes in geometry, temperature, benthic oxygen demand rate, and atmospheric reaeration rate (Connell Associates 1974, 4-49, Figure 4-20, and A-39, Table B-5).

Both the NEI and the National Estuary Program develop "segmentation" schemes for estuaries. The U.S. Environmental Protection Agency (EPA) defines estuary segmentation as "partitioning an estuary into a series of spatial units or segments ... [to permit] consolidating an extensive amount of environmental information into representative data elements when certain conditions, such as water temperature and salinity, are relatively homogeneous within a segment" (EPA 1989, 29).

"Segmentation ... on the basis of salinity is highly variable due to the many interacting factors affecting salinity concentrations, such as variations in fresh water inflow, wind, and tide" (NOAA 1985). Three guidelines were adopted for the NEI to ensure a uniform analysis among all the estuaries in Florida that were analyzed for the NEI study:

1. "first, episodic anomalies of salinity conditions ... were screened out,"
2. "second, surface and bottom salinities were averaged to determine ... [longitudinal] salinity gradients," and
3. "finally, a band was used to delineate the spatial variability over an annual cycle."

Low, moderate, and high variability classifications were calculated as a function of the relative proportion of the variability (item 3) to the length of the estuary. For example, an estuary with a length of 5 mi and salinity zone boundary of 4 mi would be classified as highly variable. The St. Johns River is classified in the NEI as highly variable from the mouth to the Main Street Bridge, moderate from the bridge to NAS, and low from NAS upstream (NOAA 1985, 2.16).

The relationship of chlorinity to salinity was established by an international commission in 1902 (cited by Sverdrup, Johnson, and Fleming 1942, 51, as referenced in Pyatt 1959, 38) as follows:

$$\textit{salinity (ppt)} = 0.03 + 1.805 \; \textit{chlorinity (ppt)} \tag{7}$$

The relation of conductivity (C), in micromhos per centimeter (μmhos/cm) at 25°C, to salinity (parts per thousand), assuming that the salts are in the same proportion as in ocean water, is

$$\begin{aligned} \textit{salinity} &= \textit{conductivity} \times 0.5625 && \textit{for } c < 16 \\ &= (\textit{conductivity} - 16.0) \times 0.6923 + 9.0 && \textit{for } 16 < c < 42 \\ &= (\textit{conductivity} - 42.0) \times 0.72222 + 27.0 && \textit{for } c > 42 \end{aligned} \tag{8}$$

Tables of salinity versus conductivity, with corrections for temperature, are available in standard tables and graphs.

The first published study of chlorides in the St. Johns River that was located for this reconnaissance was conducted in 1947 by the Bureau of Sanitary Engineering, Florida State Board of Health. The results were reported in the *Saint Johns River Pollution Survey* (referenced in Pyatt 1959, 6). The City of Jacksonville conducted measurements during 1954 and 1955 which were analyzed by Pyatt in 1959. The results of a comprehensive study on chlorides were published by USGS (Anderson and Goolsby 1973).

SALINITY AT THE OCEAN ENTRANCE

Many pollution computations employ distributions of salinity (or chlorinity) in an estuary as a measure of the rate of spread of a pollutant inflow (expressed as eddy diffusivity). This evaluation requires that the source of salinity or the salinity of the seawater entering into the exchange dynamics be known. The measured salinity at the river mouth is not sufficient to make this determination, as the freshwater discharges mixed into the river also affect salinities in the ocean. Seasonal measurements of salinity taken in 1953 by the U.S. Fish and Wildlife Service (Department of the Interior) showed that undisturbed oceanic water, with a salinity of about 36 ppt, is found about 10 mi offshore (Pyatt 1964, F31).

CHLORIDES, SALINITY, AND OTHER SALTS

The major physical constituent in ocean water is chloride, which constitutes about 55% of the dissolved, inactive solutes. Other salts that may be present in the LSJR, possibly in proportions other than those found in pure seawater, are sodium, sulfates, and magnesium, which are the most common solutes, beside chlorides, in ocean water. No data on individual concentrations of salts were found in the literature relating to LSJR hydrodynamics.

Measurements of dissolved solids in the river, taken from 1952 to 1965, range from 628 to 1,440 milligrams per liter (mg/L) at De Land and from 360 to 18,700 mg/L at Jacksonville. Measurements of chlorides during the same period range from 88 to 570 mg/L at De Land and 128 to 9,720 mg/L at Jacksonville (RSH 1974, 27). The maximum, minimum, and range of chlorides are less at De Land than at Jacksonville, because the principal source of chlorides is the ocean.

The mineral content of direct runoff to the river is relatively low. In some areas of the river, the water in the surficial aquifer is highly mineralized. Upward seepage from the aquifer may transport high levels of salts into the river during certain periods of the year and under certain conditions (e.g., as described in RSH 1974, 25–26).

Measurements of salinity and chlorides are normally made using specific conductance. However, this method cannot distinguish between the salinity in the sample and the salinity caused by minerals in the ground water, because conductance is simply a measure of the concentration of all of the various salts that are conducting electrons. Separate measures of the constituents can be performed with laboratory equipment. If it is assumed that the salinity in a location is due entirely to freshwater dilution of ocean water when there is a significant contribution from ground water as well, erroneous conclusions as to the rate of dispersion (spreading) of pollutants could result.

ZONE OF TRANSITION

The salinity of the river varies from about 30 ppt at its mouth to values approaching that of the freshwater inflows far upstream. USGS called the reach of the river between these two extremes the "zone of transition" (Anderson and Goolsby 1973, 12). On ebb flow, this mixed salinity water mass is carried toward the entrance, some is lost to the ocean, and the upstream part of the zone shortens. On flood flow, the upstream end of the zone lengthens again. USGS stated that "the rate of change in specific conductance is dependent on the gradient of the zone of transition" (p. 40).

The length of the zone of transition and the change in salinity within the zone vary with sea level and the volume of freshwater runoff. After a series of tidal cycles in which there are cumulative downstream net flow volumes, the length of the zone of transition decreases and the average conductivity gradient increases. In the extreme, the zone of transition can become so short that it lies entirely downstream of the Main Street Bridge, and the salinity there is nearly constant, with a value equal to the salinity of the freshwater runoff. When a series of tidal cycles occurs in which most of the cycles have predominant upstream flow, the upstream end of the zone of transition migrates a considerable distance upstream from the Main Street Bridge. In this case, the chloride concentration at Main Street Bridge approaches that of seawater diluted by local freshwater inflow (Anderson and Goolsby 1973, 13).

"Discharge accumulation," or "cumulative discharge," is the sum of consecutive downstream flows over a period of time; this sum increases with downstream flow and decreases with upstream flow (Anderson and Goolsby 1973, 40). As long as the zone of transition extends upstream from the Main Street Bridge, the specific conductance at the bridge decreases with increasing cumulative discharge, and vice versa. The rate of change in specific conductance depends on the **gradient** of the zone of transition. During a particular tidal cycle, the magnitude and range of chlorinity at Jacksonville depends on the length and gradient of the zone of transition. About 80% of the time, the chlorinity concentration at Main Street Bridge is greater than 250 mg/L (pp. 40–41).

CHLORINITY AND FLOW

A vertical gradient in water-column chlorides tends to exist in estuaries like the LSJR, but no well-defined interface between saltwater and freshwater masses has been found in this river. This lack of a well-defined interface between saltwater and freshwater masses has been attributed to the many bends and changes in cross section in the river, although salinity stratification is also a function of the balance of saltwater and freshwater flows. USGS found no fixed relation between chlorides at different sampling points (Anderson and Goolsby 1973, 44). For data taken from 1954 to 1966, USGS described two approximate longitudinal variations in the daily maximum chloride concentration in terms of the concentration that will be exceeded 7% and 50% of the days in a year, from the river mouth to Palatka (Figure 3.34).

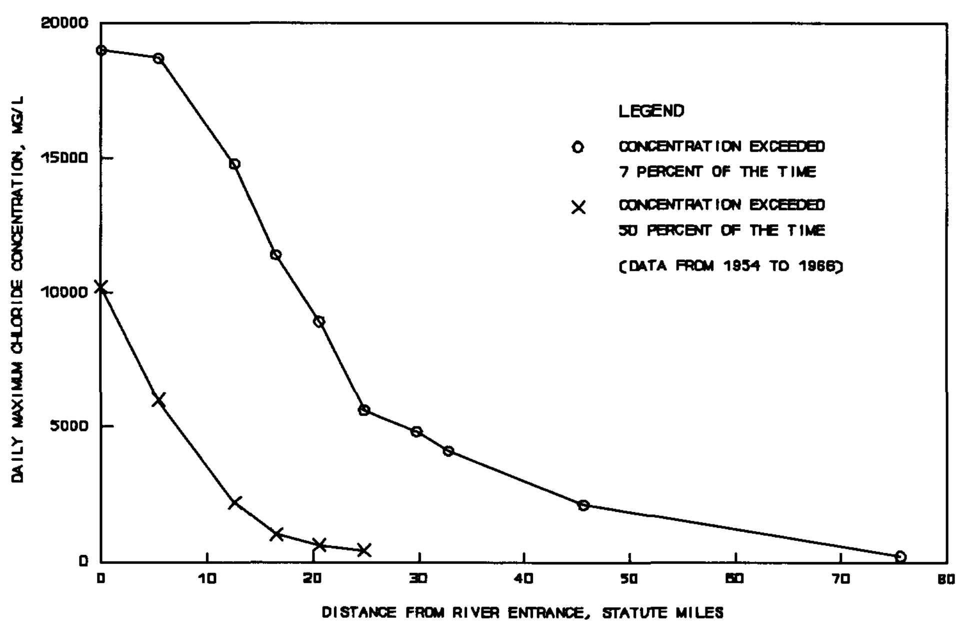


Figure 3.34 Approximate longitudinal variation in daily maximum chloride concentration that will be exceeded 7% and 50% of the days in a year (Anderson and Goolsby 1973)

In 1962, the excess of upstream flow was so great that enough seawater entered the river to cause the chlorinity concentration at Green Cove Springs, normally less than 400 mg/L, to exceed 2,000 mg/L (Anderson and Goolsby 1973, 24).

An inverse relationship exists between chlorides and net flow. The range between average maximum and average minimum chloride concentrations at Jacksonville is greatest when the net outflow is low, because the gradient of the zone of transition is steeper at Jacksonville under these conditions than when net outflow is high. That is, when net outflow is low, the Main Street Bridge is closer to the seawater end of the zone of transition, where the gradient is steep (Anderson and Goolsby 1973, 48).

From data collected between 1954 and 1966 at Main Street Bridge, the chlorinity, as would be expected, increased with an increase in upstream flow, was maximum at peak flow, and decreased as downstream flow increased. When the flow volume downstream and upstream was about equal, the chlorinity was about the same as at the start of the flood cycle. Salinity continued to decline when the volume downstream exceeded the volume upstream because the chlorinity for each ensuing cycle began at a lower concentration. These types of changes cause a wide variety of chloride distributions to occur in the river (Anderson and Goolsby 1973, 11).

STRATIFIED FLOW

The flow in a tidal river will develop a significant vertical salinity difference when freshwater inflows are relatively large and there is relatively little vertical mixing. This vertical difference can develop into a distinctly layered, or stratified, flow if there is enough freshwater inflow over a long enough period of time. Near the mouth of the river, and possibly for a long distance upstream, a salinity wedge can develop as the incoming, denser salt water pushes under a lighter, fresher outgoing surface flow. The salinity interface, or front, can often be detected at the surface by changes in color or surface flow or debris patterns.

One set of measurements taken through a half tidal cycle in May 1966 shows the vertical difference in specific conductance, decreasing from 3,000 µmhos/cm at Jacksonville upstream to 300 µmhos/cm at a point 26 mi upstream (Anderson and Goolsby 1973, 44).

On occasion, similar estuaries have a return flow in the lower layer about one-tenth the magnitude of the upstream wind-induced flow (Atlantis Scientific 1976, II-11).

A well-defined saltwater/freshwater interface is not normally found in the St. Johns River, especially in the Jacksonville area. However, in a USACE report on Mill Cove, evidence is presented for a salt wedge extending upstream to the open area beyond the Fuller Warren Bridge. This salt wedge is described as highly variable (USACE Jacksonville 1981, B-6).

MIXING

Chlorinity data were collected by USGS at three depths at each of eight stations from Mayport to Orange Park from February 1954 to October 1957. At a particular station, chlorinity was found to be homogeneous over the latter part of the flood tide, which implies extensive mixing. This reach of the river tends to stratify at high slack tide, particularly at the three lower stations downstream of Main Street Bridge. After the ebb flow, there is a tendency for stratification at low slack tide (Pyatt 1964, F36). However, there is neither a well-defined salinity front nor a salt wedge, but rather a definite longitudinal movement and vertical gradient of chlorinity in response to freshwater inflow. The data in Pyatt's report indicated that discharges below about 4,000 cfs at Main Street Bridge for 10 to 15 days results in good vertical mixing throughout the study area, but flows above 4,000 cfs for the same period of time will move the chlorinity distribution downstream and produce appreciable vertical stratification. The degree of vertical mixing was greatest at Mayport and decreased progressively the larger the cross-sectional area (Pyatt 1959, 39, 105; 1964, F32).

FLUSHING RATE

Flushing is the process of removing pollutants from a water body. Flushing rate is defined as the rate at which the total volume of a polluted water mass is exchanged with water from outside the polluted water body. It is usually quantified by an analysis of velocity and salinity data or by analyzing the results of dye diffusion tests.

Several investigators have developed methods for quantifying flushing in idealized estuaries. Assuming complete mixing of the tide with the resident water on the flood cycle, a flushing rate can be calculated by comparing the tidal prism (the volume of water introduced and removed over a tidal cycle) to the total volume of the estuary. A more advanced theory relates the longitudinal salinity distribution resulting from equating the advective flux of salt to the landward eddy-diffusion of salt, to a constant called the flushing number. A still more recent approach was based on equations that balanced the net seaward flux of a pollutant to the sum of the advective and turbulent fluxes. This method, which assumed steady-state conditions and a vertically mixed estuary, is a very simplified numerical model. Pyatt (1959) discussed the above approaches but did not publish a flushing rate for the LSJR (pp. 28–29). No other investigators mentioned this topic in connection with work in the LSJR.

OVERMIXING AND THE CONTROL SECTION

In some strongly stratified estuaries that have a net outflow in the upper layer and a net inflow in the lower layer, or for an estuary with a large runoff volume, hydraulically critical velocities may be approached or reached. When this happens, an abrupt change in channel dimensions (usually width) may act as a hydraulic control to limit both the net volume flow out and the net volume flow of seawater in. This, in effect, limits the amount of seawater available for mixing and, as a result, no matter how intense the mixing is within the estuary, no increase in the salinity of the outflowing mixture is possible. This phenomenon is called "overmixing." Stommel and Farmer (1952a) developed equations that showed that an estuary may be called overmixed if a plot of discharge versus the stratification (delta-s/s) is a straight line on log-log paper. In these equations, "delta-s" is the mean difference in top and bottom salinity, and "s" is the bottom salinity (Pyatt 1959, 106).

Stommel and Farmer (1952b) suggested that a control section that will cause an overmixed condition exists in the St. Johns River. Pyatt tested Stommel and Farmer's suggestion by calculating stratification and discharge at each of five sampling stations. He stated that the results indicated that Stommel and Farmer "were probably correct in contending that a control section exists in the St. Johns," and that the control section in the river is probably the narrow constriction at Main Street Bridge (Pyatt 1959, 106; 1964, F42).

Influence of Salinity on Pollution

The water quality of the river is controlled by its flow. The flow is such that the lower river can become saline as a result of upstream flow or severely polluted with waste inputs as a result of low net outflow (Anderson and Goolsby 1973, 51–52).

The flow at Jacksonville over a 24-hr period is often upstream. Upstream flow occurs, in part, because of the flat riverbed gradient and broad, shallow characteristics of the river. Water is stored in the upstream reaches at times of high tidal stage (not necessarily high tide) when the hydraulic gradient is reversed.

During periods in which discharge is highly variable, and often sustained in the upstream direction, the distribution of pollution may have almost nothing to do with corresponding instantaneous flow. The sequence of antecedent discharge usually explains the fate of pollutant inflows (Atlantis Scientific 1976, II-8).

Recent Observations on Salinity

Measurements of salinity taken by SJRWMD since the late 1980s indicate that salinity decreases fairly rapidly from the mouth of the river to NAS, about 30 mi upstream. Within this reach, the mean salinity changes from polyhaline (30 to about 18 ppt) to mesohaline (18 to 5 ppt). From NAS to a location just south of Black Creek, the mean salinity further decreases to about 0.2 ppt, and from this location upstream the mean salinity fluctuates between 0.15 and 0.20 ppt. In spite of the existence of these data, salinity data are still too sparse, both spatially and temporally, to permit a reliable description of salinity characteristics in the river. Instead, the following observations can be made:

- Fresh water does not stay resident in the LSJR for long. Freshwater inflows are generally carried out of the system within a relatively short time period.

- There is no oceanic salinity (i.e., salinity greater than about 30 ppt) upstream from the intersection of the river with the ICW.

- Salinity stratification, except for transient tributary inflow events, occurs only from Orange Park to the mouth of the river.

- A turbidity maximum occurs in the vicinity of Orange Park, which is the approximate limit of marine forms from downstream. In this area, the freshwater plankton from upstream also disappear.

- In the vicinity of Picolata (RM 55), a decline in the numbers of estuarine plankton, and therefore in estuarine conditions, is evident moving north toward Orange Park.

- Upstream of Palatka, freshwater inflows create a zone that is, at least physiologically, an estuarine zone, with high chlorinity (8–9 ppt) and conductivities that are driven by ground water. A resident population of estuarine organisms lives in this area.

SUMMARY OF SALINITY

Salinity in the LSJR is highly variable and dependent on flow. A comprehensive set of salinity data on the main stem as well as the tributaries will have to be collected before the salinity balance, fluctuations in the salinity distribution, and stratification can be described.

The river contains both chlorides and minerals that affect the conductivity of the water and are not discriminated in routine field sampling of conductivity, the most common method in use for salinity measurements. Therefore, specific measurements and analyses are needed to characterize the river's chemistry, density structure, and saltwater/freshwater balance.

In the past, the salinity distribution was described in terms of a "zone of transition," the region of the river in which water was not either oceanic or fresh. This is a useful general concept for describing qualitatively the seasonal fluctuations in the saltwater/freshwater balance, but not the details of density-driven circulation.

The river can be classified and segmented to a certain extent based on salinity distributions. It fluctuates between a Pritchard type A and type B, which indicates that it is characterized by moderate to high stratification.

The river occasionally becomes vertically stratified in the Jacksonville area. One investigation stated that a well-defined saltwater/freshwater interface is not usually observed, while another investigation presented evidence of a salt wedge extending upstream beyond the Fuller Warren Bridge (west of Main Street Bridge at RM 25).

For one set of measurements in 1966, the vertical-mean salinity decreases rapidly from 3,000 µmhos/cm at Jacksonville to 300 µmhos/cm 26 mi upstream. However, the longitudinal distribution of salinity is very much dependent on the hydrologic cycle and the mean tidal range.

HYDRODYNAMIC AND WATER QUALITY MODELS

Various types and categories of models have been developed for a wide range of tributary and estuarine phenomena. In general, the purpose of a water body model is to represent processes and relationships, such as the flow of water (hydrodynamics), chemical interactions, pollutant transport, and/or system ecology in a way that enables the user to study, to understand, and to predict the dynamics of the system. Hydrodynamic models can be used for investigating mass balances, cause and effect relationships, the response or sensitivity of the water body to changes in input conditions, the transport and fate of pollutants, residence and flushing times, and other characteristics. This chapter reviews the hydrodynamic model studies that have been published for the LSJR and, because in most cases these studies are linked to water quality, water quality models will be included in the review.

Models can be divided into three main categories, for which the common nomenclature is "statistical," "physical," and "numerical." A statistical model is one that is based on a relationship that has been developed by means of a statistical analysis. Statistical models are used when the structure of the system is unknown, its components and interactions are too complex to be mathematically described, or the budget or time for data collection and modeling is limited. A physical model is one that incorporates a confined flow of water, usually scaled smaller than the actual, or prototype, water body. Such a model is employed when the components and interactions of the phenomena to be represented are too complex to be mathematically described or the components and interactions operate over such a wide range of time and/or space scales that it is impractical to model them any other way. A numerical model is one that is based on mathematical equations, which are usually of the partial differential type. These models are used when the major phenomena can be adequately represented by equations that can be solved by computational (computer) techniques. Categorized in this manner, the methods of representation of the three types of models are summarized in Table 3.33.

Table 3.33 Categories and representation of water body models

Category	Representation of Prototype	Mathematical Implementation	Type of Mathematical Solution
Statistical	Mathematical	Statistical	Algebraic
Physical	Scaled-down basin partially filled with water	Scale model laws (ratios)	Algebraic
Numerical (computational)	Dynamic equations of continuity, momentum, and state	Partial differential equations and difference equations	Numerical (computational)

SPATIAL AND TEMPORAL SCALES

An important concept in modeling is the "scale," a term used loosely in this report to describe the scope, the ratio of model phenomena to prototype phenomena, and the resolution of the model. The "prototype" is the actual water body that is represented by the model. The three parameters describing the scale of the three categories of models are compared in Table 3.34.

The "spatial scope" of the model is the extent of the physical area to be represented in the model. The "spatial ratio" of model area to prototype area is a design feature of a physical model, but it does not apply to numerical models because they use prototype dimensions. The "spatial resolution" is the size of the smallest area that is quantified in the model, typically the size of a computational element. In a numerical model, spatial resolution is a design feature that is determined by the requirements of the problem, the user, and the limitations in the model.

The "temporal scope" of the model is the maximum practical length of time that a simulation can be run. Depending on the types of equation used, the duration of a numerical simulation can be limited by considerations of numerical stability. The "temporal ratio" is the ratio of model run time to real time, which depends on the model code and the computer characteristics, and may be one or more orders of magnitude less than one. The "temporal resolution" of a

Table 3.34 Spatial and temporal scales in models

Scale Parameters	Model Type		
	Statistical	Physical	Numerical
Spatial scope	Geographic area represented by data	Geographic area covered by model	Geographic area covered by model
Spatial ratio	Same as prototype	Ratio of model to prototype dimension	Same as prototype
Spatial resolution	Same as any data interpolation used in the data	Infinitely small	Size of computational element
Temporal scope	Period of time represented by the data	Longest period of time simulated	Longest period of time simulated
Temporal ratio	Dependent on method used for representing time	Ratio of model time to prototype time	Ratio of model run time to real time
Temporal resolution	Same as any data interpolation used in the data	Time step in the model	Time step in the model

numerical model is the smallest time step that is required, which also depends on the type of model, the processes represented, and the speed of the computer.

STATISTICAL MODELS

Statistical models are used when the problem does not justify the time and expense of developing a physical or numerical model and the relationships between causes and effects are relatively simple and linear but may not be describable on a deterministic or physical basis. A stochastic model is a statistical model that includes a random element. Statistics are used to determine overall characteristics of the estuary, such as mean values, ranges, and reproducible cause/effect relationships. A statistical model requires a full set of data on independent and dependent variables in order that analyses can be performed.

Water levels, flows, and concentrations are calibrated by changing unknown variables in the equations.

An example of an application of the statistical approach is a calculation of the nutrient balance in an estuary using monthly or semiannual water quality and flow measurements. In this case, the cause and effect may not be able to be described physically, yet a description of the relationship between water quality and season may be derived if the data are of high quality, consistent, and cover a long enough time period. Another example of a statistical application is the determination of assimilative capacity in a tidal water body, as described in a report on the LSJR by Pyatt (1964).

PHYSICAL MODELS

Physical models are dynamic. They attempt to reproduce the flow, salinity, and/or sand or sediment transport in an estuary, or portion of an estuary, using a scaled-down body of water. The depth irregularities (vertical scale) are reproduced at a different spatial scale than the shoreline dimensions (horizontal scale), and the flow of water through the model is controlled by a tide-generating machine. Water levels and flows are calibrated by bending small vertical metal strips that are set into the concrete model bed. Wind is often blown over the water by a fan, and the flow patterns are often quite realistic. However, because the vertical and horizontal spatial scales are different and time is often compressed, a set of model laws or mathematical ratios must be used to transform the values measured in the model to the values to be expected in the prototype.

In 1945, a physical model of the St. Johns River and its major tributaries from the mouth of the river to Welaka was constructed by USACE at the WES in Vicksburg, Mississippi. This model was used to evaluate effects of dredging and navigation improvements in the vicinity of Jacksonville. After extensive measurements of currents and salinity had been evaluated, estimates of freshwater discharge from upstream were judged to be inadequate to reproduce measured salinities. Therefore, a mean freshwater discharge of 17,000 cfs was used to obtain a "reasonably" good model verification (WES 1947, 18–19).

In 1946, the WES physical model was used to evaluate the advective strength of tidal currents along the west bank, between the mouth of the Ortega River and the CSX RR bridge. The study used a tidal range of 1.2 ft and a mean freshwater discharge of 12,000 cfs. The study was described in an appendix to the WES (1947) report and reviewed by Pyatt (1954, 14).

The University of Florida CEL constructed a similar model for an evaluation of the distribution of current in the vicinity of Baptist Memorial Hospital in Jacksonville (CEL 1959). Recommendations were made as to volume of fill and modifications to the local bulkhead.

A physical model of Mill Cove, a nearly isolated side channel east of Jacksonville, has been sponsored by the Department of the Navy and USACE Jacksonville. The model was built in the 1970s at WES. Its purpose was to test circulation, scour, and flushing in the small embayment in order to find a structural way to minimize shoaling.

A series of reports on Mill Cove was produced by WES. Report 1 described the hydraulic, salinity, and shoaling model verification (Brogdon 1979). Report 2 described the Mayport Naval Basin study phase (as reported in Brogdon and Parman 1979). Report 3 described model tests of plans to improve flushing and decrease shoaling in Mill Cove and the navigation channel (Brogdon and Parman 1979). The Brogdon and Parman report described tide stages measured at 10 stations and current velocity data at 14 locations along the navigation channel and at 14 locations in Mill Cove (p. 20).

The Mill Cove model was calibrated for conditions existing on November 7, 1974: tide at Little Talbot Island was set at 5.4 ft, river freshwater discharge was estimated to be 8,950 cfs, and ocean salinity was 33 ppt. For the shoaling tests, the same data were used except that the tide was set at 5.1 ft to achieve calibration. The navigation channel was 38 ft deep, except for a short reach through the outer bar and the entrance channel, which was set at 42 ft MSL.

Effects on baseline hydraulics, salinities, dye dispersion, and channel shoaling are described by Brogdon and Parman (1979, 5). Velocity data were analyzed to determine flow predominance. It was found that the magnitude, direction, and duration of flow could be reduced to a single expression defining the predominant direction and percentage of total flow at any given location in the cove (p. 23). Conclusions with regard to scour and flushing in Mill Cove are also given (pp. 106, 108).

NUMERICAL MODELS

The numerical models for the LSJR that have been developed and published are hydrodynamic models which, in most cases, include water quality components. In the discussion of LSJR models, it is necessary to distinguish between non-tidal tributary models, tidal tributary models, and river estuary models. The term "tributary model" does not clearly distinguish the type of flow involved, although it often implies a uni-directional flow model that does not include a tidal influence. In cases where winds may be strong enough to temporarily reverse the flow, a uni-directional model will not be adequate, even for a non-tidal tributary, unless wind effects are not included. The tidal portion of a tributary and/or a river estuary must be represented by a tidal model, which can accommodate reversing flow. The important difference between non-tidal and tidal models is that tidal models incorporate bi-directional flows.

Numerical models may be solved either by implicit, explicit, or a mixture of implicit and explicit procedures. An implicit solution solves all equations simultaneously at each time step by matrix inversion. An explicit model solves all equations sequentially at each time step. The implicit solution has the advantage of not being limited to a small time step, but it is iterative and may, therefore, require a longer time to converge to a solution. The explicit method is relatively fast but is limited to relatively small time steps because of the Courant, Friedrichs/Lewy stability criterion. This limit states that the time step must be short enough to preclude the movement of a particle into and out of the same computational cell in one time step. It also implies that, in order to use a larger time step, cell sizes must be increased proportionally. The ideal case would be to use small cells and large time steps (e.g., 15 minutes to 1 hour or greater time steps).

The limiting water movement in a tidal model is the celerity (speed) of the tidal wave, which is proportional to the depth of the navigational channel. In a 15-ft-deep channel, the tide moves at a celerity of approximately 22 feet per second. A cell length of 1,320 ft is the minimum size that can be used with a 60-second time step to accommodate this tidal celerity. Conversely, for the same channel depth, a 5-minute time step would limit the minimum cell length to 6,600 ft.

The tidal portions of tributaries, and the confluences with the main stem, have complex flow patterns varying significantly in all directions and with time. Flow in the main stem of a river will have different characteristics than in its tidal tributaries; in the LSJR, these characteristics are determined by the effects of ocean tide at the inlet, its over-100-mi length, and the combination of many inflows. Tidal flows, which are incorporated in all estuary models, also are affected by wind and the density differences caused by variations in salinity. Many hydrodynamic models do not incorporate density and some that do have only one-way ("loose") coupling to the salinity. A fully coupled salinity model will correctly simulate flow caused by salinity gradients as well as the movement of salt by transport and dispersion.

Model Selection

Selection of the model to be used for a particular water body must be based on a clear understanding of the significant characteristics of the water body, the management questions to be answered, and the expected resolution and reliability of the results. The management questions must specify both the space and time scale to be used, as well as other characteristics of the problem such as

What processes are significant?
Which variables have to be quantified?
Where in the water body are results needed?
Are instantaneous or average results required?
What physical resolution is required?
Over what time period are results required?
What accuracy of results is required?

Then, from a knowledge of the system or from some preliminary modeling effort to gain an initial understanding of the system and the problem(s) to be answered, the modeler can determine what processes need to be included in the model and the degree to which the general equations can be simplified.

A modeler selects a model, or assembles a model from various equations to represent the active processes, by considering the options available in a variety of categories. Some of the basic choices for a numerical model are summarized in Table 3.35.

Table 3.35 Numerical model feature choices

Category	Choices
Physical process	Level, velocity, momentum, density, etc.
Variation in space	Uniform vs. non-uniform (box, grid, etc.)
Variation in time	Steady, averaged, unsteady (dynamic)
Type of equation	Finite-difference, finite-element, etc.
Water surface	Free or rigid-lid (fixed)
Solution technique	Implicit, explicit, mixed-mode, etc.
Spatial viewpoint	Eulerian, Lagrangian
Temporal viewpoint	Instantaneous or time averaged
Horizontal grid type	Rectangular, curvilinear, fitted, etc.
Vertical grid type	Variable, fixed, sigma-stretched, etc.
Number of dimensions in model	1, 2 (laterally averaged), 2 (vertically averaged), 3, or mixed
Spatial scale	Near-field, far-field
Temporal scale	Intra- and inter-tidal, seasonal, multi-year

Eulerian versus Lagrangian Flow

Flow may be described as Eulerian or Lagrangian. All flows described in this report have been Eulerian; the descriptions are based on the viewpoint of the entire flow field or the patterns of all flows in a particular area. Conversely, for some phenomena, it is convenient to describe the movement of one or more particles or contiguous water masses relative to all other water in the same volume. This viewpoint, called Lagrangian flow, focuses on the tracks or time history of individual or groups of particles. The latter is of interest, for example, in determining residence times and flushing rates. No Lagrangian models of the LSJRB have been described in the literature.

NUMERICAL MODELING PROJECTS

Frederic R. Harris, Inc. Modeling

In 1972, the Jacksonville Area Planning Board (JAPB) received a grant from EPA to develop a water quality management plan for Duval County. JAPB contracted with USGS, the City of Jacksonville Department of Health, and the City of Jacksonville Bio-Environmental Services Division (BESD) to work as members of the study team to develop the plan and with Frederic R. Harris to provide overall technical direction. Frederic R. Harris subcontracted portions of the mathematical modeling to Clemson University, the University of Florida, and Florida Technological University. The purpose of the plan was to develop a cost-effective solution for managing wastewater treatment systems to achieve and to maintain water quality standards (Frederic R. Harris and the Jacksonville Area Planning Board 1973, I-5).

The assimilative capacity of key tributaries was determined using the Simplified Math Model developed for EPA by Hydroscience. Dissolved oxygen (DO) levels were calculated from known point source waste loads, and organic load allocations were determined for individual dischargers (Frederic R. Harris and the Jacksonville Area Planning Board 1973, II-6, XIII-3).

The Edge model represented the river from the ocean to Palatka. This hydrodynamic model was calibrated for low-flow conditions with a mean inflow of 6,000 cfs at Palatka and comparisons of predicted tidal levels, times of occurrence of high tide, and chloride distribution. The water quality model was calibrated with biochemical oxygen demand (BOD), DO, and chloride data collected over a 3-day period in June 1973. The model was used to evaluate alternative wastewater plans, including regional plant, military base, industrial, and municipal outfalls (Frederic R. Harris and the Jacksonville Area Planning Board 1973, II-7, XII-11–12).

Edge (Clemson) Model

A dynamic, sectionally averaged (link-node) numerical hydrodynamic model of the LSJR, which also includes a water quality component, was developed by Dr. Billy Edge of the Department of Civil Engineering, Clemson University, in 1972–73 (Edge 1973). The Dynamic Estuary Model (DEM), a one-dimensional link-node model first developed by Water Resources Engineers (WRE) beginning in 1965, served as the starting point (WRE 1965). DEM incorporates one-dimensional equations for conservation of mass and conservation of momentum to represent advection, turbulent diffusion, and dispersion phenomena (Feigner and Harris 1970). The Pearl Harbor version of this model was obtained from EPA and modified for this application. The usual assumptions for a one-dimensional estuary were accepted: it is assumed that there are no gradients in the vertical or transverse direction and that water density, the longitudinal dispersion coefficient, and all quality constituents are constant. In addition, the turbulent energy loss (friction) coefficient was set to a constant value, and it was assumed that none of the material lost from the estuary was returned by the tide.

A link-node model is based on division of a river into sections. Each section is represented by a node (or junction) and the nodes are connected by links (or channels). The LSJR from Palatka to its mouth was first represented in the DEM model by a 35-junction, 39-channel network (Table G2). The dimensions of the model are not tabulated in the report, but the network is depicted in Figure 3.35

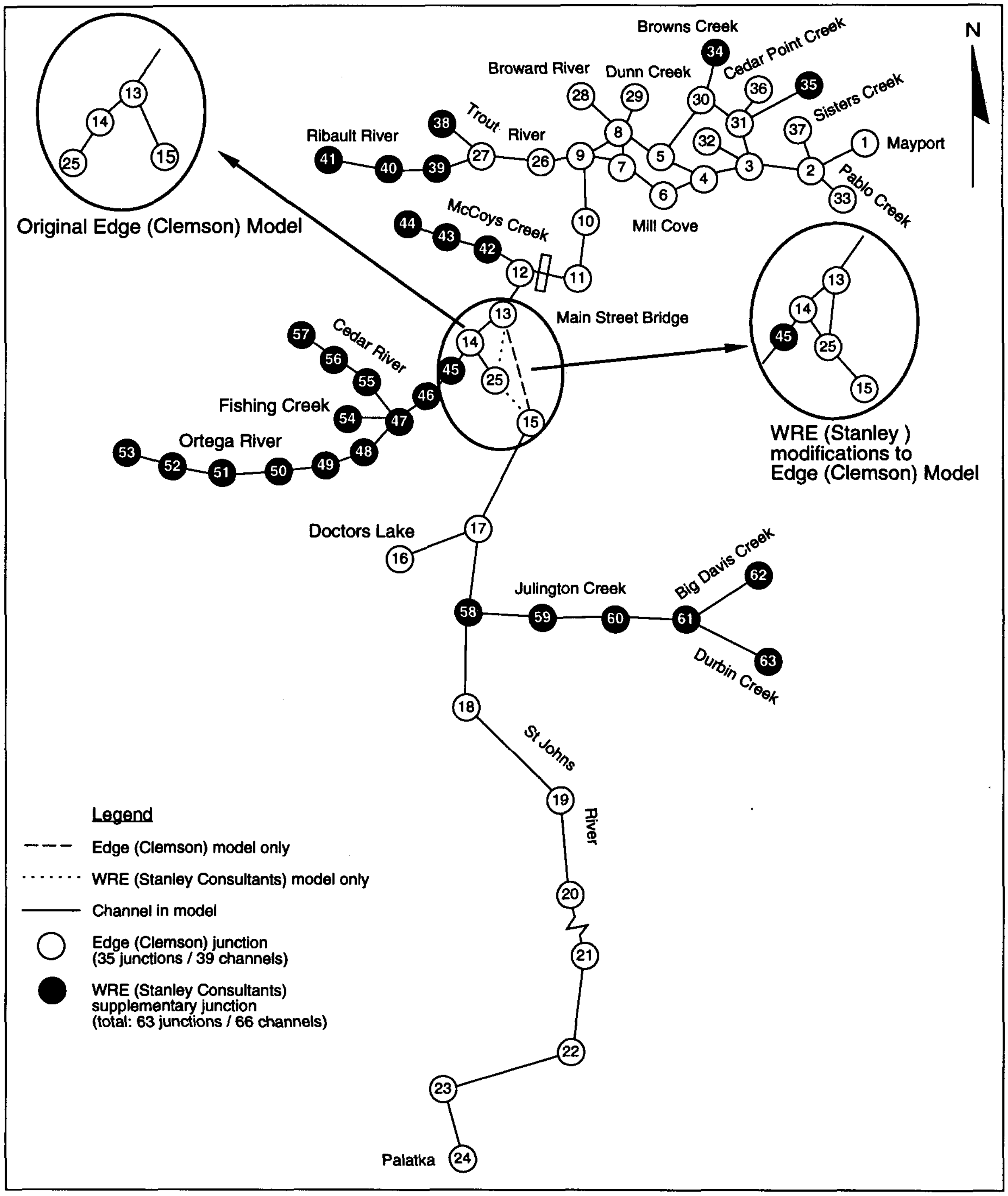


Figure 3.35 Nodal networks for the Edge (Clemson) and WRE (Stanley Consultants) link–node models (Edge 1973, 9, Figure 2; Stanley Consultants and Water Resources Engineers 1978, 4–42, Figure 4–4)

(Edge 1973, 9, Figure 2). Another company, Stanley Consultants, extended the Edge (Clemson) model to 63 junctions and 66 channels by adding major tributaries. In the process, a few of the junction numbers in the vicinity of the confluence of the Cedar and Ortega tributaries were changed (Stanley Consultants and WRE 1978, 4–42, Figure 4-4; Figure 3.35). The channel lengths, widths, and depths and the channel-to-junction connectivity are listed for both models in Table G1 (Appendix G).

The hydrodynamic part of DEM, called DYNHYD, was used in Edge's model to calculate the water level at each node and the velocity in each of the connecting links. Boundary conditions consisted of constant inflows and a single repeating tidal cycle. Calibration of the hydrodynamic model was based on tidal data from NOS for Mayport and flow data from USGS for July 1972. The verification process was discussed, but no results were reported.

The hydrodynamic model output is saved and used as input for the water quality component, DYNQAL. The quality model simulated BOD, DO, and chlorides. The reaeration rate, saturation level of DO, benthic oxygen demand, and temperature were specified as constant. Supporting field surveys were conducted in July 1972 and June and July 1973, and the 1973 surveys were used for the water quality calibration. The deoxygenation rate coefficient or rate of BOD (K1) and the rate of reaeration (K2) were calculated as a function of local depth, velocity, and temperature at Palatka. At the tidal entrance of the model, an exchange coefficient of 10% for chlorides and a fitted BOD decay coefficient were used. Calibration results were considered adequate, except for DO at some stations.

The model was applied for two conditions: (1) the 1972 loadings with a low flow of 500 cfs at Palatka and (2) the loadings expected in the year 2020. Edge states that, when used to compare management choices, the model will provide quite useful results, whereas when used for other purposes, the results may be misleading (Edge 1973, 44).

Connell (Hydroscience) Model

Connell Associates, of Coral Gables, referenced a water quality modeling study that was being conducted for the "Jacksonville metropolitan area" at the time of their report (1974, 4-48). This report referred to the support of Frederic R. Harris (described below) in assisting in the calibration of the Edge (Clemson) model as part of Harris' support for the Metropolitan Regional Plan for JAPB (Edge 1973, i).

Connell Associates conducted a model study of several Florida drainage basins, including the LSJR, for the Florida Department of Pollution Control (FDPC) in 1971 and 1972 and published the results in 1974. Connell Associates subcontracted with Hydroscience to develop and to verify the water quality model with data provided by Frederic R. Harris, JAPB, Connell Associates, FDPC, and other state agencies. The model was to be used primarily as a management tool for formulating decisions on waste load allocations through predictions of DO and eutrophication. Water quality field studies were limited to the part of the river upstream of Palatka.

The model was based on steady flows; it was not a dynamic model. Its scope was initially limited to that part of the river lying between Lake Hellen Blazes in the Upper St. Johns River Basin (Figure 1) and the Duval County line near Jacksonville. This reach was represented with 25 segments ranging from 1.5 to 4.2 mi long. Later, the model had to be extended to the river mouth with 41 additional segments to resolve steep salinity gradients. Net flows (20-day averages of data taken in July 1972) to Palatka were estimated directly from USGS gaging station records at De Land, Palatka, intermediate tributaries, and Jacksonville. Only the main stem of the river was modeled; tributaries were treated as inputs.

The river geometry segmentation is summarized in a report on the water quality modeling study for four Florida basins. The segmentation is reproduced in Figure 3.36 (Connell Associates 1974, Figure 4-20, 4-49–51). The segment widths, depths, and volumes used in the Edge (Clemson) model are compared in parts A–C of

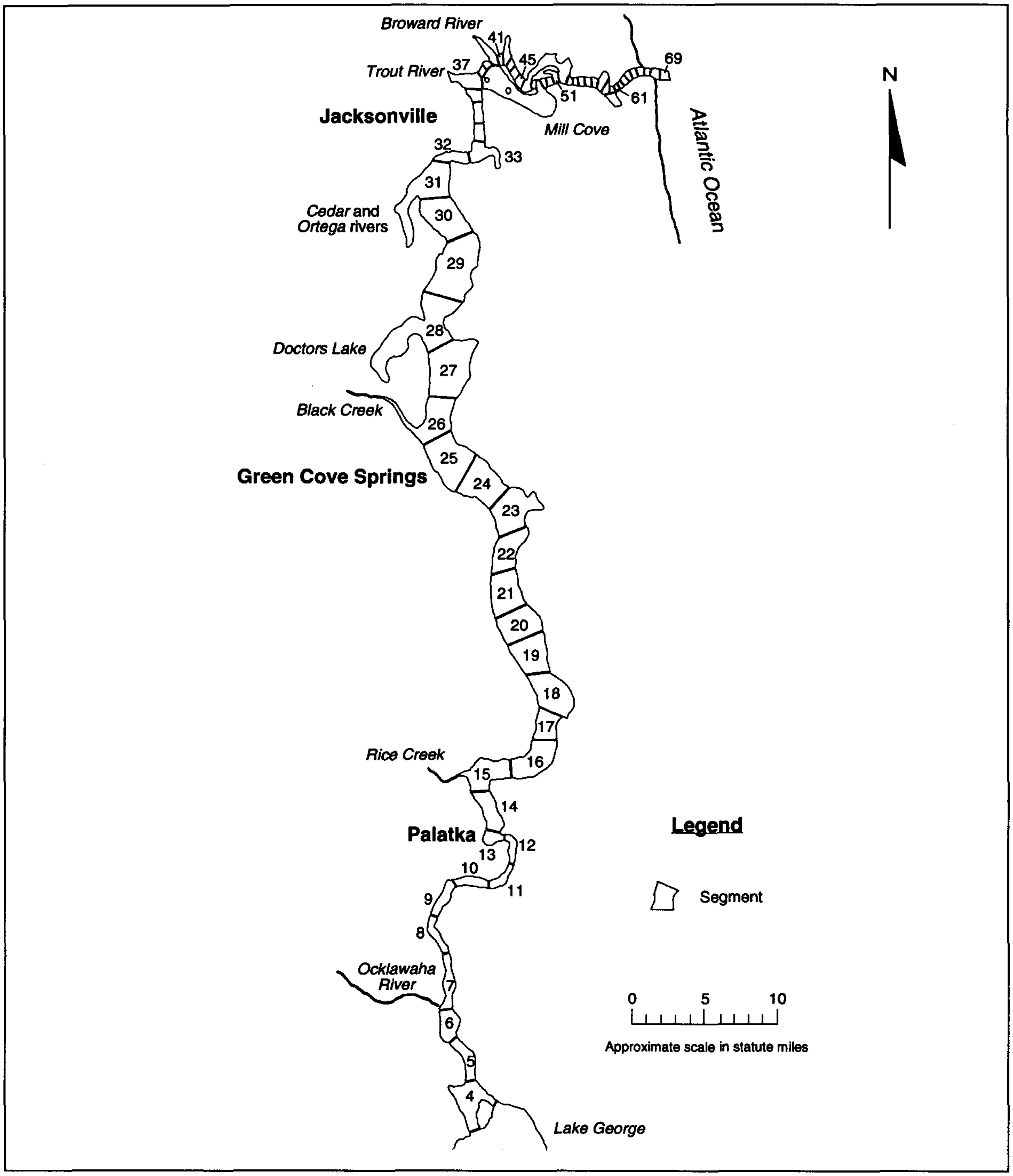


Figure 3.36 Network for the Connell one-dimensional segmented model
(Connell Associates 1974, 4-49, Figure 4-20)

Figure 3.37, with the corresponding estimates of river geometry given by Connell Associates.

The reader should not expect the pairs of distributions in Figure 3.37 to match the dimensions represented in Figure 3.2. In addition to their role in representing the shape of the river, segment dimensions for a model also must represent the dimensions that will modify the simulated flow to account for energy (friction) losses. Model dimensions are often modified to assist in calibrating a one-dimensional model.

The conservation of constituent mass equations in this model use a two-dimensional (horizontal) set of constant net-non-tidal flow and tidal mixing coefficients to allow for lateral flow as well as longitudinal flow in the tidal hydrodynamics. These longitudinal and lateral flow advection constants were used to calibrate the model. The longitudinal dispersion coefficients, obtained during verification, varied from 23 mi^2 per day at the mouth to 0.5 mi^2 per day near the Ocklawaha River (Connell Associates 1974, 4-53).

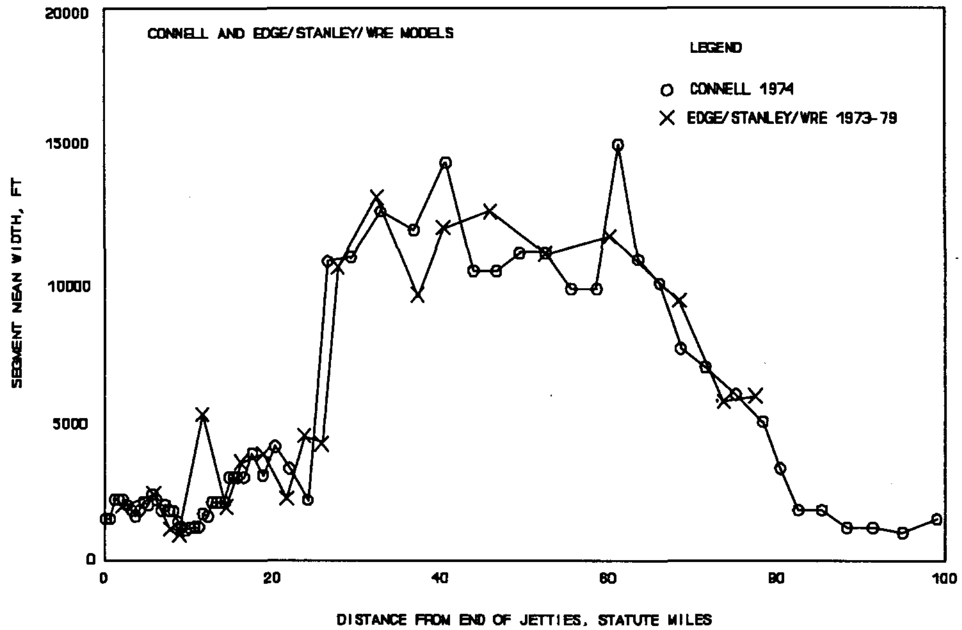
Water quality data were collected at 24 sampling stations from Palatka to the mouth of the river during 1972. Parameters included chloride, temperature, suspended solids, total phosphate, total nitrogen, BOD, DO, and total coliform. Other data, including some from STORET (EPA's data base), were used. Hydrologic data were obtained from six USGS stations, the most southerly located at Palatka.

Basin water quality models developed by Hydroscience were used to allocate waste loadings through DO and eutrophication assessments.

HydroQual Model

In the early 1970s, HydroQual developed a steady-state finite-difference model called the Sparse Matrix Analysis Model (SPAM) for EPA. EPA changed the name of this model to HARO3 for its original general-use release. Later, a PC version of SPAM, called the Estuary Steady State Model (ESSM), was made available.

A



B

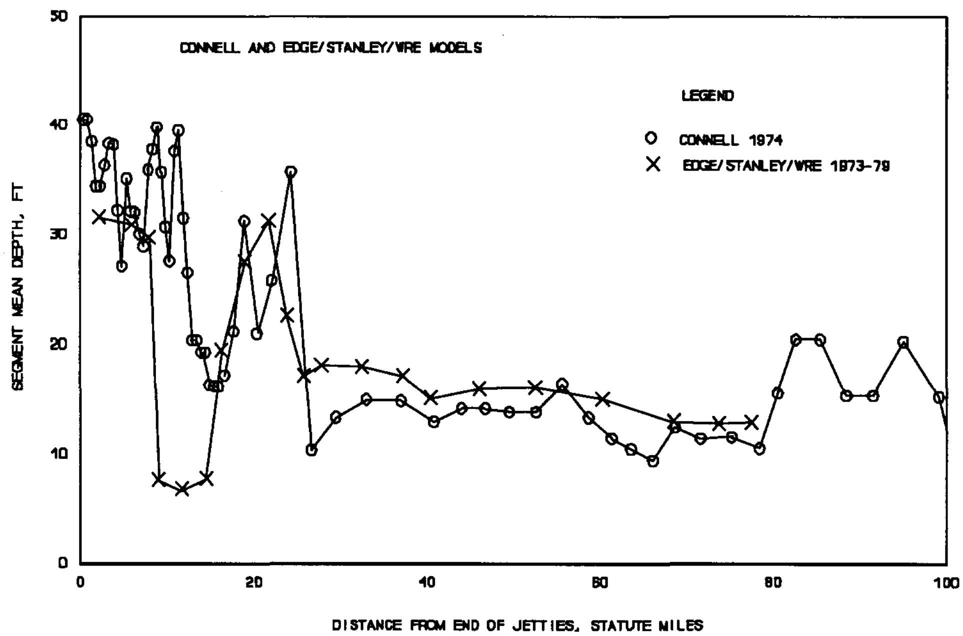


Figure 3.37 Comparison of mean widths (*A*), mean depths (*B*), and mean volumes (*C*) of the lower 100 miles of the St. Johns River as used in numerical models of the river

C

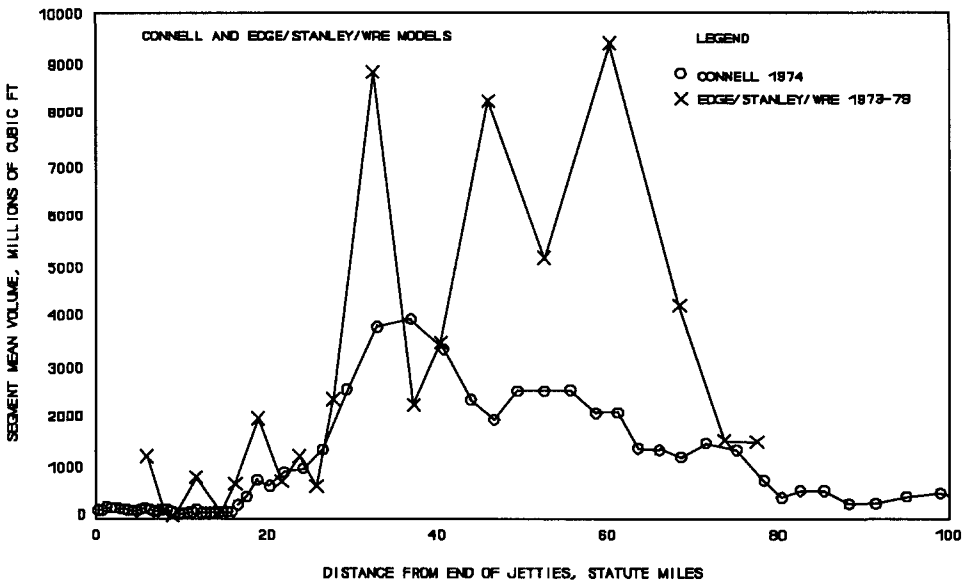


Figure 3.37—***Continued***

SPAM was used for water quality simulations in the St. Johns River by Hydroscience in 1973 (Connell Associates 1974; HydroQual 1994). SPAM simulates salinity, DO, BOD, carbonaceous oxygen demand, nitrogenous BOD, sediment oxygen demand, and net daily photosynthesis, respiration, and reaeration for algal growth and decay. In 1976, this model was used by HydroQual for the St. Johns River part of the Rice Creek water quality model. Since the 1980s, HydroQual has adapted SPAM to represent both Rice Creek and the contiguous St. Johns River.

Atlantis Scientific Model

Atlantis Scientific conducted a water quality analysis on the Duval County area of the river and published results in 1976. The stated objective was to separate point-source impacts from natural conditions. At that time, the best estimate of the average net discharge of the LSJR was between a low of about 3,000 cfs in May and a high of about 9,000 cfs in October (Atlantis Scientific 1976, V-

1a, Figure V-2). The calculated monthly mean was 5,833 cfs and the estimated monthly mean was 8,100 cfs (RSH 1975, as referenced in Atlantis Scientific 1976, II-8). It was considered necessary to modify the Edge and Connell models because the flows did not adequately represent the 7-day, 10-year conditions. Atlantis Scientific considered Connell's flow (7,200 cfs in Connell Associates 1974, 4-53) to be slightly greater than the average and stated that the Edge model did not show the reverse flows, which occur frequently and for long periods. Design flows covering a range of downstream flows typical of the seasons with substantial, but conservative reverse flows, were selected for model runs. Examination of oxygen deficits versus flow suggested that natural conditions other than flow (e.g., temperature, evaporation, and photosynthesis) dominate the system. Also, Atlantis Scientific recommended the use of data for October, February, June, and August for design at both Jacksonville and Palatka because those months include the seasonal extremes and mid-points (Atlantis Scientific 1976, V-1).

Water Resources Engineers (Stanley Consultants) Model

Water quality modeling studies of the St. Johns River were conducted in 1977 and 1978 by WRE as subcontractor to Stanley Consultants, in support of the Areawide Wastewater Management Study element of Stage II of the Metropolitan Jacksonville Water Resources Study conducted by USACE through the Urban Studies Program. The objective was to extrapolate allowable waste loads from nonpoint sources to ten additional watersheds, considering runoff and streamflow characteristics, drainage area size, and land use.

Water quality modeling was conducted in both riverine and estuarine regions of the St. Johns River.

The WRE Riverine Model. The riverine part of the WRE model, a one-dimensional link/node network, was applied to Sixmile Creek (in the non-tidal reaches of the Ribault River), the non-tidal reaches of Julington Creek, McGirts Creek (in the non-tideal reaches of the Ortega River), and the non-tidal reaches of the Cedar River. Boundary conditions included steady (non-time varying) freshwater inflows, steady wastewater discharges, and one representative tidal cycle. Internal effects include surface reaeration, DO, BOD, benthic oxygen demand, photosynthesis, nitrification, and biodegradation (WRE 1979, 1, 5).

Development of riverine water quality models for the non-tidal reaches of the Cedar and Ortega rivers and Sixmile and Julington creeks was completed in two stages. First, a simplified BOD/DO model for each system used QUAL-1, a set of Eulerian numerical constituent routing models incorporating temperature, BOD, DO, and conservative constituents in a one-dimensional, vertically well-mixed, branching stream system. Second, a more advanced version (QUAL-2) with an extended list of water quality parameters and chemical-biological processes was used. The QUAL-2 model could simulate up to 13 water quality constituents, but it too was limited to steady stream flow and input waste loads. This model can be operated either in a steady or a dynamic mode to show diurnal variations in meteorological data, diurnal DO variations due to algae growth and respiration, the impact of a slug load, or the impact of seasonal or periodic discharges (WRE 1979, 9–13).

WRE acknowledged several limitations of its model. Most important, some data necessary for calibration were unavailable, especially background loadings. Also, hydraulic characteristics had to be expressed as arithmetic (power) functions. There were a limited number of streamflow gages, and only constant tributary flow rates could be used for each simulation period (WRE 1979, 14–21). Because not enough information was available to quantify point sources for each individual baseline water quality sampling period used in model calibration, the same point source loadings were used for all simulations (p. 24). Also, because no data were available for most water quality parameters, literature values and experience with similar systems were extended to this model (p. 27).

The WRE Estuarine Model. The initial estuarine modeling effort in the LSJR began with the Edge (Clemson) model. The network was extended to include the tidal reaches of the Cedar-Ortega River System, Julington Creek, and McCoy Creek, using 63 junctions and 66 channels (Figure 3.35). The model segmentation network is given in the report by Stanley Consultants and WRE (1978, 4-42, Figure 4-4) and in Supplement A, Annex 1, of the Metropolitan Jacksonville Water Resources Study (WRE 1979, 62, Figure 3.2, and 69, Table 3.1). As a result of preliminary model runs on this configuration, it was determined that an expanded version of the DEM was appropriate for this application. The Tidal Temperature Model (TTM) was selected, which is a version of the DEM first applied to an analysis of the hydrodynamics of Pearl Harbor. In this version, the hydrodynamics are run separately to provide inputs for the water quality model (Stanley Consultants and WRE 1978, 4-40; WRE 1979, 61).

The hydrologic input to the model was developed from USGS data. The DEM/TTM did not have the ability to handle time-varying stormwater loadings; it used steady-state runoff values based on drainage areas and unit area flow rates (WRE 1979, 67; Stanley Consultants and WRE 1978, 4-41). Also, background loadings for the model were unknown (Stanley Consultants and WRE 1978, 4-49), and only steady point and nonpoint sources were used (WRE 1979, 66).

Tidal data for calibration of the hydrodynamic model were obtained from NOS for the NOAA gage at Mayport. For each historical period, the model was operated with a repeating representative 12-hr record after reaching equilibrium. Records from 13 additional gages from Mill Cove to Cedar River were used in the calibration (WRE 1979, 73, Table 3.4). Also, stage records from the USGS gages at Palatka and Main Street Bridge were used (p. 72). The hydraulic calibration of the estuary model was conducted in the usual manner for the 1970s, by adjusting channel configurations, geometry, and bottom roughness until satisfactory results were achieved (Stanley Consultants and WRE 1978, 4-44).

Water quality data for estuary model calibration and analysis were collected by USACE and the City of Jacksonville BESD at about 20 locations through several tidal cycles. These data were supplemented with additional data from ongoing monitoring programs such as USGS water quality measurements at Palatka (WRE 1979, 72).

The estuarine model was used to evaluate the assimilative capacity of the river under both wet and dry conditions. For the dry season, water quality calibration data that were used for the Edge model were selected. For the wet season, flow corresponding to the historical average monthly flow for the period May through September (the high runoff season) was used. Results were tabulated by tidal organic loadings and assimilation capacity. Average travel time from Palatka to Jacksonville was found to be about 60 to 80 days for a river discharge of 1,000 to 2,000 cfs at Palatka (Stanley Consultants and WRE 1978, 4-47). Results for the lower and middle parts of the main stem, McCoys Creek, Julington Creek, Ortega River, Cedar River, and Ribault River are discussed in the WRE report (1979, 104).

Results of the calibration of the water quality model, shown in simulated profiles for selected water quality parameters for the main stem and the Cedar/Ortega River System, generally agreed favorably with the data collected under the direction of WRE, although some extremes were not reproduced (Stanley Consultants and WRE 1978, 4-44). Results of calibrations using September 1977 and July 1988 data are summarized (Stanley Consultants and WRE 1978, 4-44–45), and tables of organic loadings for each of seven estuary model segments for each data period are given in Tables 3.9 and 3.11 of the WRE report (1979, 96, 105).

FDER Pollutant Impact Models

Recognizing that disposal of multiple sources of pollution competes for the use of surface waters for dilution and/or flushing, the Florida Department of Environmental Regulation (FDER, now FDEP) used an EPA procedure called waste load allocation (WLA) for determining the allowable wastewater loads from treatment plants and tributaries to major rivers. The allowable loads are called water quality based effluent limitations (WQBELs).

Intensive surveys were conducted by the Bureau of Water Analysis (BuWA/FDER) in the LSJRB tributaries. The objective of the intensive surveys was to collect data for calibrating and verifying models to be used to evaluate WLAs. These surveys are summarized in Table F1, Appendix F. The reports are identified by the Water Quality Technical Series (WQTS) volume number and sequence number in the form (Volume #:Sequence #).

Volume 2 of the WQTS series describes WLAs. The principal recommendations of WLAs are expressed in terms of WQBELs (Table F2).

A series of models developed in the early 1980s was used by FDER to support the analyses needed for the WLA evaluations. The WLAs were evaluated using the models, ranging from simplified analytic and statistical methods to non-tidal and tidal dynamic models. Three different models were used in connection with subareas of the LSJR: SIMRIV for non-tidal portions of tributaries, DYNRIV for tidal tributaries, and DYNEST (or ESTH) for the confluence of a tributary and the main stem.

SIMRIV is a one-dimensional, steady-state stream model incorporating stream geometry as a function of flow and modified Streeter-Phelps equations. This model was derived from RIVER (Connell Associates 1974) with subsequent additions and revisions of water quality parameters in the RIV1 and RIV2 versions (FDER, WQTS 3:14, 1). RIVMOD is another link-node variant that is often used because it is an implicit-solution model.

DYNRIV is a one-dimensional, time-varying, tidal tributary model that allows non-uniform longitudinal flows and incorporates pollutant advection and dispersion. Because the model is one-dimensional, it can only be applied to tributary reaches that are primarily laterally and vertically homogeneous. The model includes an equation of continuity and an equation of momentum for flow, dispersion as a function of depth and velocity, and mass-balance equations for salinity, temperature, DO, BOD, and total Kjeldahl nitrogen. Inflows from tributaries and sewage treatment plants are included. The model is finite-difference, solved explicitly.

DYNEST (or ESTH) is a two-dimensional, vertically averaged, tidal hydrodynamic model incorporating salinity, temperature, DO deficit, 5-day BOD, and nutrients. The model uses an explicit finite-difference solution and incorporates wind, partial blockages, and particle-tracking options (FDER, WQTS 3:11, 24). In the 1980s, constituents and kinetics from the RIV1 model were being incorporated into this model.

Seminole Power Plant Site Model Study

The model study for the Seminole Power Plant Units 1 and 2 is an example of a detailed study in a small area of the LSJR. Similar to WLA studies that are conducted to evaluate the impacts of pollutants from a point source, the objective of a power plant impact analysis is to evaluate the effect of a thermal discharge on the ambient temperature in the receiving part of a tributary or the main stem of the river. Often both a near-field and a far-field model are employed. The near-field model simulates the extent of the thermal plume in the immediate vicinity of the outfall; the far-field model simulates the extent of mixing and transport to the location where temperatures meet state requirements.

Dames and Moore conducted a thermal impact study at the Seminole Power Plant site north of Palatka from 1977 to 1979. USGS flow measurements at Palatka and Dames and Moore's tide and combined water quality measurements were used to calibrate the plume model NEWJET and the Dames and Moore hydrodynamic model TIDAL2 and water quality model WQUAL2. NEWJET is a quasi-three-dimensional, buoyant, surface plume model employing an integral vertical-velocity profile. TIDAL2 and WQUAL2 are two-dimensional vertically integrated derivatives of the Leendertse (1970) dynamic three-dimensional models incorporating local and convective accelerations, pressure variations, wind, and atmospheric pressure (Dames and Moore 1977, C-1–17; 1979, Vol. 3, Appendix C).

Bailard/Jenkins Model

A one-dimensional box model was developed for use in evaluating two methods for reducing sedimentation in the Mayport Turning Basin (Bailard and Jenkins 1987).

The model was calibrated with two sets of data: (1) 1 day in April 1984 and (2) 1 month beginning in February 1985. These data were supplemented with water level data by Jenkins et al. (1983). Differences in water level, flow, and suspended sediment concentrations between the river and the turning basin were used to derive the final results.

FEMA Hurricane Surge Model

The Federal Emergency Management Agency (FEMA) conducts studies to establish flood insurance rates and guidelines for floodplain management in coastal areas. Their methodology is based on a set of numerical models that are used to predict the flooding that may occur as a result of severe storms, such as hurricanes, with specific recurrence intervals. Several such studies have been conducted for the northern part of the LSJR, including the City of Jacksonville. A typical study combines the predicted effects of coastal storm surge height, wave setup, and tide. The study is extended to a hydraulic analysis of the height of water in all affected tributaries, considering the mean discharge and tide expected to occur in each.

A two-dimensional, vertically averaged, finite-difference model, FEMA Coastal Flooding Storm Surge Model (SURGE), was used to predict storm surge heights in the LSJR. The river and surrounding terrain were represented on a grid of either 5 × 5 nm or 1 × 1 nm, depending on the required resolution. The effects of storms with 10-, 50-, 100-, or 500-year return periods were simulated with variations in central pressure depression, radius to maximum winds, forward speed of the storm, shoreline crossing point, and crossing angle. The model was calibrated with data from Hurricane Dora (September 1964), which was the most powerful storm, albeit a minimal strength storm, to be recorded in that area (FEMA 1989, 5–28).

Divoky and Bhat Black Creek Storm Surge Study

In 1988, the SURGE model was used by Divoky and Bhat (1988) of Engineering Methods and Applications to investigate the effects of a hurricane on Black Creek for USACE Jacksonville. The objective was to determine the surge height and time of arrival of water levels resulting from maximum winds at the mouth of the creek.

A nested grid was used. The coarse grid, with a spacing of 5 nm, covered an ocean area extending 110 nm offshore and 200 nm alongshore. The inner fine grid, using a 1-nm spacing, extended 27 nm offshore and 39 nm alongshore. Fifteen tributaries were included in the model from the mouth of the St. Johns River to Black Creek. The two-dimensional, vertically averaged, long-wave equations for conservation of mass and momentum were solved explicitly. Energy losses were represented by Manning's coefficients. A tide of 0.5 ft amplitude at and a discharge of 2,000 cfs from Black Creek were assumed. The model was calibrated with data from Hurricane Dora.

The study was limited to five storms (one for each Saffir-Simpson storm category) on arrival tracks of east and southeast. Predicted marigrams (surge height, in feet versus time) are given for the mouth of Black Creek, Mill Log Creek, Bradley Creek, Little Black Creek, Lake Asbury, and the North and South Forks for each storm-arrival direction. The results showed the expected increase in surge amplitude with storm category, that the northwest-bound storms produce slightly less surge amplitude than the westward-bound storms, that amplitude increases slightly with distance upstream, and that the peaks along Black Creek occur at approximately the same time.

Camp Dresser and McKee Hydrologic and Water Quality Models

One of the first projects initiated under the SWIM Plan for the LSJR was the development of a Master Stormwater Management Plan (MSMP) for the City of Jacksonville. Phase 2 of the MSMP project included development of hydrologic and water quality models for nine subbasins in Duval County by Camp Dresser and McKee (1992–93). The following tributary subbasins were modeled: the LSJR upstream of Trout River, the ICW, Trout River, Ortega River, Broward River, Dunn Creek, Arlington River, the LSJR downstream of Trout River, and Julington Creek. None of the models extended downstream into tidally affected areas.

The water quality models for the nine Duval County subbasins simulated stages and discharges for 10-, 25-, and 100-year 24-hour storms, using the RUNOFF and EXTRAN components of the Surface Water Management Model (SWMM). Even though the SWMM model is capable of continuous simulation, it was used in this application only for single-event runs.

All of the Duval County subbasin models also included a spreadsheet water quality component based on annual loads for screening purposes. Five of the subbasins (the LSJR upstream of Trout River, the ICW, Trout River, Ortega River, and Broward River) were modeled with the water quality component of SWMM. Results were provided for an average year, which in Jacksonville consists of about 50 events. These models include steady loadings of BOD, total nitrogen, total phosphorus, zinc, and lead and use the RUNOFF and TRANSPORT components of SWMM. The quantities of pollutant loads were calculated from Nationwide Urban Runoff Program (NURP) data, which specifies concentrations of specific water quality parameters based on land use.

The results of the simulations are to be published in a set of reports that will be available from SJRWMD or the City of Jacksonville. The entire set will consist of nine volumes (one volume per subbasin) plus a general volume describing the methodology applied.

NOAA Screening Assessment Model

It is assumed that the NOAA Screening Assessment model was used to develop the description of the LSJR in the NEI (NOAA 1985).

The NOAA screening assessment model is a steady-state, two-dimensional (vertically averaged), finite-element model used to provide a preliminary assessment of hydrodynamics or water quality in an estuary. Results from this model are based on an assumption that the hydrodynamic features are known or can be postulated and can be provided through boundary conditions. The model is used primarily to provide a framework for the organization of existing data to assist in assessing the significance of circulation features on salinities and to assist in the development of field programs to support real-time modeling (Klein and Galt 1986, 483–501).

The flow field is developed on an assumption of incompressible, irrotational flow and on an assumption that the circulation is controlled completely by bathymetry. Thus, the only factor in this model that can influence flow is the shape of the basin. The model cannot be used to resolve processes requiring temporal resolution of less than about a month. In cases where the relative merits of alternative, relatively long-term management strategies are to be evaluated, the model, if accurate, may be applicable.

The literature emphasizes that this type of model is not appropriate when inadequate data exist to set the hydrodynamics or when details of flow are needed in space or time. The model is appropriate to use for assisting in management decision-making after more comprehensive models have been developed and river dynamics have been quantified with all of the significant variables in the prototype system. Then the model developer may consider simplifying the model to a screening level capability, provided the resulting simplification does not misrepresent the significant dynamics.

SUMMARY OF MODELING THE LSJR

The first physical model of the river was constructed by USACE in 1945. This model was used in a successive series of efforts to study tidal currents, salinity, and dredge spoil disposal, but the salinity studies suffered from a lack of adequate data. Later physical model studies of circulation, scour, flushing, and sedimentation were used to evaluate dredging plans for Jacksonville Harbor.

The first computer models of the river were produced by Connell Associates, Frederic R. Harris, and Clemson University in 1972 and 1973. The water quality model was intended for use in studying pollution loading in the Jacksonville area. The model used steady inflows, due to the lack of flow data, and was not reliable enough to be used to set water quality effluent limits.

Additional water quality models were developed through the 1970s by extension of the Connell model and by separate efforts of federal and state agencies and various consultants during the 1970s and 1980s. Models designed to answer specific questions, such as questions about sedimentation, power plant siting, tributary WLA, and storm surge elevations, were developed. In general, these models were all limited by a lack of basic data and knowledge on the functioning and variability of the river.

The models were unable to describe more than measured events and could not be used to reproduce realistic long-term sequences of events or to predict future conditions.

SUMMARY

This reconnaissance report has two major purposes. The first is to describe, compare, and evaluate the available literature and data on the hydrodynamics and salinity of the LSJR. The second is to recommend future work needed to develop a more complete understanding of the dynamics of the river. This volume brings together the facts and opinions that have been developed through many past investigations, it documents the sources, and it attempts to put the investigations into perspective.

The LSJRB is defined as that part of the St. Johns River located downstream of the confluence with the Ocklawaha River. It is the part that is directly connected to the ocean, that is tidally influenced, and that is impacted by industry and development.

SCOPE OF THE REPORT

Hydrodynamics is the dynamics of water movement. It is described in terms of water heights (elevations or "levels"), water flows (currents), and water volumes. To assure a proper perspective, both time scales and space scales must be specified for a particular description or investigation of the river.

Time scales are the periods of time over which characteristics of the river change. For example, water levels can change within a few minutes, while the period of a tidal cycle is over 12 hours. Likewise, space scales are the distances over which changes take place. For example, tides affect at least the lowest 100 mi of the river on a regular basis, whereas a tributary discharge may only impact a few miles of the main stem.

In order to completely describe river water levels, flows, and volumes, the magnitudes and variability of major forces that affect these features of the river must be quantified. This report describes the shape of the river (i.e., its geometry), the tides, winds, flows, and variation of salinity. It refers to the freshwater inflows that are described in more detail in Volume 2 of the Reconnaissance Report.

Computer models have proven to be convenient for describing and investigating the dynamics of a river. A properly calibrated and verified model can reproduce the fundamental dynamics and then can be used to explore features of the dynamics that cannot be easily measured. Because water quality models require complete hydrodynamic descriptions that provide the depths, flows, volumes, and salinities of water for the calculations, both existing quantity and quality models of the LSJR are reviewed in this report.

DESCRIPTION OF THE RIVER

The St. Johns River begins in marsh headwaters north of Lake Okeechobee, flows northward to Jacksonville, and then eastward to its ocean entrance. The river is over 300 mi long and has a total drainage area of over 9,000 mi^2, making it the third largest drainage basin in Florida. It has the fifth largest discharge of all the rivers in Florida, on the order of 6,000 to 15,000 cfs. Its average slope over its length is 0.08 ft/mi (about 25 ft over 300 mi).

The LSJR is ordinarily tidal upstream at least to Crescent Lake and Lake George. Tidal effects have been reported as far south as Lake Harney, upstream of De Land. The river's volume and flow are affected by numerous tributaries, both large and small. Its total flow—the combination of tide and tributary inflow—may reach 150,000 cfs (over 232,000 million gallons per day) at the mouth.

The dimensions of the river—the changes in width and depth along its length—divide it into different zones. The river is relatively deep, narrow, and sinuous from the ocean through Jacksonville, with many tributaries. Upstream of Jacksonville it widens and has fewer, but some larger, tributaries. Farther upstream still, past its confluence with the Ocklawaha River, it flows through a sequence of large lakes. Throughout its length, from the ocean to Lake Harney, it has a federally maintained navigation channel which acts to slightly increase the natural speed of propagation of the tide.

Water levels in the river are principally influenced by local river dimensions, tides, winds, and freshwater inflows. The tidal characteristics, in terms of heights and times of propagation, are fairly well quantified. The average range of tide (difference between mean high and mean low tide) varies from 5.49 ft at Little Talbot Island to 4.51 ft at Mayport, 1.51 ft at the Acosta Bridge in Jacksonville, and a minimum of 0.71 ft at Julington Creek. It increases to 1.09 ft at Palatka and decreases to 0.93 ft at Buffalo Bluff and 0.35 ft at Welaka near the confluence with the Ocklawaha River.

The times of high and low water upstream relative to the times of high and low water at the river entrance change relatively smoothly along the river. The time differences of high water near the entrance are greater than the time differences of low water. This characteristic reverses around RM 10, indicating that the characteristics of the tides at some stations may not be symmetric. When high tide is approaching East Tocoi (RM 61) on its progression upstream, the flood tide at the mouth is turning to ebb.

Flood levels have been recorded at a few locations in the river between 1944 and 1964. FEMA published flood contours for all of the counties surrounding the main stem of the river. Data from Hurricane Dora (1964) were used to develop design flood elevations for various zones along the river from the mouth to Palatka.

The total river flow may be divided into tidal and non-tidal components. Measured flow is equivalent to total river flow, because the measurement techniques that are available cannot detect the difference between these components. Some researchers have separated non-tidal flow from tidal flow by subtracting successive upstream and downstream measurements, but these calculations have only resulted in a few order-of-magnitude estimates of each component. Its average non-tidal flow ranged from about 6,000 to 15,000 cfs, and its average total flow is normally greater than 50,000 cfs.

Data on the flow in the main stem of the LSJR, as well as in the tributaries, have been scarce. Measurements at Jacksonville from 1971 to 1974, 1980 to 1981, and 1987 to 1990, and measurements at

Palatka are poor; measurements at De Land, 145 mi upstream outside the limits of the LSJRB, are relevant but quite far removed from the area of interest. The principal reason for the lack of reliable data has been that flow measurements have been technologically limited—until 1992—by inadequate instrumentation.

Tidal elevation and flow can be analyzed from continuous series of data as long as the dataset is long enough. The resulting astronomic coefficients can be used to hindcast or predict tidal elevations and currents over an almost 20-year time period. However, this capability is not of much use in describing total river flow except during prolonged, extremely dry seasons. Tidal analyses have produced astronomic coefficients for three stations on the river.

River salinity is considered to be part of the hydrodynamics because it is a conservative parameter, directly related to the density of water masses, volumes, and flows. The density of water masses also affects flow on a local scale. Salinity also is affected by tide and the time history of tributary flows over periods as long as weeks, or more. River salinity changes constantly and fluctuates with the tide.

The open ocean is a source of an almost constant 36-ppt salinity. Near the mouth of the river, salinity may be significantly lower, due to mixing with fresher river discharge. However, the variations of inflow into the river from upstream, temporary mixing of large freshwater outflows beyond the mouth and the details of local stratification, mixing of fresh water and salt water, and possible salt wedge movement are not at all understood in the LSJR. Salinity distribution in the river is highly variable and highly dependent on the local freshwater/saltwater balance.

The effects of wind and water level on the river flow have been described in only a few studies. According to Pyatt, winds of about 7 mph (which is below the average wind speed at the Imeson Airport in Jacksonville), can cause wind setup in the river ranging from -0.92 to +3.20 ft.

REPORTS REVIEWED

The majority of the available information on the hydrodynamics of the LSJR is found in reports by federal agencies. A substantial quantity of technical literature has been located, but there are only a few core studies—from the 1950s to the 1970s—that provide original analyses and insight. Additional useful information is provided by reports on developments of numerical models, but these reports fall short of correctly and comprehensively describing the overall hydrodynamics of the river.

DATA COLLECTION ON THE RIVER

Water level and flow data collection have continued intermittently since the first gages were set in the river. Collection of flow data has frustrated dedicated agencies due to the complexities of flow and inadequacies of instrumentation. Water levels were measured intensively in the 1970s, but the network had been mostly dismantled by 1980 and only the long-term measurements at Mayport and Jacksonville have been maintained. Until 1991, flows were found to be impractical and too expensive to measure due to the effects of tides and channel irregularities. By 1993, new systems for instantly measuring the total flow across a relatively narrow channel were proving to be effective. Tributary inflows, also difficult to measure because of large cross sections and the effects of tide, are being monitored (in 1995) more accurately at locations where the river is relatively narrow.

Salinity has been sampled, either intensively for a short time period to show an "instantaneous" profile over a long reach of the river or at relatively long-term stations at long sampling intervals. The relationship of salinity to hydrodynamics has not been adequately measured or described in this river.

MODELING OF THE RIVER

The first physical model of the river was constructed by USACE in 1945. This model was used to study tidal currents, salinity, and dredge spoil disposal, but the salinity studies suffered from a lack of adequate data. Later physical model studies of circulation, scour, flushing, and sedimentation were used to establish dredging plans for Jacksonville Harbor.

The first computer models of the river were produced by Connell Associates, Frederic R. Harris, and Clemson University in 1972 and 1973. The water quality model was intended for use in studying pollution loading in the Jacksonville area. The model used steady inflows, due to the lack of flow data, and was not reliable enough to be used to set water quality effluent limits.

Additional water quality models were developed through the 1970s by extension of the Connell model and by separate efforts of federal and state agencies and various consultants during the 1970s and 1980s. Limited-area models designed to answer specific questions, such as sedimentation, power plant siting, tributary waste load allocation, and storm surge elevations, were developed. In general, these models were all constrained by a lack of basic data and knowledge on the functioning and variability of the river.

RECOMMENDATIONS

In 1989, SJRWMD determined that a reconnaissance report series on the LSJRB was needed. This series would document all significant sources of information then available on the river, describe the relative significance of the information, and summarize its meaning. In 1990, a plan and outline for the LSJRB reconnaissance report series was established. While Volume 3 of the reconnaissance report was being written, between 1991 and 1993, a major new investigation of some physical characteristics of the river was initiated and jointly funded by USACE Jacksonville and SJRWMD. This investigation was called Phase 1 of the Feasibility Level Cost Share Agreement (FLCSA), or the Water Quality Feasibility Study. As important results were received from this investigation, parts of this volume were substantially modified. This "recommendations" section is based on the status of investigations on the LSJR as of 1994.

TIDES

Previous investigations, most notably tidal studies by NOS and USGS, had established basic tidal characteristics of the river as of the 1970s. Since then, however, the navigation channel has been improved and the shorelines and depths of the inlet and some tributaries have changed as a result of storms and sea level rise. Phase 2 of the FLCSA was initiated in October 1994 to develop an updated description of the tidal characteristics of the river. As part of Phase 2, water level monitoring began in May 1995 at 13 stations located from the ocean to Welaka, from which new tidal and water level characteristics will be derived.

- Recommendation: that, after 2 years of comprehensive hydrodynamics and salinity (H/S) monitoring, SJRWMD modify the existing monitoring network into an optimal long-term monitoring network for water level, wind, and salinity measurements to enable the long-term tidal and wind-driven characteristics of the river to be determined.

TRIBUTARY INFLOWS

Discharges from tributary basins have the greatest influence on mainstem flows in the LSJR; these discharges are dependent on the hydrologic cycle, soil types, and land use. Hydrologic models have been developed for all of the nine hydrologic subbasins in Duval County, but these models were limited to describing flooding conditions and average discharges. Continuous-event runoff models have not yet been developed for any of the LSJR subbasins.

Reliable hydrologic models require an extensive data base, which is not currently available for the LSJR. The topography must be described, preferably in terms of 1-ft contours due to the relatively low relief in the LSJRB. Rainfall and corresponding runoff have been measured for many years, but the measurements need to be continued for a period long enough to permit the calculation of return-period rainfall and runoff statistics for historical and predictive simulations.

- Recommendation: that SJRWMD continue to support efforts to obtain the data necessary to develop appropriate hydrologic models for the tributary basins of the LSJRB. Initial efforts should focus on development of detailed topography, particularly in the vicinities of streams and tributaries.

RIVER FLOWS

Flows from the Middle St. Johns River Basin and the Ocklawaha River change substantially from year to year with changes in meteorology and climatology. These flows combine with tributary discharges into the main stem and with the tide, all of which become the total flow of the river. A new, approximate calculation of total river flow was attempted for this report (Appendix E) by combining USGS discharge measurements at upstream sites. Since 1991, USGS has added new flow measurement stations in all of the major tributaries and at Buffalo Bluff in the main stem near the upstream extent of the LSJRB. Phase 2 of the FLCSA will further quantify the details of flow over several tidal cycles at several cross sections in the main stem. Watershed models are planned that will provide estimates of point and nonpoint runoff to the tidal parts of tributaries and to the main stem.

- Recommendation: that, after 2 years of comprehensive surveys in the main stem, SJRWMD determine the critical locations for flow measurements and continue funding long-term monitoring of discharge and flow at these key locations.

SALINITY

From long-term monthly samples of salinity at stations in the SJRWMD water quality monitoring network, a mean and range of salinity have been determined for the main stem. However, the short-term tidal dynamics of salinity have not yet been adequately described. In Phase 2 of the FLCSA, stations have been established at four bridges to sample the vertical salinity distribution. A fifth salinity monitor has been installed at Buffalo Bluff. Salinity is also being monitored at 11 of the water level (tide) stations. From these data, future samples from the water quality network, and the application of numerical models it will be possible to describe how salinity changes with freshwater inflows from the tributaries and under what conditions salinity stratification occurs.

- Recommendation: that SJRWMD continue short-term, intensive salinity measurements to develop comprehensive descriptions of salinity characteristics.

GROUND WATER INTERCHANGES

The interchange of ground water and surface water in a river can have a significant effect on the volume of water stored in and transported by the river. Ground water seepage also can affect river conductivity near locations of seepage. Volume 1 of the reconnaissance report (Toth 1993) summarized the known ground water characteristics of the LSJRB. This review of the hydrodynamics and salinity of the river, Volume 3, supports a need for accurate determinations of ground water movement and conductivity, at least to the extent that these parameters directly contribute to the characteristics of the surface water.

- Recommendation: that SJRWMD locate and quantify the significant sources of ground water seepage in the LSJRB and determine the conductivity of this ground water.

SEDIMENT TRANSPORT

The distribution of sediments in the LSJR is primarily due to the volumes of tributary discharges and the sediment loadings, the local current speed in the water column, and the effects of wind and waves on mixing in the water column and on producing bottom currents that cause erosion and resuspension of sediment from the bed. Volume 5 of the reconnaissance report (Keller and Schell 1993) described sediments in the river, but did not stress the dependence of sediment investigations on a quantitative understanding of hydrodynamics and salinity. This report, Volume 3, provides a review of basic hydrodynamics that will support investigations on sediment transport.

The movement of sediment in the river only can be described accurately after a predictive hydrodynamics/salinity/sediment model has been completed and existing locations and inflows of sediment are adequately described.

- Recommendation: that SJRWMD map the significant locations and characteristics of river sediments and related sediment quality parameters. With the assistance of a predictive model, correlate simulated hydrodynamics characteristics of the river with these significant locations and correlate corresponding sediment characteristics with a description of sediment dynamics.

LONG-TERM MONITORING

Monitoring is an extremely important activity of SJRWMD. Data collected at regular intervals over a long period of time are vital for describing and detecting trends in physical characteristics and water quality. SJRWMD has recently established effective monitoring networks in the LSJR, significant portions of which should be maintained for an indefinite period.

It is recognized that substantial funding is required to maintain these monitoring networks. SJRWMD continually evaluates the effectiveness of each station in the network, ascertaining whether a station is needed or if it is redundant and whether the data obtained from each station will continue to be useful.

- Recommendation: that SJRWMD continue to carefully scrutinize its monitoring networks, optimizing the number and locations of stations and maintaining a monitoring capability for as long as evaluation of river dynamics is an SJRWMD mission.

APPLICATIONS OF MODELS

Models are used to assist management to understand the effects of limits on the quantity, quality, and timing of releases of controllable inflows to the river. Models also serve the important functions of explaining how the river operates under various conditions and predicting how it would probably fluctuate under conditions not yet experienced. As part of Phase 2 of the FLCSA, both a management-level one-dimensional H/S water quality model and a three-dimensional H/S model are being developed. SJRWMD will use these models to describe the physical operation of the river, to explore its characteristics under predicted conditions, and to assess the impacts of pollutants in tributary discharges. Additional higher resolution tributary models may be needed to investigate localized water quality problems.

- Recommendation: that SJRWMD continue to support hydrologic, basin, mainstem, and tributary water quantity and quality modeling programs in the LSJRB. These models serve several uses: to explain cause-and-effect observations and relations, to predict effects of man-made changes to surrounding basins or the river, and to describe the characteristics of the river to managers and the public.

GLOSSARY

Bathymetry. Measurements of water depth that describe bottom topography.

Chart datum. The datum used for local navigation charts (mean lower low water in the lower St. Johns River).

Circulation. The pattern of flow of water inside a water body.

Conductivity. The ability of a fluid containing minerals or other impurities to conduct an electric current.

Coupling. The connection of equations for fluid motion with water quality equations. Full coupling is desired in a salinity model, because water density (as represented by salinity) and hydrodynamics affect each other and sometimes these equations must be solved simultaneously.

Current. A moving water mass.

Current meter. An instrument that measures the velocity of movement of water. Some current meters only measure the speed of current.

Datum (vertical). A reference elevation for measurements of heights or depths. Examples are NGVD and NAD.

Discharge. The amount of water released from a structure, tributary, etc., with units of volume per time. It is more specific to released volumes than the general term "flow."

Discharge accumulation. The sum of consecutive downstream flows over a period of time.

Diurnal. An event that occurs twice each day, such as a diurnal tide.

Diurnal inequality. The difference in height between the two high waters or the two low waters that occur each day. This term also can be used to describe the difference in speed between two tidal ebbs or floods.

Ebb current. The movement of a tidal current down a tidal river or estuary to the mouth.

Epoch. See tidal epoch.

Equilibrium tide. The hypothetical tide due only to the tide-producing forces under the equilibrium theory, which assumes that earth is uniformly covered by water and that there are no land masses to retard flow.

Estuary. A semi-enclosed body of water affected by the tide, in which there is substantial freshwater inflow and measurable dilution of the salt water by fresh water.

Eulerian. A coordinate system used to describe flow from the viewpoint of fixed locations in the flow field (see Lagrangian).

Fetch. The distance over which wind blows to cause an effect on the river.

Flood current. The movement of a tidal current into a tidal river or estuary from the mouth.

Flow. The volume rate of movement of a water current (in units of volume/time).

Flushing rate. The rate at which the total volume of a polluted water mass is exchanged with water from outside the polluted water body.

Freshet. A relatively small, transient wind which may cause some effect on the surface of a water body.

Geodesy. The mathematical study of the size and shape of the earth, and of surveys that must consider size and shape.

Harmonic analysis. The mathematical process by which the observed tidal heights or tidal current at any location are separated into basic periodic constituents or components.

Harmonic constant. An amplitude or phase (epoch) of a harmonic constituent of the tidal height or current at a location.

Harmonic constituent. One of the harmonic (periodic) elements in the mathematical expression for the tide-producing force and in corresponding formulas for the tidal height or current, consisting of an amplitude and a phase.

High water. The maximum height reached by a rising tide.

Hydrodynamics. The science dealing with the dynamics of water movement.

Knot. A unit of speed of one international nautical mile (1,852.0 meters) per hour.

Lagrangian. A coordinate system used to describe flow from the viewpoint of a moving particle, that is, at a fixed location in the moving water mass (see Eulerian).

Mean high water. The mean of observations of high water, preferably over a 19-year Metonic cycle (a National Tidal Datum Epoch).

Mean higher high water. The mean of observations of higher high water, preferably over a 19-year Metonic cycle. The higher high water is the higher of the pair of highs occurring with a semidiurnal tide.

Mean low water. The mean of observations of low water, preferably over a 19-year Metonic cycle.

Mean lower low water. The mean of observations of lower low water, preferably over a 19-year Metonic cycle. The lower low water is the lower of the pair of lows occurring with a semidiurnal tide. This is the reference datum for navigation charts of the lower St. Johns River.

Mean sea level. The mean of measured water levels at a location, preferably over a specific 19-year Metonic cycle (a National Tidal Datum Epoch). If calculated over a shorter time period, the mean sea level (MSL) is called the "yearly MSL" or the "monthly MSL," as appropriate.

Mean tide level. A tidal datum midway between mean high water and mean low water, also called the half-tide level. Mean tide level is given in the Table of Tidal Differences (for the subordinate stations) referenced to chart datum in the tide tables.

Mean water level. The mean of measured water levels at a location over the period of record.

Mean range of tide. The difference in height between mean high water and mean low water at a location.

Metonic cycle. A period of 19 years or 235 cycles of the moon, during which the new moon and the full moon will recur on the same day of the year (the actual period of the moon's orbit with respect to the earth's orbit is 18.6 years). Nineteen years is the period used for the National Tidal Datum Epochs: the most recent complete tidal epoch is 1979 through 1987.

North American Datum. The North American Datum of 1983, which was readjusted in 1990 (NAD 83/90), is the preferred reference for horizontal survey control in Florida.

North American Vertical Datum (NAVD). NAVD, which was completed in 1988, is an adjustment to NGVD for the irregular shape of the geoid. NAVD 88 is the preferred reference for vertical survey control in Florida.

Neap tide (or current). The lowest range of tide occurring semimonthly as a result of the moon being in quadrature, that is, lined up perpendicular to the sun relative to the earth (and in its first or third quarter).

Net non-tidal flow. The component of river or estuarine flow that is not tidal, that is, the unidirectional component of flow that includes direct rainfall, freshwater runoff, and seepage.

National Geodetic Vertical Datum (NGVD). The vertical datum used for all surveys. NGVD is equivalent to mean sea level of 1929.

Overmixing. A condition in stratified flow in which the amount of seawater available for mixing is limited and no increase in salinity of the outflowing water mass is possible.

Progressive wave. A type of wave in which the surface moves in a horizontal direction.

Reference station. An NOS/NOAA tide or current station operated for a relatively long time (over a year) for analyses of long-term tidal characteristics. Daily high and low peak elevations and times are published in the tide tables for each reference station and are used, with published elevation difference or ratios to predict water levels at subordinate stations.

River mile. The distance along the thalweg, or main course of a river, measured from a specified origin (usually the mouth of the river).

Runoff. The volume of water that drains from an upland into a water body.

Salinity. The concentration of oceanic salts (ocean salinity is 36 parts per thousand).

Secondary flow. Components of flow that are not directed in the primary direction, for example, horizontal or vertical circulatory flows.

Semidiurnal. Having a period of approximately one-half of a (tidal) day.

Setup. The difference in water surface elevation caused by a force on the water (e.g., wind blowing on the surface).

Slack. Slack water or slack tide is the current speed or tidal water level at the time when current reverses direction or tidal water level changes from rise to fall. Generally, slack water (current) occurs near maximum tidal peak.

Speed of current. The magnitude of the velocity in the direction of flow.

Stage. The elevation of the water surface, usually in conjunction with a structure or a measurement instrument. "Stage" is equivalent to "water level."

Standing wave (stationary wave). A type of wave in which the surface moves vertically without progressing in a horizontal direction.

State plane coordinates. A coordinate system for location on the earth's surface (units of feet), with a different reference location in each state.

Strength of current. The maximum speed of tidal current.

Subordinate station. An NOS/NOAA tide or current station with a relatively short series of observations. When the station is listed in the tide tables, the elevation and time of occurrence of highs and lows are calculated by the user from published water level differences and ratios applied to the data for a particular reference station.

Tidal epoch. The lag (or angular retardation) of the maximum of a tidal constituent of the observed tide behind the corresponding maximum of the same constituent of the equilibrium tide.

Tidal flow. Tidal flow is the component of total flow that is caused by tidal forces.

Tidal prism. The volume of water introduced and removed over a tidal cycle.

Tide. Vertical movement of water level due to the attraction of sun and moon. Tide travels as a long wave in a water body at a speed dependent on the depth of the water.

Total flow. Total flow is the flow caused by all forces on the water body.

Waste load allocation. A procedure for determining the allowable wastewater loads to major rivers from treatment plants and tributaries.

Water quality based effluent limitations. Allowable wastewater loads based on specific water quality criteria.

Source: NOS Tide Tables; U.S. Naval Oceanographic Office 1966; Hunt and Groves 1965

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APPENDIX A: RIVER MILES

NOTICE

OF

ILLEGIBILITY

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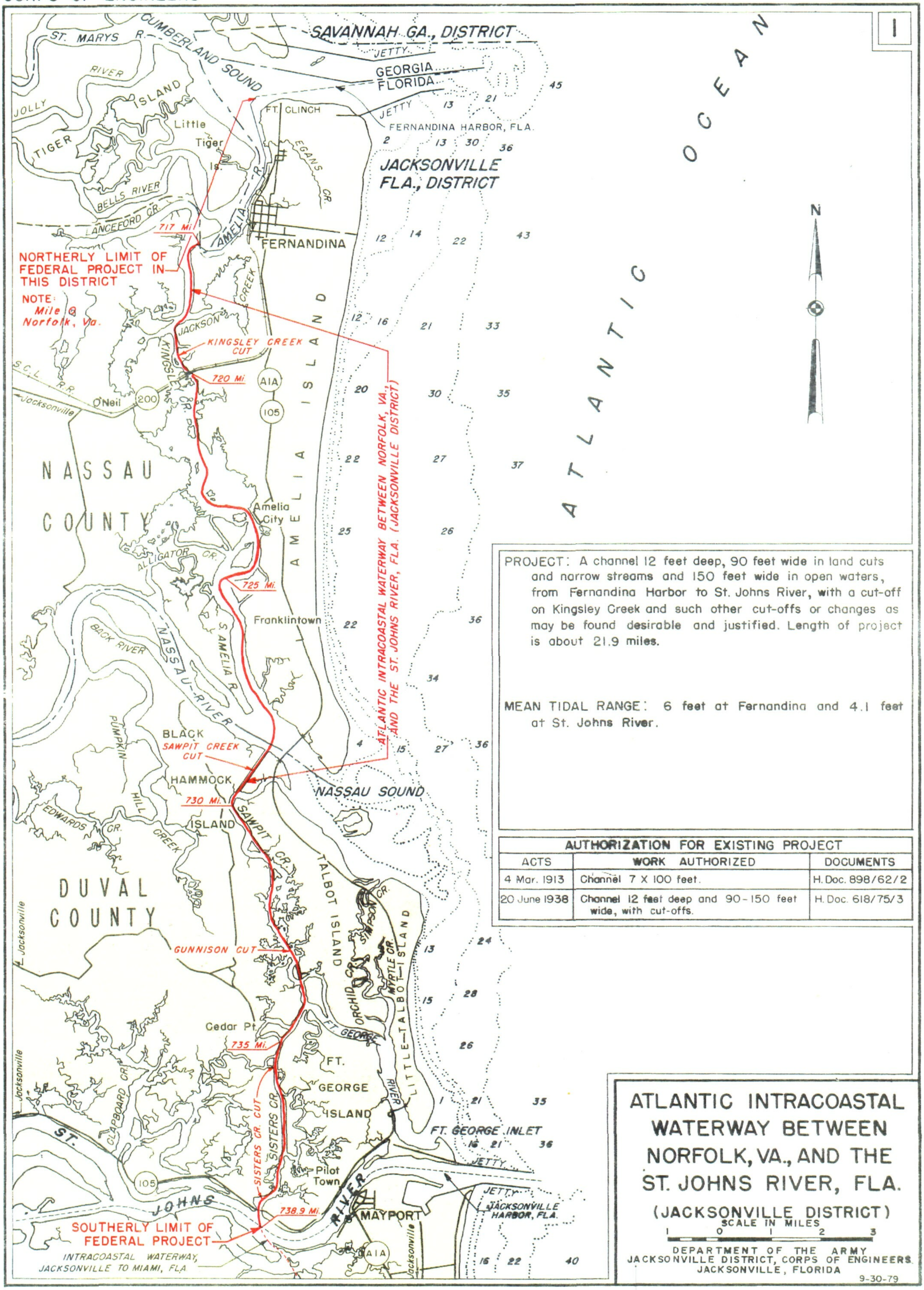


PROJECT: A channel 12 feet deep, 90 feet wide in land cuts and narrow streams and 150 feet wide in open waters, from Fernandina Harbor to St. Johns River, with a cut-off on Kingsley Creek and such other cut-offs or changes as may be found desirable and justified. Length of project is about 21.9 miles.

MEAN TIDAL RANGE: 6 feet at Fernandina and 4.1 feet at St. Johns River.

AUTHORIZATION FOR EXISTING PROJECT

ACTS	WORK AUTHORIZED	DOCUMENTS
4 Mar. 1913	Channel 7 X 100 feet.	H. Doc. 898/62/2
20 June 1938	Channel 12 feet deep and 90-150 feet wide, with cut-offs.	H. Doc. 618/75/3

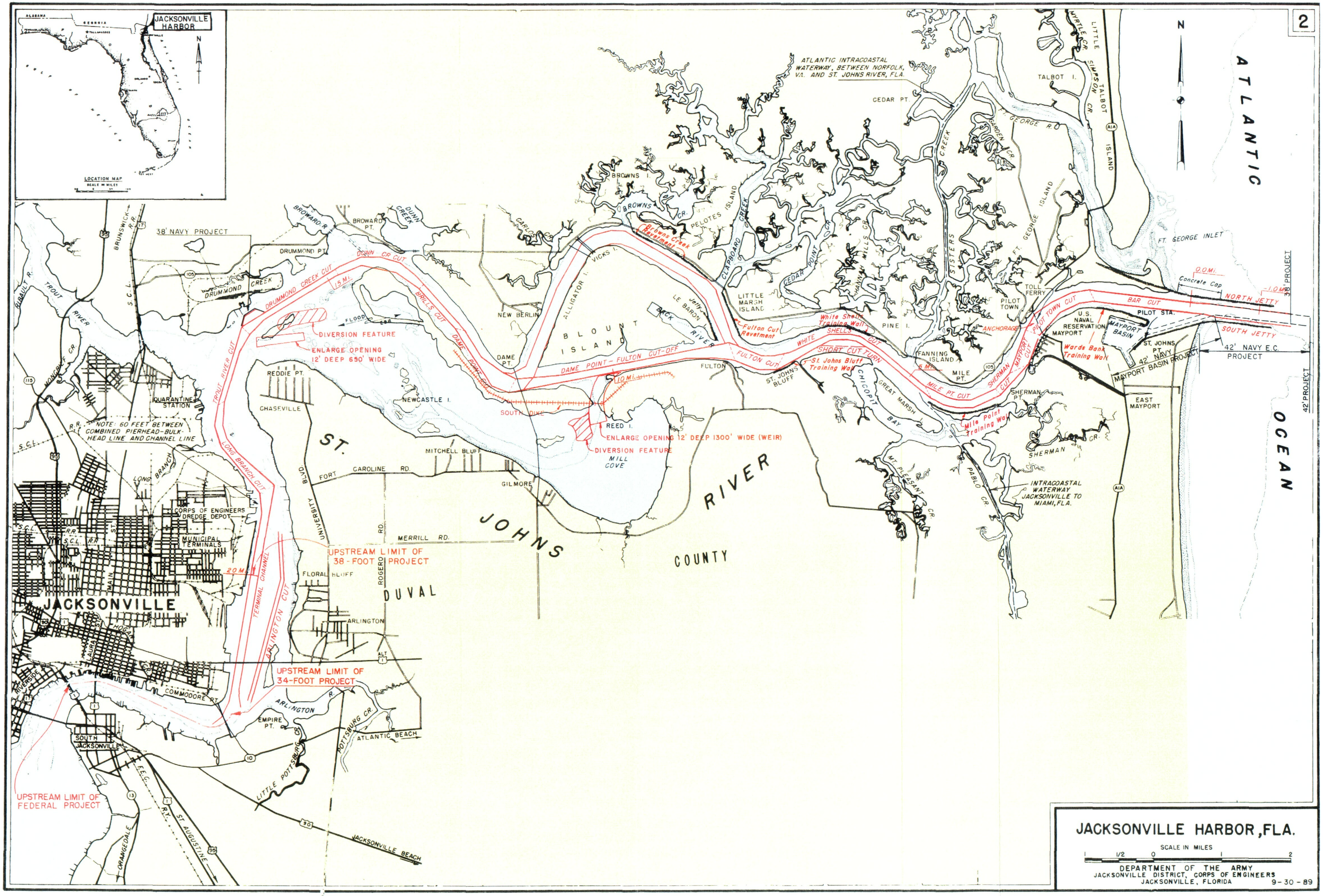
ATLANTIC INTRACOASTAL WATERWAY BETWEEN NORFOLK, VA., AND THE ST. JOHNS RIVER, FLA.

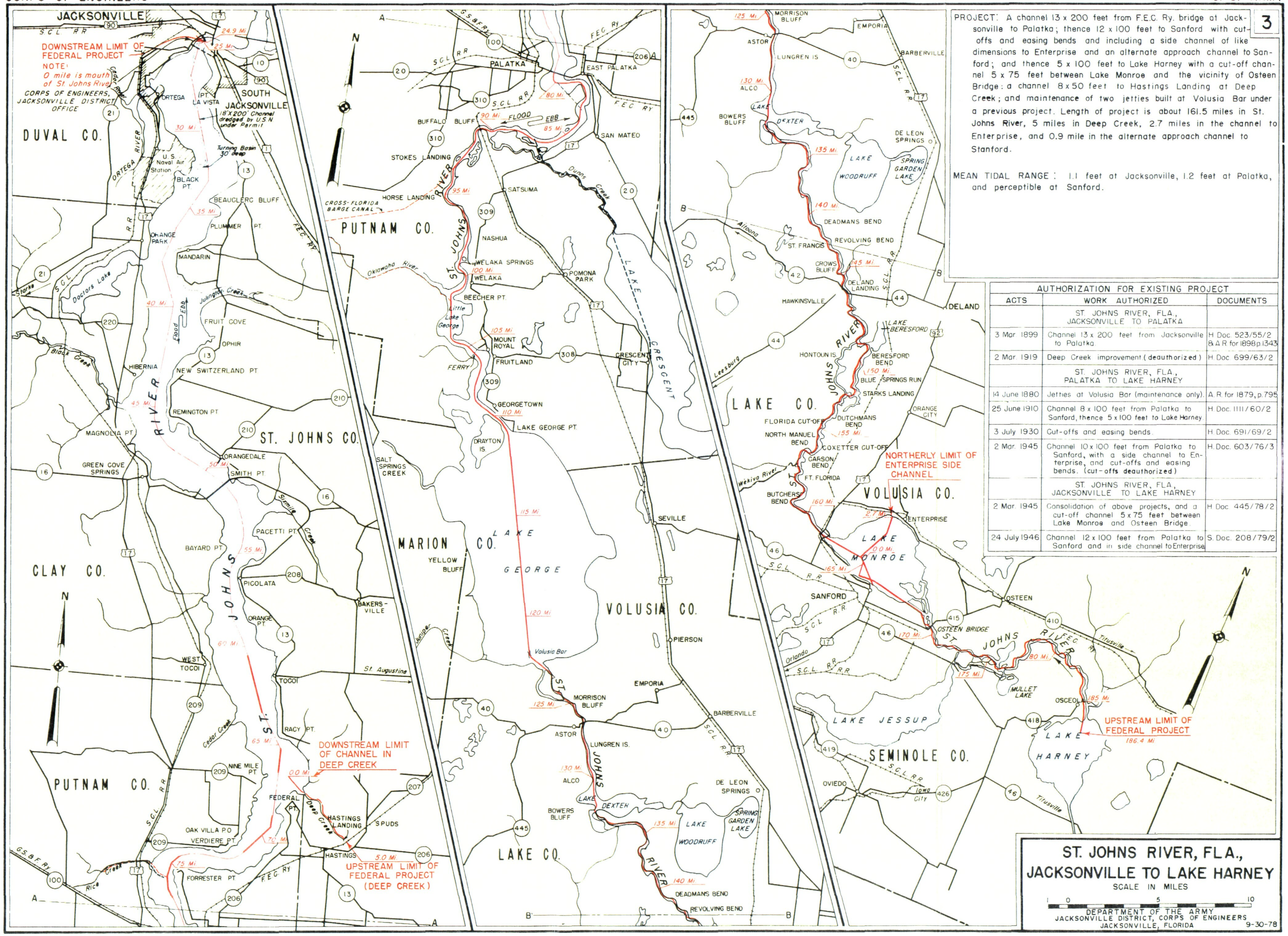
(JACKSONVILLE DISTRICT)

SCALE IN MILES
1 0 1 2 3

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

9-30-79


2
JACKSONVILLE HARBOR
LOCATION MAP
N
ATLANTIC OCEAN
ATLANTIC INTRACOASTAL WATERWAY, BETWEEN NORFOLK, VA. AND ST. JOHNS RIVER, FLA.
INTRACOASTAL WATERWAY JACKSONVILLE TO MIAMI, FLA.
38' NAVY PROJECT
38' PROJECT
42' PROJECT
42' NAVY E.C. PROJECT
42' NAVY MAYPORT BASIN PROJECT
NORTH JETTY
SOUTH JETTY
BAR CUT
Concrete Cap
0.0 MI.
1.0 MI.
5 MI.
10 MI.
15 MI.
20 MI.
PILOT STA.
U.S. NAVAL RESERVATION MAYPORT
MAYPORT BASIN
Wards Bank Training Wall
ST. JOHNS PT.
EAST MAYPORT
FT. GEORGE INLET
FT. GEORGE ISLAND
TALBOT I.
TALBOT ISLAND
LITTLE TALBOT ISLAND
SIMPSON CR.
CEDAR PT.
TOLL FERRY
PILOT TOWN
PILOT TOWN CUT
MAYPORT CUT
SHERMAN CUT
SHERMAN PT.
SHERMAN CR.
ANCHORAGE
MILE PT.
MILE PT. CUT
Mile Point Training Wall
FANNING ISLAND
PINE I.
SISTERS CREEK
WHITE SHELLS CUT
White Shells Training Wall
SHORT CUT TURN
St. Johns Bluff Training Wall
ST. JOHNS BLUFF
FULTON CUT
Fulton Cut Revetment
FULTON
LITTLE MARSH ISLAND
CLAPBOARD CREEK
CEDAR POINT CR.
PELOTES ISLAND
BROWNS I.
BROWNS CR.
Browns Creek Revetment
BLOUNT ISLAND
BACK RIVER
LE BARON
VICKS I.
ALLIGATOR I.
DAME POINT - FULTON CUT-OFF
DAME PT.
DAME POINT CUT
NEW BERLIN
CHICOPIT BAY
GREAT MARSH
MT. PLEASANT CR.
PABLO CR.
BROWARD PT.
BROWARD R.
DUNN CREEK
DUNN CR. CUT
DRUMMOND PT.
DRUMMOND CREEK
DRUMMOND CREEK CUT
BRILLS CUT
FLOOD
DIVERSION FEATURE
ENLARGE OPENING 12' DEEP 650' WIDE
SOUTH DIKE
REED I.
ENLARGE OPENING 12' DEEP 1300' WIDE (WEIR)
DIVERSION FEATURE
MILL COVE
NEWCASTLE I.
REDDIE PT.
CHASEVILLE
MITCHELL BLUFF
GILMORE
FORT CAROLINE RD.
MERRILL RD.
UNIVERSITY BLVD.
ROGERO RD.
ST. JOHNS RIVER
DUVAL COUNTY
TROUT RIVER
TROUT RIVER CUT
LONG BRANCH CUT
LONG BRANCH
RIBAULT R.
MONCRIEF CR.
QUARANTINE STATION
NOTE: 60 FEET BETWEEN COMBINED PIERHEAD-BULKHEAD LINE AND CHANNEL LINE
CORPS OF ENGINEERS DREDGE DEPOT
MUNICIPAL TERMINALS
TERMINAL CHANNEL
ARLINGTON CUT
UPSTREAM LIMIT OF 38-FOOT PROJECT
UPSTREAM LIMIT OF 34-FOOT PROJECT
UPSTREAM LIMIT OF FEDERAL PROJECT
FLORAL BLUFF
ARLINGTON
ARLINGTON R.
EMPIRE PT.
POTTSBURG CR.
LITTLE POTTSBURG CR.
ATLANTIC BEACH
JACKSONVILLE BEACH
JACKSONVILLE
SOUTH JACKSONVILLE
RIVERSIDE
COMMODORE PT.
BRUNSWICK R.R.
S.C.L. R.R.
F.E.C. RY.
ST. AUGUSTINE
ORANGEDALE
JACKSONVILLE HARBOR, FLA.
SCALE IN MILES
1/2 0 1 2
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA
9-30-89



PROJECT: A channel 13 x 200 feet from F.E.C. Ry. bridge at Jacksonville to Palatka; thence 12 x 100 feet to Sanford with cut-offs and easing bends and including a side channel of like dimensions to Enterprise and an alternate approach channel to Sanford; and thence 5 x 100 feet to Lake Harney with a cut-off channel 5 x 75 feet between Lake Monroe and the vicinity of Osteen Bridge: a channel 8 x 50 feet to Hastings Landing at Deep Creek; and maintenance of two jetties built at Volusia Bar under a previous project. Length of project is about 161.5 miles in St. Johns River, 5 miles in Deep Creek, 2.7 miles in the channel to Enterprise, and 0.9 mile in the alternate approach channel to Stanford.

MEAN TIDAL RANGE: 1.1 feet at Jacksonville, 1.2 feet at Palatka, and perceptible at Sanford.

AUTHORIZATION FOR EXISTING PROJECT

ACTS	WORK AUTHORIZED	DOCUMENTS
	ST. JOHNS RIVER, FLA., JACKSONVILLE TO PALATKA	
3 Mar. 1899	Channel 13 x 200 feet from Jacksonville to Palatka	H Doc. 523/55/2 & A R for 1898 p.1343
2 Mar. 1919	Deep Creek improvement (deauthorized)	H. Doc. 699/63/2
	ST. JOHNS RIVER, FLA., PALATKA TO LAKE HARNEY	
14 June 1880	Jetties at Volusia Bar (maintenance only).	A. R. for 1879, p. 795
25 June 1910	Channel 8 x 100 feet from Palatka to Sanford, thence 5 x 100 feet to Lake Harney.	H. Doc. 1111/60/2
3 July 1930	Cut-offs and easing bends.	H. Doc. 691/69/2
2 Mar. 1945	Channel 10 x 100 feet from Palatka to Sanford, with a side channel to Enterprise, and cut-offs and easing bends. (cut-offs deauthorized)	H. Doc. 603/76/3
	ST. JOHNS RIVER, FLA., JACKSONVILLE TO LAKE HARNEY	
2 Mar. 1945	Consolidation of above projects, and a cut-off channel 5 x 75 feet between Lake Monroe and Osteen Bridge.	H Doc. 445/78/2
24 July 1946	Channel 12 x 100 feet from Palatka to Sanford and in side channel to Enterprise	S. Doc. 208/79/2

ST. JOHNS RIVER, FLA., JACKSONVILLE TO LAKE HARNEY

SCALE IN MILES

0 5 10

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA
9-30-78

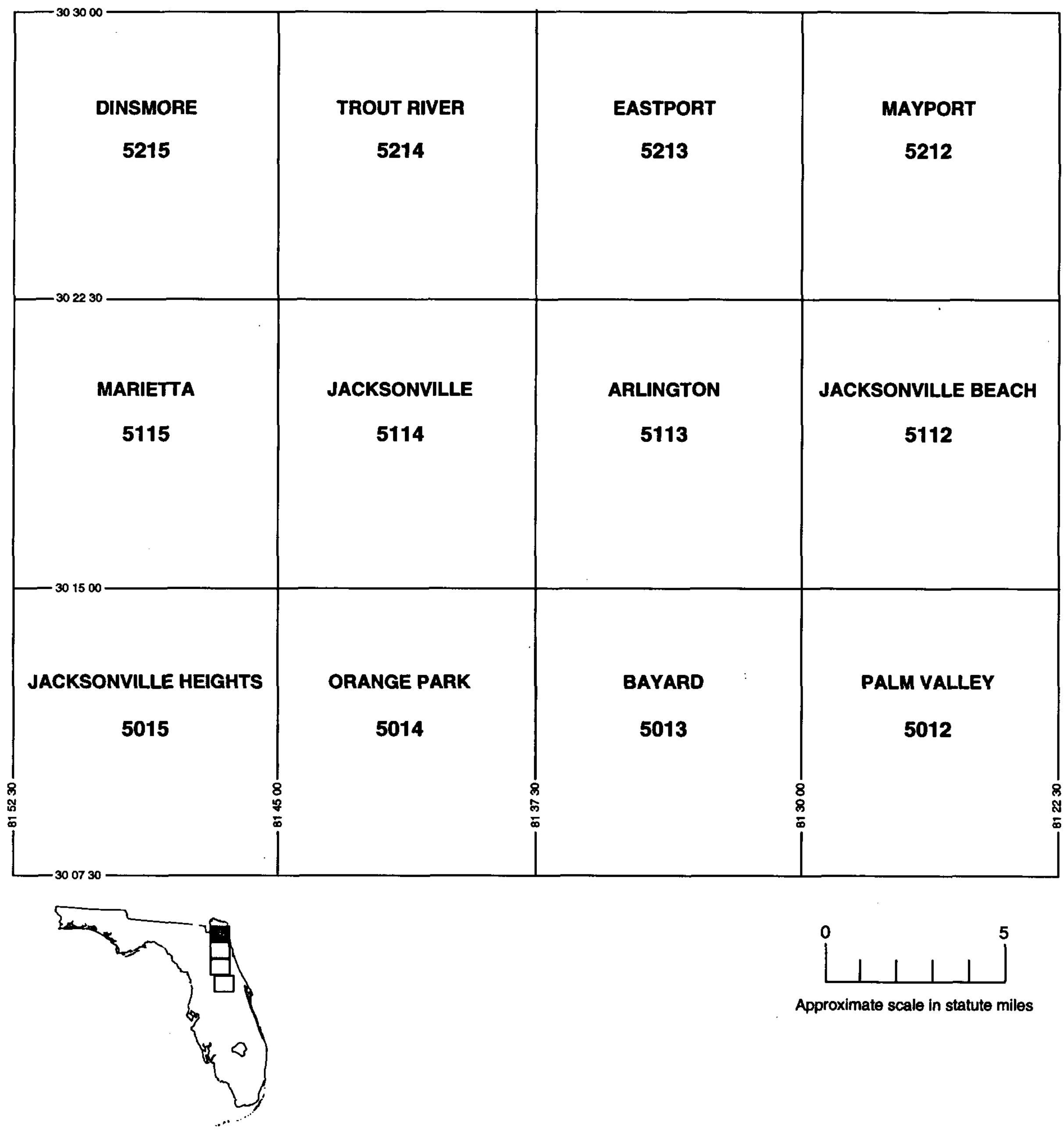


Figure A4. Diagram of USGS 7½-minute quadrangle map sheets lying between 30°30′00″ North and 30°07′30″ North, with map name and SJRWMD identification number. *Each 7½-minute subarea is aligned with a USGS quadrangle.*

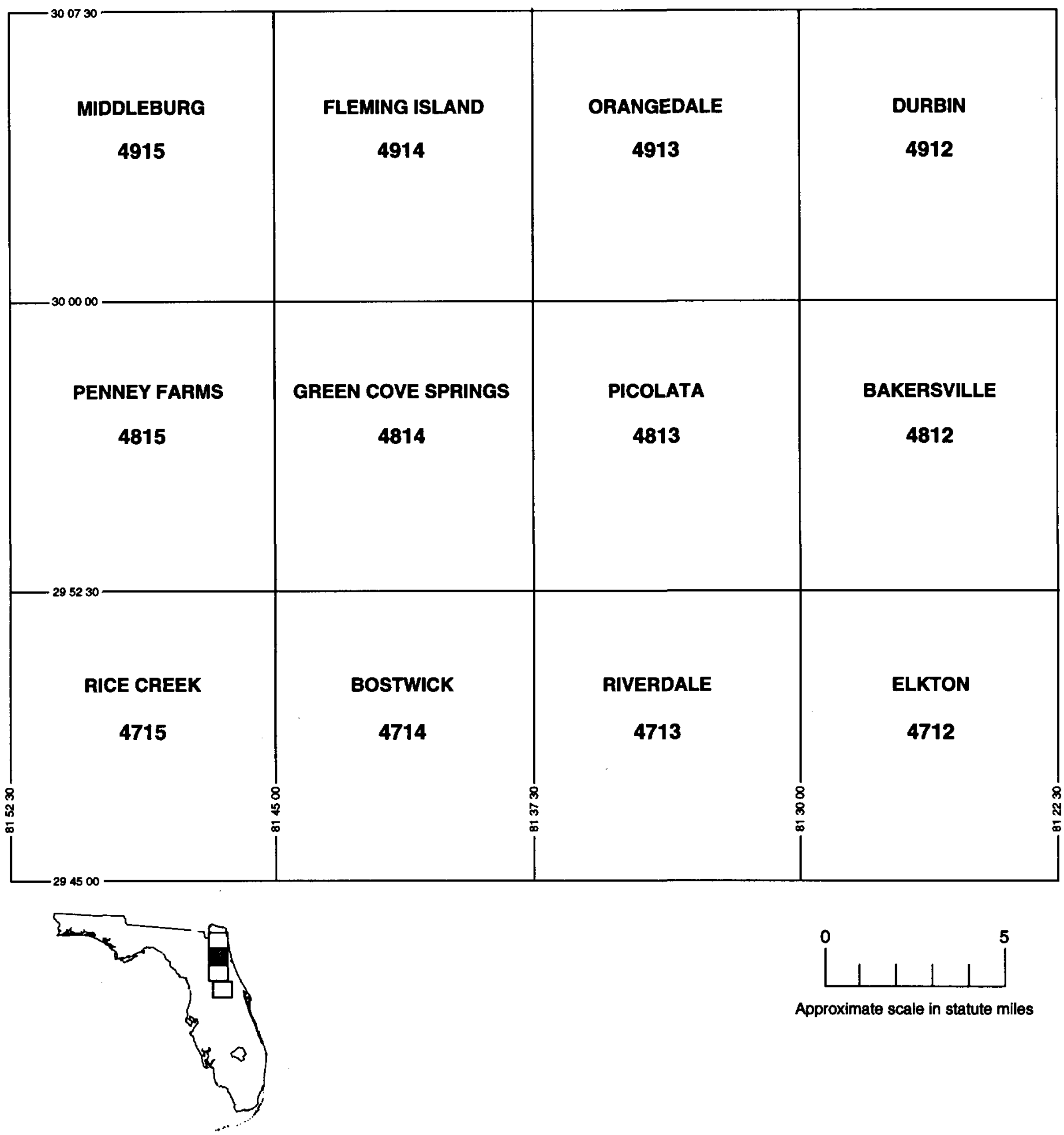


Figure A5. Diagram of USGS 7½-minute quadrangle map sheets lying between 30°07′30″ North and 29°45′00″ North, with map name and SJRWMD identification number. *Each 7½-minute subarea is aligned with a USGS quadrangle.*

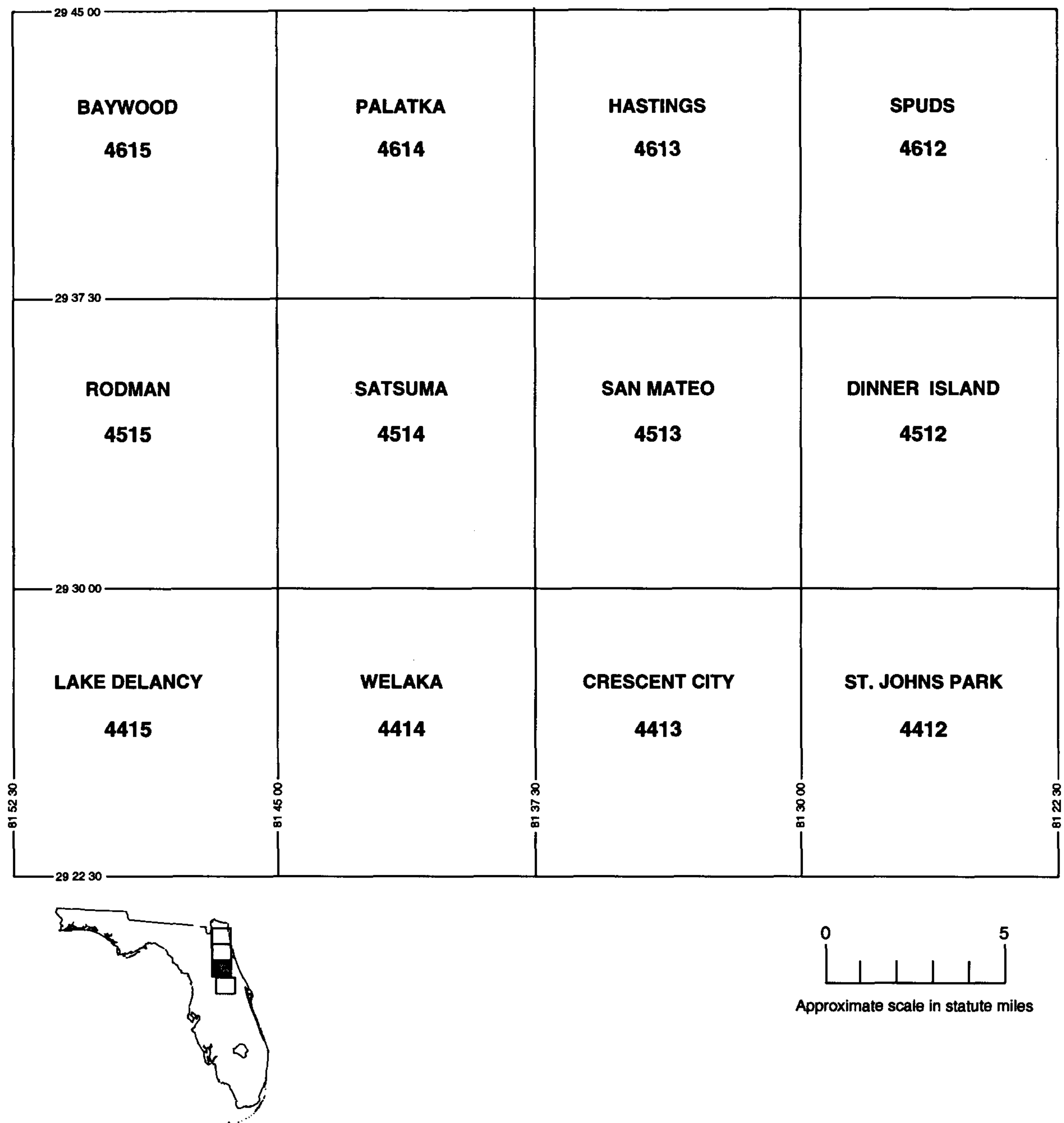


Figure A6. Diagram of USGS 7½-minute quadrangle map sheets lying between 29°45′00″ North and 29°22′30″ North, with map name and SJRWMD identification number. *Each 7½-minute subarea is aligned with a USGS quadrangle.*

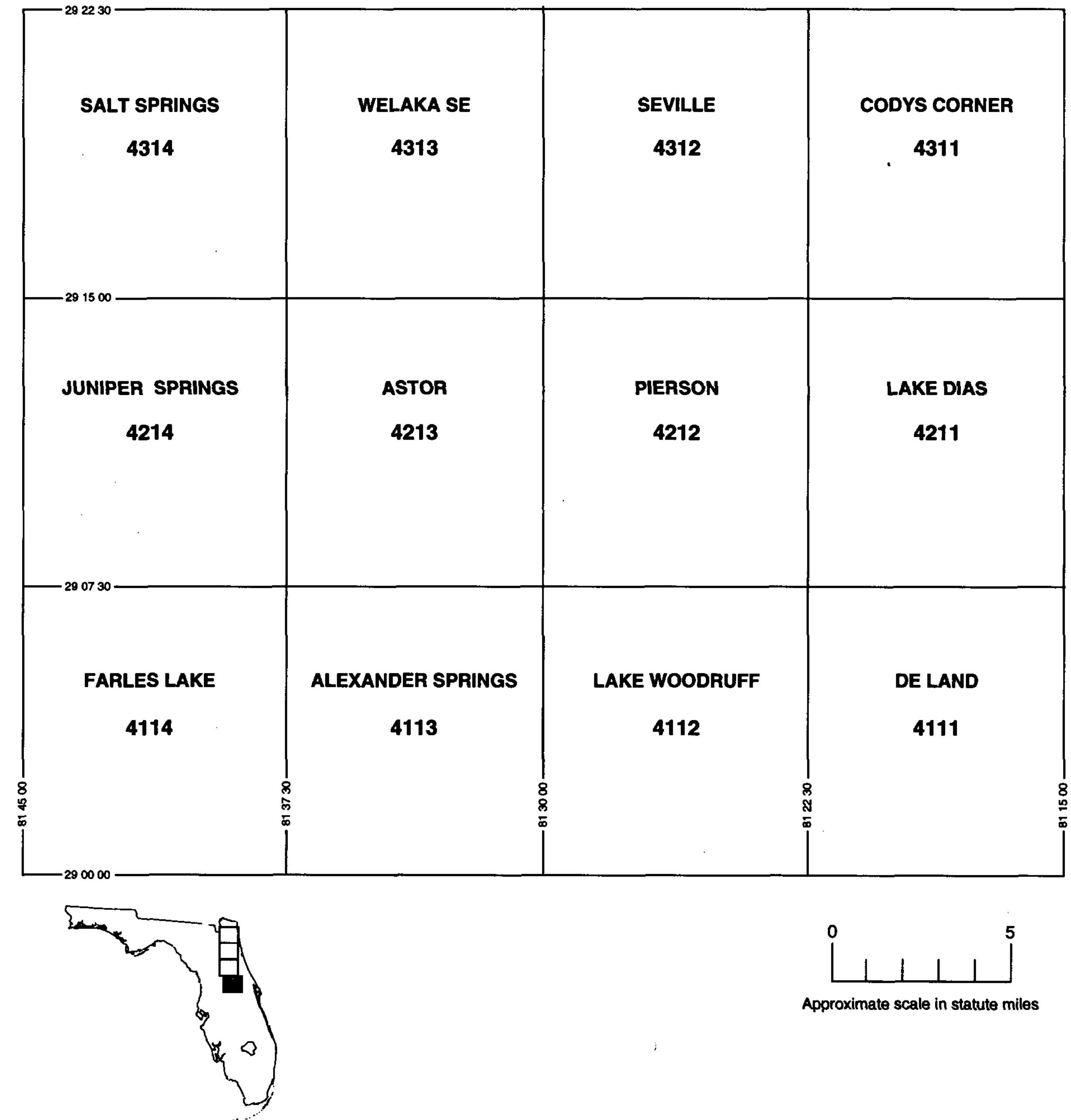


Figure A7. Diagram of USGS 7½-minute quadrangle map sheets lying between 29°22′30″ North and 29°00′00″ North, with map name and SJRWMD identification number. *Each 7½-minute subarea is aligned with a USGS quadrangle.*

Table A1. Locations of NOS tide stations

NOS ID Number	Distance from River Mouth (miles)	State Plane Coordinates		Latitude (N)			Longitude (W)		
		E/W (x) (feet)	N/S (y) (feet)	deg	min	sec	deg	min	sec
872186	†	363438	2219551	30	26	18	81	26	00
872189	18.4	295153	2219303	30	26	13	81	38	60
872194	†	371330	2217658	30	25	60	81	24	30
872196	6.5	357297	2208992	30	24	34	81	27	10
872198	8.7	339388	2208632	30	24	29	81	30	34
872202	21.4	281378	2211476	30	24	54	81	41	37
872203	10.4	328900	2211629	30	24	58	81	32	34
872213	23.4	270845	2212323	30	25	02	81	43	37
872215	15.6	303464	2206376	30	24	05	81	37	24
872216	21.7	279431	2205152	30	23	52	81	41	59
872217	18.5	290265	2203490	30	23	36	81	39	55
872219	10.8	323751	2201215	30	23	15	81	33	32
872220	2.7	363842	2203093	30	23	35	81	25	55
872221	8.3	339372	2201446	30	23	18	81	30	34
872222	15.6	307052	2201780	30	23	20	81	36	43
872223	3.2	363044	2200805	30	23	13	81	26	04
872225	16.9	300046	2199119	30	22	53	81	38	03
872232	6.5	359014	2196793	30	22	33	81	26	50
872242	19.4	302770	2188978	30	21	13	81	37	31
872244	11.5	323694	2194299	30	22	07	81	33	33
872267	8.9	360431	2178783	30	19	35	81	26	33
872268	24.2	289796	2178566	30	19	29	81	39	58
872274	22.6	308016	2172609	30	18	31	81	36	30
872296	28.2	278738	2162621	30	16	51	81	42	03
872305	14.5	363593	2152459	30	15	14	81	25	55
872333	31.9	289367	2142332	30	13	30	81	40	01
872339	33.7	306922	2138333	30	12	52	81	36	41
872374	36.2	280326	2121759	30	10	06	81	41	43
872377	36.2	288719	2118710	30	09	37	81	40	07
872406	41.8	259499	2104612	30	07	15	81	45	38
872409	41.3	299985	2109389	30	08	05	81	37	58
872411	41.7	264702	2102657	30	06	56	81	44	39
872421	43.2	263521	2096199	30	05	52	81	44	52
872434	50.2	259227	2089091	30	04	42	81	45	40
872496	47.8	285934	2059212	29	59	47	81	40	34
872499	56.3	322126	2064809	30	00	45	81	33	43
872589	60.5	324261	2008252	29	51	25	81	33	16
872596	61.0	324042	2006127	29	51	04	81	33	18

Table A1—*Continued*

NOS ID Number	Distance from River Mouth (miles)	State Plane Coordinates		Latitude (N)			Longitude (W)		
		E/W (x) (feet)	N/S (y) (feet)	deg	min	sec	deg	min	sec
872653	67.2	321432	1974359	29	45	49	81	33	46
872767	90.2	282470	1912498	29	35	35	81	41	04
872774	79.8	298125	1930133	29	38	30	81	38	08
872782	89.1	306859	1903959	29	34	12	81	36	27
872832	100.4	285020	1868516	29	28	20	81	40	32
872841	100.6	345417	1875345	29	29	30	81	29	09
872855	102.9	338652	1854736	29	26	06	81	30	25
872877	109.4	298566	1836451	29	23	03	81	37	57
872878	109.6	299998	1835688	29	22	56	81	37	41
8721002	118.7	298035	1787663	29	14	60	81	37	60
8721061	127.3	334486	1757206	29	10	00	81	31	07
8721175	143.7	376978	1701290	29	00	48	81	23	06

†Station not located directly on the St. Johns River

APPENDIX B: HYDROGRAPHIC SURVEYS

Table B1. Hydrographic surveys conducted by the Coast and Geodetic Survey in the LSJR (NOS 1992)

Hydrographic Index Number	Survey Number	Year(s)	Location
76A	H-351	1853	North side of Inlet
	H-481	1855	West of Mayport to Fulton
	H-482	1855	Fulton to west of Chaseville (Sixmile Creek)
	H-484	1855	Arlington River vicinity
	H-586	1857	Inlet to west of Mayport
	H-1147	1872	Intracoastal waterway north of the lower St. Johns River
76B	H-1384a	1876–77	Jacksonville to Mandarin Point (Orange Park)
	H-1384b	1877	Mandarin to San Patricio Point (Green Cove Springs)
	H-1389	1878	Green Cove Springs to Tocoi
	H-1541	1883–89	Inlet to west of Mayport
	H-1542a	1883	West of Mayport to east of Chaseville
	H-1542b	1883	Northwest of Jacksonville
76C	H-1636	1885	Racy Point to Palatka
	H-2337	1898	South of Jacksonville
	H-4376	1924	North of Inlet
	H-5910	1934–35	North of Inlet
	H-6126	1935	Fulton area and Mill Cove
	H-6127	1935	Trout River and northwest of Jacksonville
	H-6130	1935–37	Horseshoe Point to Trout Creek (Dunns Creek to Satsuma)
	H-6131	1935–37	Satsuma to Welaka
	H-6132	1935–37	Crescent Lake
	H-6194	1935–37	San Mateo to Edgewater
	H-6239	1935	Edgewater to Dunns Creek
	H-6296	1934–39	South of Jacksonville to Cunningham Creek
	H-6297	1935	Cunningham Creek to Watson Island (Picolata)
	H-6298	1935	Watson Island (Picolata) to Racy Point
	H-6299	1935	Racy Point to Whetstone Point (Bridgeport)
	H-6300	1935	Palatka to San Mateo
	H-6327	1935	Whetstone Point to Palatka (with Rice Creek inset)
76D	H-6263	1937	Lower Crescent Lake
	H-6266	1937	Lake George
	H-6290	1937–39	Welaka to Mount Royal
	H-6295	1937	Mount Royal to Lake George
	H-6530	1939	Cedar and Ortega rivers
	H-6535	1939	Southwest of Ortega River
	H-6536	1939	Trout River
	H-6537	1939	Ribault River
	H-6538	1939	Arlington River
	H-6544	1939	Mouth of Black Creek
	H-6545	1939	Upstream Black Creek
	H-8412	1959	Cedar and Ortega rivers to Mandarin
	H-8463	1958–59	West of Fulton to southeast Jacksonville
	H-8464	1959	Arlington River to Cedar and Ortega rivers

APPENDIX C: WIND STATISTICS

Table C1. Wind speed, direction, and percent of time wind speed is within given speed range, Naval Air Station, Jacksonville, 1973–77

Direction	Degrees	<1 kn	1–6 kn	1–10 kn	1–16 kn	1–21 kn
N	0.0		3.2	5.3	6.9	7.1
NNE	22.5		3.3	5.5	6.8	7.0
NE	45.0		2.6	4.4	5.5	5.6
ENE	67.5		2.8	4.0	4.5	4.5
E	90.0		2.7	6.5	7.1	7.1
ESE	112.5		3.7	5.4	5.8	5.8
SE	135.0		3.0	4.7	5.0	5.0
SSE	157.5		3.0	5.2	5.6	5.8
S	180.0		4.5	7.6	8.9	8.9
SSW	202.5		3.1	4.4	5.0	5.0
SW	225.0		3.1	4.5	5.4	5.5
WSW	247.5		4.8	6.4	7.0	7.2
W	270.0		5.1	6.5	7.3	7.3
WNW	292.5		2.5	3.4	4.0	4.0
NW	315.0		2.0	3.2	3.8	3.8
NNW	337.5		2.1	3.4	4.2	4.2
Calm*		6.2				
Total		6.2	51.5	80.4	92.8	93.8

*Calm = no direction

Wind speed ranges given in original wind rose were <1*, 1–6, 7–10, 11–16, 17–21, and >21 knots (kn)

To find percent of time wind was within a certain range, subtract given percentages: for example, percent of time wind blew from the north at between 6 and 10 kn was 5.3 - 3.2 = 2.1%.

Use totals as follows: Wind blew at less than 7 kn 57.7% of the time (6.2% + 51.5%).

Source: USACE Jacksonville 1990a, 5, Figure 2

Table C2. Seasonal wind frequency (percent of time), Naval Air Station, Jacksonville, 1973–77

Direction	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
N	16.7	8.0	6.5	18.8
NE	10.0	9.2	8.5	17.9
E	5.8	15.2	16.5	11.9
SE	6.0	15.0	13.5	9.0
S	13.9	16.2	18.0	8.8
SW	11.5	13.0	14.8	7.2
W	15.6	13.2	11.8	10.1
NW	13.0	6.6	3.6	9.8
Calm*	7.5	3.6	6.8	6.5
Total	100.0	100.0	100.0	100.0

*Calm = no direction

Source: USACE Jacksonville 1990a, 6, Figure 3

APPENDIX D: TIDE STATIONS AND TIDAL CHARACTERISTICS

Table D1. Historical NOS tide recorder stations* having data appropriate for analysis

Station Number@	Station Name	River Mile**	Station Location		Date Installed	Date Removed	Number of Days	A	B	C	D
			Latitude (N)	Longitude (W)				(see note)			
8720186	Fort George Island	†	30 26.4	81 26.3	2/12/54	4/7/54	54	N	N	N	N
					4/1/78	9/30/78	182	Y	N	N	Y
8720189	Cedar Heights (Broward River)	18.4	30 26.2	81 38.5	8/9/77	1/31/78	175	Y	Y	N	Y
8720194	Little Talbot Island	†	30 25.8	81 24.3	4/28/74	11/27/74	213	Y	Y	N	Y
					1/16/75	2/8/75	23	Y	-	-	-
8720196	Sisters Creek	6.5	30 25.0	81 41.8	9/1/77	3/23/78	203	Y	N	N	Y
8720198	Clapboard Creek	8.7	30 24.4	81 30.6	8/12/77	1/31/78	172	Y	Y	N	Y
8720203	Blount Island Bridge	10.8	30 24.8	81 32.7	8/15/77	1/23/78	161	Y	Y	N	Y
8720213	Trout River, Sherwood Forest	23.1	30 25.2	81 43.7	3/23/78	12/31/78	283	Y	N	N	Y
8720215	Jacksonville, Navy Fuel Depot	15.6	30 24.0	81 37.6	1/1/59	3/31/59	89	N	N	N	N
					8/26/77	3/28/78	214	Y	Y	N	Y
8720216	Ribault River, Lake Forest	21.7	30 23.9	81 41.9	3/22/78	8/25/78	156	Y	N	N	Y
8720217	Moncrief Creek entrance	18.3	30 23.5	81 39.7	8/26/77	1/31/78	158	Y	N	N	Y
8720219	Dame Point	10.8	30 23.5	81 33.9	8/12/77	2/23/78	195	Y	Y	N	Y
8720220	Mayport	2.4	30 23.5	81 25.9	4/26/28	12/31/60	11937	N	-	-	-
					1/1/61	N/A	N/A	Y	Y	Y	Y
8720221	Fulton	7.8	30 23.4	81 30.4	9/1/77	3/6/78	186	Y	N	N	Y
8720225	Phoenix Park	16.9	30 23.0	81 38.2	6/1/23	7/31/24	426	N	N	N	N
					8/17/77	2/23/78	190	Y	N	N	Y
8720232	Pablo Creek entrance	5.0	30 22.6	81 26.9	8/30/77	1/31/78	154	Y	Y	N	Y
8720242	Longbranch (USACE dredge depot)	19.0	30 21.6	81 37.2	7/21/28	6/30/33	1805	N	N	Y	-
					1/1/35	7/31/35	211	-	-	-	-
					1/12/39	2/1/39	20	-	-	-	-
					5/1/53	4/30/68	5478	N	Y	N	Y
					8/22/77	1/31/78	162	Y	N	N	N
8720244	Mill Cove	11.5	30 22.2	81 33.5	8/22/77	3/31/78	221	Y	Y	N	Y
8720268	Jacksonville, Acosta Bridge	24.0	30 19.5	81 39.9	12/1/58	3/31/59	120	N	N	N	N
					7/5/78	3/14/79	252	Y	N	N	Y
8720274	Little Pottsburg Creek	22.6	30 18.6	81 36.6	6/14/78	1/17/79	217	Y	N	N	Y
8720296	Ortega River entrance	28.0	30 16.7	81 42.3	8/2/78	2/13/79	195	Y	N	Y	Y
8720333	Piney Point	31.0	30 13.7	81 39.8	2/1/59	3/31/59	58	N	N	N	N
					3/10/78	2/21/79	348	Y	N	N	Y
8720374	Orange Park	36.0	30 10.1	81 41.7	6/9/78	11/20/78	164	Y	N	N	Y
8720406	Doctors Lake, Peoria Point	41.8	30 07.2	81 45.5	5/18/78	11/29/78	195	Y	N	N	Y
8720409	Julington Creek	40.5	30 08.1	81 37.8	4/12/78	11/28/78	230	Y	N	N	Y
8720434	Black Creek	45.5	30 04.8	81 45.7	7/27/78	11/6/78	102	Y	N	N	Y
8720496	Green Cove Springs	47.0	29 59.4	81 39.8	3/11/35	5/14/35	64	N	N	N	N
					3/9/78	4/19/79	406	Y	Y	N	Y
8720596	East Tocoi	60.5	29 51.5	81 33.2	5/15/35	6/11/35	27	N	N	N	N
					8/14/78	2/14/79	184	Y	N	N	Y

Table D1—*Continued*

Station Number@	Station Name	River Mile**	Station Location: Latitude (N)	Station Location: Longitude (W)	Date Installed	Date Removed	Number of Days	A	B	C	D
									(see note)		
8720653	Palmetto Bluff (Bridgeport)	66.5	29 45.8	81 33.7	8/10/78	4/30/79	263	Y	N	N	Y
8720767	Buffalo Bluff	90.0	29 35.7	81 40.9	10/5/78	4/24/79	201	Y	N	N	Y
8720774	Palatka	79.5	29 38.6	81 37.9	6/1/35	7/31/35	60	N	N	N	N
					12/16/73	12/31/73	15	Y	-	-	-
					8/2/74	3/31/76	607	Y	-	-	-
					8/2/78	4/30/79	271	Y	Y	N	Y
8720782	Sutherlands Still, Dunns Creek	89.1	29 34.4	81 36.2	11/1/78	4/18/79	168	Y	N	N	Y
8720832	Welaka	100.4	29 28.6	81 40.5	1/25/37	2/28/37	34	N	N	N	N
					8/14/78	5/8/79	267	Y	-	-	-
					12/5/79	2/1/80	58	Y	N	N	Y
8720855	Crescent City, Crescent Lake	102.9	29 25.8	81 30.4	11/2/79	11/30/79	28	Y	N	N	N
8720877	Georgetown	109.4	29 23.1	81 38.2	12/30/73	5/23/74	144	Y	-	-	-
					9/8/74	12/31/74	114	Y	-	-	-
					3/1/75	6/30/75	121	Y	-	-	-
					3/1/76	3/31/76	30	Y	N	N	N
8721002	Juniper Club, Lake George	118.7	29 14.8	81 38.3	3/7/37	4/8/37	32	N	-	-	-
					2/14/80	3/5/80	20	Y	N	N	NN
8721061	Astor and Volusia	127.3	29 10.0	81 31.4	1/5/38	3/1/38	55	N	N	N	N
					3/5/80	3/10/80	5	Y	N	N	NN
8721175	De Land Landing	144.0	29 00.5	81 22.9	11/20/37	3/31/38	131	N	N	N	N
					3/10/80	3/28/80	18	Y	N	N	YN

Note: A = digital data available from NOS
B = level to geodetic network exists
C = harmonic constants available from NOS
D = published or issued tidal datums available from NOS
- = *yes* or *no* not indicated in source table
N/A = not applicable

*Stations are listed in the 1990 NOS Index
@See Figures 3.10a–d for location of stations
**River miles taken from Figures 3.1a–d
†Station not located directly on the St. Johns River

Source: USACE Jacksonville 1994b, 3, Table 1

Table D2. Stations listed in the 1990 NOS Index not included in Table D1

Station Number*	Station Name	River Mile**	Station Location		Date Installed	Date Removed	Number of Days
			Latitude (N)	Longitude (W)			
(none)	South jetty	-0.7					
8720202	Trout River	21.4	30 25.0	81 41.8	1/12/39	1/23/39	11
8720222	Chaseville	15.6	30 23.4	81 36.8	11/13/58	12/8/58	25
8720223	Mayport (backup)	3.0	30 23.5	81 25.9	7/12/77	N/A	N/A
8720267	Pablo Creek	9.0	30 19.4	81 26.3	8/19/77	1/23/78	157
8720339	Goodbys Creek	33.7	30 13.0	81 37.1	1/25/77	1/25/77	0
8720377	Mandarin	35.9	30 09.8	81 40.0	1/19/34	2/26/35	403
8720411	Catfish Point, Doctors Lake	41.7	30 06.9	81 44.9	1/27/77	1/27/77	0
8720421	Swimming Pen Creek	43.2	30 06.0	81 44.8	2/10/77	2/11/77	1
8720499	Trout Creek	56.3	29 59.1	81 33.9	2/16/77	2/18/77	2
8720589	Lane Landing	60.2	29 51.3	81 33.5	2/24/77	3/4/77	8
8720841	Shell Bluff, Crescent Lake	99.5	29 29.5	81 29.3	7/13/35	1/22/37	558
8720878	Georgetown (backup)	109.6	29 23.1	81 38.2	5/5/77	7/15/77	70

*See Figures 3.10a–d for location of stations
**River miles taken from Figures 3.1a–d

Note: N/A = not applicable

Source: NOS 1990a

Table D3. Longitudinal distribution of water elevations from the river mouth to Lake George

Station Number*	Station Name	River Mile**	Estimated Low Tide Jan 40	Low Tide Dec 56	Mean Low Water	Half Tide	Mean High Water	Minimum Annual High Water	Peak Stage, Hurricane Dora	Maximum Recorded Stage
(none)	South jetty	-0.7	-2.17	2.70						
8720220	Mayport	2.4	-5.22	-3.90	-1.86	0.38	2.62	2.93	4.82	5.39
8720221	Fulton	7.8	-4.30	-3.10	-1.15		2.27	2.75	4.90	
8720219	Dame Point	10.8		-0.85		2.13				
8720222	Chaseville	15.6			-0.45		1.86			
8720242	USACE dredge depot	19.0		-2.00	-0.28	0.73	1.70		5.35	
N/A	Main Street Bridge	23.8		-1.85						
8720268	Jacksonville, Acosta Bridge	24.0			0.22		1.32	2.17		
8720296	Ortega River entrance	28.0			0.27	1.15		1.98		
8720333	Naval Air Station	31.0			0.31	0.73	1.13		5.80	
8720374	Orange Park	36.0			0.40		1.09	1.85		
8720496	Green Cove Springs	47.0			0.39		1.20	1.95		
8720596	East Tocoi	60.5			0.30		1.29	2.12		
8720653	Palmetto Bluff (Bridgeport)	66.5			0.26		1.37	2.19		
N/A	Rice Creek	75.8							5.62	
8720774	Palatka	79.5			0.22		1.44	2.24		
8720767	Buffalo Bluff	90.0			0.35		1.32			
8720832	Welaka	100.4			0.58		1.08			
8720877	Georgetown	109.4			0.00	0.00	0.00			
8721175	De Land Landing	144.0	-0.35			0.95				

*See Figures 3.10a–d for location of stations
**River miles taken from Figures 3.1a–d

Note: N/A = not applicable
R/R = railroad

All elevations are in feet referenced to National Geodetic Vertical Datum.
This table of water levels shows the values plotted on the source water level plot. These values are plotted in Figure 3.18.

Source: USACE Jacksonville 1968

Table D4. Mean and spring range of tide and mean tide level for NOS stations

Station Index Number	Station Number*	Station Name	River Mile**	Time Difference		Height Ratios		Mean Range (feet)	Spring Range (feet)	Mean Tide Level (feet)
				Highs (hour mean)	Lows (hour mean)	Highs (feet)	Lows (feet)			
3349	(none)	South jetty	-0.7	-0 35	-0 19	1.09	1.07	4.9	5.7	2.6
3351	8720220	Mayport	2.4	(daily predictions)				4.5	5.3	2.4
3353	8720267	Pablo Creek	9.0	+1 27	+1 13	0.64	0.67	2.9	3.4	1.5
3355	8720221	Fulton	7.8	+0 17	+0 40	0.74	0.73	3.4	4.0	1.8
3357	8720219	Dame Point	10.8	+0 34	+0 53	0.67	0.67	3.0	3.5	1.6
3359	8720225	Phoenix Park (Cummers Mill)	16.9	+0 46	+1 23	0.45	0.47	2.0	2.3	1.1
3361	8720242	Jacksonville (dredge depot)	19.0	+1 12	+1 48	0.45	0.47	2.0	2.3	1.1
3363	8720268	Jacksonville, Acosta Bridge	24.0	+1 54	+2 11	0.26	0.27	1.2	1.4	0.6
3365	8720296	Ortega River entrance	28.0	+2 15	+2 48	0.19	0.20		0.9	1.1
3367	8720374	Orange Park	36.0	+3 37	+4 12	0.14	0.13	0.7	0.8	0.3
3369	8720496	Green Cove Springs	47.0	+5 14	+6 11	0.17	0.20	0.8	0.9	0.4
3371	8720596	East Tocoi	60.5	+6 35	+7 16	0.21	0.20	1.0	1.2	0.5
3373	8720653	Palmetto Bluff (Bridgeport)	66.5	+6 46	+7 30	0.23	0.27	1.1	1.3	0.5
3375	8720774	Palatka	79.5	+7 14	+8 19	0.26	0.27	1.2	1.4	0.6
3377	8720832	Welaka	100.4	+7 34	+8 23	0.11	0.11	0.5	0.6	0.2

*See Figures 3.10a–d for location of stations
**River miles taken from Figures 3.1a–d

Elevations relative to chart datum, mean lower low water

Source: NOS 1990b, 226–27

Table D5. Summary of tidal characteristics*

Station Number**	Station Name	River Miles	High Water (hours)	Low Water (hours)	Mean Range (feet)	Mean Diurnal Range (feet)	MTL NGVD (feet)	Data Series Length
8720194	Little Talbot Island	†	0.00	0.00	5.49	6.09	0.53	4 months
8720220	Mayport	2.4	0.39	0.06	4.51	4.92	0.31	19 years
8720186	Fort George Island	†	0.78	0.80	4.84	5.29	N/A	5 months
8720196	Sisters Creek	6.5	0.92	0.81	4.34	4.70	N/A	3 months
8720232	Pablo Creek entrance	5.0	0.87	0.53	3.89	4.24	0.41	1 months
8720221	Fulton	7.8	0.80	0.64	3.66	3.97	0.43	4 months
8720198	Clapboard Creek	8.7	0.93	0.90	3.64	3.94	0.47	5 months
8720203	Blount Island Bridge	10.8	1.10	1.06	3.51	3.80	0.43	3 months
8720219	Dame Point	10.8	1.10	1.17	3.19	3.44	0.45	5 months
8720215	Jacksonville, Navy Fuel Depot	15.6	1.59	1.76	2.63	2.83	0.56	5 months
8720189	Cedar Heights, Broward River	18.4	1.54	1.73	3.03	3.24	0.46	3 months
8720217	Moncrief Creek, Trout River	18.3	1.60	1.98	2.56	2.76	N/A	3 months
8720213	Trout River, Sherwood Forest	23.1	2.09	2.19	2.65	2.88	N/A	4 months
8720216	Ribault River, Lake Forest	21.7	1.61	2.14	2.64	2.82	N/A	2 months
8720225	Phoenix Park	16.9	1.42	1.75	2.54	2.75	0.56	5 months
8720242	Longbranch (USACE dredge depot)	19.0	1.61	1.82	2.08	2.27	0.73	14 years
8720274	Little Pottsburg Creek	22.6	1.90	2.12	2.05	2.23	0.77	6 months
8720268	Jacksonville, Acosta Bridge	24.0	2.14	2.19	1.51	1.68	0.75	6 months
8720296	Ortega River entrance	28.0	2.54	2.75	1.11	1.26	0.85	6 months
8720333	Piney Point	31.0	3.03	3.56	0.88	1.00	0.79	2 months
8720374	Orange Park	36.0	3.79	4.71	0.74	0.87	0.68	4 months
8720406	Doctors Lake	41.8	3.98	4.94	0.78	0.91	N/A	5 months
8720409	Julington Creek	40.5	4.36	5.19	0.71	0.83	0.81	6 months
8720434	Black Creek	45.5	5.16	5.85	0.82	0.92	N/A	3 months
8720496	Green Cove Springs	47.0	5.45	6.15	0.74	0.86	0.69	12 months
8720596	East Tocoi	60.5	6.51	6.96	0.97	1.10	0.68	4 months
8720653	Palmetto Bluff (Bridgeport)	66.5	6.98	6.59	1.04	1.18	0.67	5 months
8720774	Palatka	79.5	7.57	8.61	1.09	1.22	0.65	4 months

Table D5—*Continued*

Station Number**	Station Name	River Miles	High Water (hours)	Low Water (hours)	Mean Range (feet)	Mean Diurnal Range (feet)	MTL NGVD (feet)	Data Series Length
8720782	Sutherlands Still, Dunns Creek	89.1	8.23	9.32	0.79	0.91	N/A	4 months
8720855	Crescent City, Crescent Lake	102.9	tidal	influence	negligible			27 days
8720767	Buffalo Bluff	90.0	7.85	8.95	0.93	1.03	0.90	5 months
8720832	Welaka	100.4	8.04	8.02	0.35	0.42	0.92	5 months
8720877	Georgetown	109.4	tidal	influence	negligible			4 months

*All elevations computed relative to the 1960–78 National Tidal Datum Epoch
**See Figure 3.10a–d for location of stations
†Station not located directly on the St. Johns River

Explanation of table headings:

River Mile	From file used to create Figures 3.10a–d
High Water	Difference in time of high water from ocean entrance (hours)
Low Water	Difference in time of low water from ocean entrance (hours)
Mean Range	Mean high water - mean low water (MHW - MLW) (feet)
Mean Diurnal Range	Mean higher high water - mean lower low water (MHHW - MLLW) (feet)
MTL NGVD	Mean tide level (MTL) above National Geodetic Vertical Datum (NGVD) (from USACE Jacksonville 1994b, Table 5)
Data Series Length	Length of data series from which tidal datums are determined

Note: N/A = not available

Tributaries separated by dotted lines

Source: USACE Jacksonville 1994b, 6, Table 2

Table D6. Predicted average tidal currents, 1990

Tidal Current Station Number	Station Location	Approx. River Mile	Average Speeds and Directions					
			Maximum Flood			Maximum Ebb		
			kn	fps	deg	kn	fps	deg
7781	St. Johns River entrance (between jetties)	0	1.9	3.2	277	2.3	3.9	099
7786	Mayport	2	2.2	3.7	211	3.1	5.2	026
7791	Mile Point, southeast of	4	2.7	4.6	241	2.9	4.9	073
7796	Pablo Creek	9	3.4	5.8	180	5.2	8.8	000
7801	Sisters Creek entrance (bridge)	5	1.4	2.4	000	1.4	2.4	180
7806	St. Johns Bluff	7	1.6	2.7	244	2.2	3.7	059
7811	Drummond Point, channel south of	14	1.3	2.2	232	1.6	2.7	060
7816	Phoenix Park	17	1.1	1.9	192	1.0	1.7	352
7821	Chaseville, channel near	17	1.1	1.9	151	1.6	2.7	337
7826	Quarantine Station	17	1.1	1.9	183	1.2	2.0	001
7831	Commodore Point, terminal channel	22	1.0	1.7	209	1.0	1.7	062
7836	Jacksonville, off Washington Street	23	1.8	3.0	281	1.9	3.2	118
7841	Jacksonville, Acosta Bridge	24	1.6	2.7	240	1.7	2.9	060
7846	Winter Point	25	1.1	1.9	200	1.1	1.9	015
7851	Mandarin Point	37	0.6	1.0	179	0.7	1.2	013
7856	Red Bay Point, drawbridge	50	0.9	1.5	115	0.6	1.0	300
7861	Tocoi to Lake George	N/A	current weak and variable					

Note: kn = knot
fps = feet per second
deg = degree
N/A = not applicable

Source: NOS 1988b

Table D7. Amplitudes and phases of harmonic constituents (1992 analysis)

Station Name	Component															
	M_2		N_2		S_2		K_1		O_1		P_1		M_4		M_6	
	Amp (ft)	Phase (deg)	Amp (ft)	Phase (deg)	Amp (ft)	Phase (deg)	Amp (ft)	Phase (deg)	Amp (ft)	Phase (deg)	Amp (ft)	Phase (deg)	Amp (ft)	Phase (deg)	Amp (ft)	Phase (deg)
Little Talbot Island	2.62	215.2	0.61	195.1	0.42	239.7	0.37	110.5	0.26	119.4	0.12	111.2	0.05	063.3	0.02	356.0
Mayport	2.17	225.3	0.49	207.3	0.36	248.6	0.27	122.5	0.20	130.8	0.09	115.0	0.08	204.8	0.03	083.7
Pablo Creek entrance	1.88	236.2	0.34	223.9	0.23	258.8	0.29	145.6	0.19	130.6	0.10	144.5	0.05	257.9	0.04	091.9
Fulton	1.78	245.9	0.36	224.0	0.29	264.7	0.20	141.4	0.14	143.2	0.07	141.5	0.02	264.7	0.05	129.9
Clapboard Creek	1.76	243.4	0.35	230.0	0.24	268.9	0.22	145.1	0.15	136.3	0.07	144.4	0.03	954.8	0/06	142.7
Blount Island Bridge	1.75	243.4	0.30	231.7	0.22	266,6	0.27	150.2	0.17	130.8	0.09	148.7	0.03	025.8	0.06	145.5
Dame Point	1.58	247.2	0.30	235.0	0.21	272.9	0.19	151.8	0.14	146.2	0.07	151.5	0.03	350.1	0.07	166.4
Jacksonville, Navy Fuel Depot	1.31	260.6	0.24	249.1	0.17	284.8	0.15	160.7	0.11	149.2	0.04	159.9	0.04	097.2	0.08	211.4
Phoenix Park	1.26	264.7	0.24	257.4	0.17	286.4	0.16	163.5	0.11	155.2	0.05	162.8	0.05	108.3	0.07	220.7
USACE dredge depot	1.13	264.4	0.22	256.1	0.15	289.1	0.13	166.6	0.09	154.9	0.04	165.8	0.04	082.5	0.07	222.5
Little Pottsburg	1.02	268.4	0.19	258.6	0.14	292.6	0.13	170.0	0.09	151.0	0.04	168.5	0.04	119.4	0.05	222.8
Jacksonville, Acosta Bridge	0.75	274.9	0.12	258.5	0.10	305.2	0.10	183.2	0.06	161.2	0.03	181.6	0.02	078.9	0.04	253.9
Ortega River entrance	0.53	286.1	0.08	270.1	0.07	317.9	0.08	201.8	0.04	169.7	0.02	199.4	0.03	190.8	0.04	298.9
Piney Point	0.43	301.7	0.07	285.4	0.05	334.2	0.05	220.5	0.03	186.3	0.02	217.0	0.02	186.4	0.03	337.1
Orange Park	0.38	322.5	0.06	316.2	0.05	341.8	0.08	208.1	0.04	202.3	0.02	207.7	0.03	244.0	0.03	032.5
Julington Creek	0.36	332.9	0.06	317.2	0.04	363.5	0.06	203.2	0.06	209.1	0.02	203.6	0.04	265.5	0.04	052.6
Green Cove Springs	0.36	363.9	0.06	348.5	0.04	347.3	0.06	216.8	0.05	220.8	0.01	213.4	0.03	283.5	0.03	108.5
East Tocoi	0.43	401.5	0.06	387.2	0.04	434.0	0.06	247.6	0.05	226.0	0.02	245.9	0.03	351.9	0.03	200.5
Palmetto Bluff (Bridgeport)	0.49	413.4	0.08	394.7	0.02	449.7	0.06	238.4	0.05	237.8	0.02	238.4	0.03	028.3	0.03	253.7
Palatka	0.54	429.4	0.08	414.7	0.07	467.7	0.05	248.7	0.05	228.6	0.02	247.2	0.05	080.9	0.03	343.4
Buffalo Bluff	0.44	449.3	0.07	442.8	0.04	465.8	0.03	263.7	0.02	256.8	0.01	263.2	0.02	123.2	0.04	061.4
Welaka	0.15	455.1	0.02	432.5	0.02	487.7	0.01	267.6	0.01	284.2	0.00	——	0.04	179.4	0.02	145.9
Georgetown	0.02	562.0	——	——	——	——	0.01	337.6	——	——	——	——	——	——	0.01	215.6

Note: —— = negligible values
amp = amplitude
ft = feet
deg = degrees

See Table 3.13 for name of constituent

Source: USACE Jacksonville 1994b, 12, Table 3

Table D8. Tidal constituents for all locations having adequate water level data for analysis (1992)

Little St. Marys River — NOS/NOAA Station Number: 8720006
Series Start Date: 2/1/1985 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.29100

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
1.881	312.7	0.243	3.8	0.376	310.7	0.199	187.8	0.255	74.1	0.244	196.3	0.088	242.9
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.048	207.2	0.000	0.0	0.073	310.9	0.013	331.1	0.045	237.9	0.050	308.7
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.010	179.3	0.013	336.4	0.000	0.0	0.017	192.0	0.019	183.5	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.009	199.9	0.047	200.5	0.014	1.8	0.002	5.9
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.006	204.7	0.066	188.4	0.000	0.0	0.000	0.0	0.053	314.6	0.000	0.0	0.066	8.0
M_8		MS_4											
0.023	29.0	0.000	0.0										

Roses Bluff — NOS/NOAA Station Number: 8720007
Series Start Date: 2/1/1985 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.10800

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
2.919	258.0	0.520	282.5	0.663	247.9	0.230	146.1	0.135	306.5	0.268	146.6	0.081	89.4
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.038	77.9	0.000	0.0	0.129	249.2	0.010	208.0	0.070	210.2	0.088	237.8
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.011	145.6	0.020	269.3	0.000	0.0	0.019	146.3	0.021	145.8	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.010	146.8	0.052	146.8	0.031	281.5	0.004	283.4
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.007	147.0	0.076	146.1	0.000	0.0	0.000	0.0	0.082	268.1	0.000	0.0	0.141	284.5
M_8		MS_4											
0.030	134.3	0.000	0.0										

Fernandina Beach — NOS/NOAA Station Number: 8720030
Series Start Date: N/A — Series Length (in days): N/A
Series Mean Sea Level (in feet): 4.78000

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
2.911	248.5	0.470	273.6	0.633	235.6	0.339	133.7	0.103	263.3	0.252	146.0	0.021	42.1
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.042	169.2	0.020	35.5	0.052	267.8	0.147	233.0	0.000	0.0	0.087	283.6	0.075	219.3
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.011	121.4	0.062	241.2	0.049	89.4	0.018	139.8	0.020	127.5	0.000	0.0	0.310	186.9
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.241	57.5	0.000	0.0	0.000	0.0	0.010	151.2	0.056	143.6	0.046	267.0	0.004	273.4
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.007	158.2	0.116	132.5	0.014	315.8	0.041	320.7	0.121	239.3	0.031	183.8	0.119	269.1
M_8		MS_4											
0.016	75.6	0.062	291.0										

Fernandina Beach — NOS/NOAA Station Number: 8720030
Series Start Date: 1/1/1987 — Series Length (in days): 365
Series Mean Sea Level (in feet): 4.93500

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
2.910	248.3	0.453	272.3	0.631	238.3	0.342	132.7	0.105	266.0	0.249	145.6	0.019	36.9
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.041	168.5	0.021	28.2	0.057	280.2	0.134	226.6	0.002	354.0	0.087	276.7	0.105	225.0
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.013	159.7	0.060	235.7	0.050	87.1	0.014	182.9	0.020	129.5	0.081	60.1	0.243	21.9
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.137	243.0	0.045	130.9	0.056	331.6	0.012	133.0	0.050	141.4	0.053	256.0	0.025	172.1
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.005	101.8	0.118	132.7	0.021	314.5	0.052	317.9	0.123	239.6	0.038	180.7	0.112	270.4
M_8		MS_4											
0.015	76.7	0.059	294.5										

Table D8—*Continued*

Fernandina Beach — NOS/NOAA Station Number: 8720030
Series Start Date: 5/1/1988 — Series Length (in days): 276
Series Mean Sea Level (in feet): 4.95700

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.931 249.9	0.476 275.5	0.620 236.9	0.333 136.1	0.111 263.3	0.257 146.0	0.021 53.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.040 169.9	0.019 39.6	0.050 267.3	0.142 231.7	0.005 356.9	0.086 299.3	0.067 240.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.012 140.0	0.044 247.7	0.042 85.4	0.014 176.0	0.021 149.7	0.075 11.4	0.303 37.6
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.088 221.1	0.065 35.1	0.073 302.2	0.010 121.4	0.055 137.3	0.058 281.4	0.042 199.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.009 156.5	0.124 131.5	0.005 265.1	0.049 313.5	0.141 243.8	0.035 181.8	0.140 272.8
M_8	MS_4					
0.018 82.7	0.054 290.6					

Fernandina Beach — NOS/NOAA Station Number: 8720030
Series Start Date: 1/1/1990 — Series Length (in days): 365
Series Mean Sea Level (in feet): 4.93100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.911 248.2	0.470 272.9	0.645 232.8	0.336 132.3	0.101 262.0	0.250 147.0	0.021 39.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.049 166.4	0.018 37.6	0.051 264.6	0.183 238.7	0.002 347.0	0.108 273.3	0.073 192.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.011 165.2	0.091 238.3	0.054 96.8	0.028 188.5	0.018 175.1	0.074 67.1	0.266 45.6
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.351 167.3	0.036 221.5	0.023 326.2	0.015 139.7	0.056 149.6	0.049 257.1	0.036 177.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.008 204.1	0.112 129.4	0.006 311.1	0.027 314.5	0.120 243.7	0.028 192.6	0.120 274.4
M_8	MS_4					
0.014 72.0	0.059 287.2					

Fernandina Beach — NOS/NOAA Station Number: 8720030
Series Start Date: 1/1/1991 — Series Length (in days): 365
Series Mean Sea Level (in feet): 5.18000

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.886 248.9	0.464 272.5	0.647 235.4	0.347 134.2	0.107 270.9	0.257 145.8	0.017 55.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.050 170.5	0.021 45.6	0.060 278.3	0.151 230.1	0.002 357.3	0.089 283.8	0.103 217.5
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.011 150.5	0.053 223.2	0.045 98.6	0.010 174.5	0.018 158.6	0.084 57.5	0.228 47.5
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.337 166.2	0.038 309.9	0.036 304.5	0.013 149.8	0.052 151.9	0.054 245.1	0.029 163.5
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.013 136.5	0.109 132.6	0.005 44.0	0.025 338.6	0.146 253.1	0.027 207.1	0.101 270.0
M_8	MS_4					
0.015 68.1	0.064 294.7					

Fernandina Beach — NOS/NOAA Station Number: 8720030
Series Start Date: 1/1/1992 — Series Length (in days): 366
Series Mean Sea Level (in feet): 5.12100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.871 248.4	0.454 275.0	0.656 234.4	0.347 133.8	0.108 267.5	0.250 145.9	0.021 50.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.049 176.8	0.019 34.3	0.057 270.1	0.122 217.7	0.003 323.2	0.090 286.0	0.113 233.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.015 151.6	0.043 231.8	0.047 93.0	0.016 159.1	0.023 168.9	0.090 265.1	0.294 87.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.316 193.9	0.051 56.8	0.121 32.5	0.012 108.0	0.062 141.8	0.038 253.5	0.034 139.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.015 176.9	0.118 129.0	0.021 288.9	0.033 340.7	0.205 259.4	0.032 215.4	0.097 271.1
M_8	MS_4					
0.015 63.9	0.060 296.9					

Table D8—*Continued*

Fernandina Beach — NOS/NOAA Station Number: 8720030
Series Start Date: 1/1/1980 — Series Length (in days): 366
Series Mean Sea Level (in feet): 4.77900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.905 248.0	0.461 273.3	0.612 235.1	0.350 133.9	0.108 269.7	0.240 144.5	0.027 16.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.045 166.8	0.023 41.3	0.051 273.7	0.111 236.1	0.002 344.8	0.091 293.8	0.061 232.4
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.023 141.5	0.063 215.9	0.056 89.7	0.017 169.5	0.020 144.6	0.034 17.0	0.105 89.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.128 249.5	0.072 352.3	0.050 290.9	0.013 147.1	0.056 140.0	0.042 260.1	0.025 162.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.006 43.6	0.118 134.4	0.012 314.0	0.043 305.0	0.149 235.4	0.021 164.3	0.130 273.6
M_8	MS_4					
0.014 74.3	0.061 298.0					

Kingsley Creek — NOS/NOAA Station Number: 8720058
Series Start Date: 5/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.48600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.842 255.0	0.440 284.8	0.654 245.4	0.370 133.4	0.096 283.4	0.297 154.5	0.066 55.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.019 48.9	0.000 0.0	0.127 246.7	0.008 14.5	0.068 202.2	0.087 235.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.013 112.2	0.020 268.8	0.000 0.0	0.021 143.8	0.024 122.9	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.011 163.6	0.058 165.0	0.026 283.6	0.004 285.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.008 175.5	0.122 134.9	0.000 0.0	0.000 0.0	0.080 264.6	0.000 0.0	0.120 287.2
M_8	MS_4					
0.025 93.5	0.000 0.0					

Kingsley Creek — NOS/NOAA Station Number: 8720058
Series Start Date: 6/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.55100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.813 256.3	0.450 282.7	0.573 246.1	0.382 133.5	0.092 288.5	0.281 152.1	0.073 75.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.007 15.2	0.000 0.0	0.111 247.5	0.005 226.6	0.068 206.7	0.076 236.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.012 114.9	0.020 268.5	0.000 0.0	0.020 142.7	0.022 124.3	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.011 160.0	0.055 161.3	0.027 281.7	0.004 283.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.007 170.5	0.127 134.9	0.000 0.0	0.000 0.0	0.079 266.4	0.000 0.0	0.122 284.9
M_8	MS_4					
0.016 89.2	0.000 0.0					

Amelia City — NOS/NOAA Station Number: 8720086
Series Start Date: 1/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 3.62400

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.485 258.7	0.379 286.6	0.458 249.4	0.278 150.7	0.050 82.4	0.185 160.2	0.062 87.6
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.024 57.6	0.000 0.0	0.089 250.7	0.020 18.0	0.060 207.7	0.061 240.2
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.008 141.1	0.017 271.6	0.000 0.0	0.013 155.4	0.015 145.9	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.007 164.2	0.036 164.9	0.022 285.5	0.003 287.7
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.005 169.6	0.092 151.4	0.000 0.0	0.000 0.0	0.070 268.0	0.000 0.0	0.103 288.8
M_8	MS_4					
0.001 231.9	0.000 0.0					

Table D8—*Continued*

Amelia City
Series Start Date: 4/1/1978
Series Mean Sea Level (in feet): 3.96400
NOS/NOAA Station Number: 8720086
Series Length (in days): 29

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.529 257.9	0.366 293.8	0.487 261.8	0.419 107.9	0.054 42.7	0.252 178.7	0.087 76.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.012 43.0	0.000 0.0	0.094 261.3	0.008 268.6	0.061 198.9	0.065 265.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.011 37.1	0.018 274.5	0.000 0.0	0.018 143.0	0.020 72.8	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.010 209.1	0.049 213.8	0.022 292.4	0.003 295.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.006 249.0	0.139 113.2	0.000 0.0	0.000 0.0	0.071 254.0	0.000 0.0	0.099 296.7
M_8	MS_4					
0.012 90.0	0.000 0.0					

Fort George Island
Series Start Date: 4/1/1978
Series Mean Sea Level (in feet): 5.43200
NOS/NOAA Station Number: 8720186
Series Length (in days): 29

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.363 255.6	0.356 282.7	0.474 252.9	0.350 121.0	0.078 9.2	0.210 149.0	0.031 73.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.012 21.3	0.000 0.0	0.092 253.2	0.005 263.0	0.057 205.4	0.063 250.2
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.009 93.0	0.017 268.2	0.000 0.0	0.015 134.8	0.017 107.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.008 161.0	0.041 162.8	0.021 281.6	0.003 283.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.005 176.7	0.116 123.1	0.000 0.0	0.000 0.0	0.066 258.3	0.000 0.0	0.097 284.9
M_8	MS_4					
0.003 125.8	0.000 0.0					

Fort George Island
Series Start Date: 9/1/1978
Series Mean Sea Level (in feet): 6.13500
NOS/NOAA Station Number: 8720186
Series Length (in days): 29

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.220 260.7	0.371 282.0	0.479 249.8	0.347 159.3	0.086 359.5	0.213 140.6	0.019 89.0
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.018 58.1	0.000 0.0	0.093 251.3	0.001 235.0	0.053 216.4	0.064 239.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.009 178.0	0.016 270.6	0.000 0.0	0.015 150.0	0.017 168.6	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.008 132.6	0.041 131.3	0.022 281.1	0.003 282.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.005 122.1	0.115 157.9	0.000 0.0	0.000 0.0	0.062 271.5	0.000 0.0	0.101 283.7
M_8	MS_4					
0.005 83.5	0.000 0.0					

Cedar Heights, St. Johns River
Series Start Date: 10/1/1977
Series Mean Sea Level (in feet): 4.64800
NOS/NOAA Station Number: 8720189
Series Length (in days): 29

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.453 283.5	0.189 313.9	0.318 282.9	0.168 175.6	0.069 104.6	0.120 166.5	0.058 279.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.007 74.7	0.000 0.0	0.062 283.0	0.001 20.8	0.035 229.8	0.042 282.2
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 184.7	0.010 297.6	0.000 0.0	0.008 171.1	0.009 180.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 162.6	0.023 161.9	0.011 312.6	0.002 315.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 157.4	0.056 174.9	0.000 0.0	0.000 0.0	0.041 284.2	0.000 0.0	0.052 316.3
M_8	MS_4					
0.007 163.9	0.000 0.0					

Table D8—*Continued*

Cedar Heights, St. Johns River — NOS/NOAA Station Number: 8720189
Series Start Date: 1/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.03100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.476 283.2	0.157 317.5	0.290 269.3	0.140 170.1	0.117 136.2	0.108 191.6	0.058 273.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.016 32.8	0.000 0.0	0.056 271.1	0.011 102.3	0.035 225.5	0.039 255.3
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 148.7	0.010 299.1	0.000 0.0	0.008 180.8	0.008 159.5	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 200.8	0.021 202.2	0.009 316.1	0.001 318.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 212.8	0.046 171.7	0.000 0.0	0.000 0.0	0.041 297.2	0.000 0.0	0.043 320.3
M_8	MS_4					
0.012 123.1	0.000 0.0					

Little Talbot Island — NOS/NOAA Station Number: 8720194
Series Start Date: 5/1/1974 — Series Length (in days): 29
Series Mean Sea Level (in feet): 30.5960

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.637 231.3	0.415 250.4	0.622 215.4	0.386 114.8	0.046 94.2	0.272 128.3	0.012 68.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.009 153.0	0.000 0.0	0.121 217.5	0.003 250.9	0.063 189.1	0.083 199.5
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.012 101.3	0.019 240.2	0.000 0.0	0.019 121.5	0.022 108.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.010 134.1	0.053 135.0	0.025 249.7	0.003 251.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.007 141.7	0.128 115.8	0.000 0.0	0.000 0.0	0.074 247.1	0.000 0.0	0.113 252.0
M_8	MS_4					
0.003 155.6	0.000 0.0					

Little Talbot Island — NOS/NOAA Station Number: 8720194
Series Start Date: 6/1/1974 — Series Length (in days): 29
Series Mean Sea Level (in feet): 30.7840

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.611 233.7	0.407 258.9	0.615 214.8	0.353 116.2	0.048 103.7	0.258 134.5	0.022 37.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.008 34.3	0.000 0.0	0.119 217.3	0.000 331.0	0.063 185.7	0.082 195.9
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.011 97.9	0.018 245.4	0.000 0.0	0.018 125.3	0.020 107.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.010 142.4	0.050 143.6	0.024 257.9	0.003 259.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.007 152.7	0.117 117.6	0.000 0.0	0.000 0.0	0.073 252.7	0.000 0.0	0.111 260.9
M_8	MS_4					
0.010 209.0	0.000 0.0					

Little Talbot Island — NOS/NOAA Station Number: 8720194
Series Start Date: 7/1/1974 — Series Length (in days): 29
Series Mean Sea Level (in feet): 30.4480

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.616 234.1	0.446 248.3	0.607 216.9	0.376 119.1	0.050 99.2	0.249 130.4	0.018 37.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.017 298.9	0.000 0.0	0.118 219.2	0.008 184.2	0.063 197.0	0.081 199.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.011 107.7	0.018 240.7	0.000 0.0	0.018 124.7	0.020 113.5	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.009 135.3	0.048 136.1	0.026 247.8	0.004 248.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.006 141.7	0.124 119.9	0.000 0.0	0.000 0.0	0.073 251.3	0.000 0.0	0.121 249.5
M_8	MS_4					
0.001 359.6	0.000 0.0					

Table D8—*Continued*

Little Talbot Island — NOS/NOAA Station Number: 8720194
Series Start Date: 8/1/1974 — Series Length (in days): 29
Series Mean Sea Level (in feet): 30.5810

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.609 233.8	0.446 247.5	0.641 217.7	0.365 127.1	0.046 95.8	0.243 130.9	0.020 25.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.019 328.0	0.000 0.0	0.124 219.9	0.010 166.0	0.063 197.3	0.085 201.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.010 123.4	0.018 240.2	0.000 0.0	0.017 129.0	0.019 125.3	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.009 132.5	0.047 132.8	0.026 246.9	0.004 248.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.006 134.6	0.121 127.4	0.000 0.0	0.000 0.0	0.073 250.0	0.000 0.0	0.121 248.6
M_8	MS_4					
0.005 120.6	0.000 0.0					

Sister Creek — NOS/NOAA Station Number: 8720196
Series Start Date: 9/1/1977 — Series Length (in days): 203
Series Mean Sea Level (in feet): 5.32300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.116 260.2	0.350 281.8	0.434 251.9	0.280 144.2	0.069 351.7	0.197 152.4	0.035 193.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.034 201.0	0.019 53.6	0.039 338.7	0.105 233.4	0.003 12.6	0.065 333.4	0.059 237.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.011 219.0	0.044 226.7	0.046 107.0	0.024 173.6	0.023 138.4	0.097 86.1	0.371 27.8
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.395 242.2	0.082 342.6	0.096 203.5	0.013 220.3	0.053 156.9	0.017 236.8	0.063 195.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.012 211.5	0.101 141.6	0.005 236.4	0.023 350.4	0.123 248.1	0.043 196.8	0.089 310.8
M_8	MS_4					
0.010 152.0	0.026 329.6					

Clapboard Creek, Pelotes Island — NOS/NOAA Station Number: 8720198
Series Start Date: 9/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.61600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.790 261.1	0.224 276.7	0.316 252.8	0.263 155.8	0.032 100.6	0.175 143.9	0.066 199.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.016 66.9	0.000 0.0	0.061 253.9	0.006 214.4	0.043 222.3	0.042 244.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.007 167.7	0.012 268.3	0.000 0.0	0.012 149.9	0.014 161.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.007 138.9	0.034 138.1	0.013 276.1	0.002 277.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.005 132.2	0.087 154.9	0.000 0.0	0.000 0.0	0.050 269.3	0.000 0.0	0.061 277.9
M_8	MS_4					
0.017 73.7	0.000 0.0					

Clapboard Creek, Pelotes Island — NOS/NOAA Station Number: 8720198
Series Start Date: 10/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.56200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.758 260.4	0.232 286.8	0.363 254.0	0.205 153.9	0.026 72.5	0.150 151.4	0.065 195.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.009 32.6	0.000 0.0	0.070 254.9	0.002 340.9	0.042 210.9	0.048 247.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.006 156.4	0.012 272.7	0.000 0.0	0.011 152.7	0.012 155.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.006 150.3	0.029 150.1	0.014 285.7	0.002 287.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 148.9	0.068 153.7	0.000 0.0	0.000 0.0	0.049 266.8	0.000 0.0	0.063 288.9
M_8	MS_4					
0.009 79.1	0.000 0.0					

Table D8—*Continued*

Clapboard Creek, Pelotes Island — NOS/NOAA Station Number: 8720198
Series Start Date: 11/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.81900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.742 262.9	0.255 282.2	0.367 245.8	0.195 144.6	0.023 99.7	0.132 148.8	0.050 196.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.011 43.3	0.000 0.0	0.071 248.1	0.004 354.2	0.042 220.4	0.049 228.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.006 140.3	0.012 271.9	0.000 0.0	0.009 146.7	0.010 142.4	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 150.7	0.026 151.0	0.015 281.5	0.002 283.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 153.1	0.065 144.9	0.000 0.0	0.000 0.0	0.049 280.0	0.000 0.0	0.069 283.8
M_8	MS_4					
0.007 71.5	0.000 0.0					

Clapboard Creek, Pelotes Island — NOS/NOAA Station Number: 8720198
Series Start Date: 12/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.33400

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.795 260.8	0.280 279.6	0.375 247.2	0.213 145.5	0.025 95.5	0.153 158.6	0.047 195.0
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.019 48.4	0.000 0.0	0.073 249.0	0.008 352.9	0.043 218.7	0.050 233.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.007 132.5	0.013 269.5	0.000 0.0	0.011 152.0	0.012 139.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.006 164.2	0.030 165.0	0.017 278.9	0.002 280.4
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 171.5	0.070 146.5	0.000 0.0	0.000 0.0	0.050 274.3	0.000 0.0	0.076 281.1
M_8	MS_4					
0.010 118.2	0.000 0.0					

Blount Island Bridge, St. Johns — NOS/NOAA Station Number: 8720203
Series Start Date: 9/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 3.90900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.749 261.6	0.217 279.6	0.305 252.6	0.270 156.5	0.028 62.2	0.172 142.7	0.063 200.0
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.014 54.2	0.000 0.0	0.059 253.8	0.006 191.5	0.042 220.3	0.041 243.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.007 170.3	0.012 270.0	0.000 0.0	0.012 149.6	0.014 163.4	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.006 136.7	0.033 135.8	0.013 278.9	0.002 280.4
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 128.9	0.089 155.5	0.000 0.0	0.000 0.0	0.049 270.6	0.000 0.0	0.059 281.1
M_8	MS_4					
0.006 71.1	0.000 0.0					

Trout River, Sherwood Forest — NOS/NOAA Station Number: 8720213
Series Start Date: 8/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.34300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.444 291.9	0.183 319.0	0.292 283.9	0.199 149.7	0.070 165.6	0.146 170.0	0.063 325.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.013 210.6	0.000 0.0	0.057 285.0	0.005 13.5	0.035 241.2	0.039 275.9
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.006 129.4	0.010 304.5	0.000 0.0	0.010 159.8	0.012 139.6	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.006 178.7	0.028 180.1	0.011 317.9	0.002 320.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 190.2	0.066 151.2	0.000 0.0	0.000 0.0	0.040 299.9	0.000 0.0	0.050 321.2
M_8	MS_4					
0.010 192.8	0.000 0.0					

Table D8—*Continued*

Trout River, Sherwood Forest — NOS/NOAA Station Number: 8720213
Series Start Date: 9/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.79000

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.334 291.7	0.210 323.3	0.257 281.6	0.204 179.6	0.017 147.1	0.098 160.6	0.077 324.0
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.017 159.5	0.000 0.0	0.050 282.9	0.006 91.9	0.032 236.4	0.034 271.5
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 198.7	0.009 306.4	0.000 0.0	0.007 170.2	0.008 189.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 152.4	0.019 151.1	0.012 322.1	0.002 324.6
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 141.7	0.067 178.2	0.000 0.0	0.000 0.0	0.037 301.8	0.000 0.0	0.057 325.9
M_8	MS_4					
0.014 103.4	0.000 0.0					

Trout River, Sherwood Forest — NOS/NOAA Station Number: 8720213
Series Start Date: 10/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.94300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.288 296.3	0.171 328.4	0.224 293.6	0.147 188.7	0.003 354.1	0.090 168.3	0.072 335.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.028 86.9	0.000 0.0	0.043 293.9	0.005 13.0	0.031 240.5	0.030 290.9
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 209.2	0.009 311.2	0.000 0.0	0.006 178.6	0.007 198.9	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 159.5	0.018 158.2	0.010 327.1	0.001 329.7
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 148.0	0.049 187.2	0.000 0.0	0.000 0.0	0.036 299.0	0.000 0.0	0.046 331.0
M_8	MS_4					
0.023 90.7	0.000 0.0					

Trout River, Sherwood Forest — NOS/NOAA Station Number: 8720213
Series Start Date: 11/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.92800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.283 297.5	0.158 331.9	0.259 294.6	0.125 173.2	0.005 354.6	0.103 174.2	0.079 341.2
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.012 102.2	0.000 0.0	0.050 295.0	0.008 133.8	0.031 239.5	0.035 291.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 172.2	0.009 313.5	0.000 0.0	0.007 173.7	0.008 172.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 174.6	0.020 174.6	0.009 330.5	0.001 333.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 175.1	0.042 173.3	0.000 0.0	0.000 0.0	0.036 300.5	0.000 0.0	0.043 334.7
M_8	MS_4					
0.016 94.4	0.000 0.0					

Jacksonville, Navy Fuel Depot, St. Johns River — NOS/NOAA Station Number: 8720215
Series Start Date: 9/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.58800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.330 278.4	0.163 288.0	0.237 268.4	0.196 171.3	0.042 125.6	0.134 156.7	0.081 266.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.014 112.9	0.000 0.0	0.046 269.8	0.006 288.6	0.032 245.5	0.032 258.4
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.006 185.8	0.009 282.9	0.000 0.0	0.010 164.1	0.011 178.5	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 150.5	0.026 149.5	0.010 287.6	0.001 288.4
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 142.3	0.065 170.2	0.000 0.0	0.000 0.0	0.037 288.4	0.000 0.0	0.044 288.8
M_8	MS_4					
0.007 161.5	0.000 0.0					

Table D8—*Continued*

Jacksonville, Navy Fuel Depot, St. Johns River NOS/NOAA Station Number: 8720215
Series Start Date: 10/1/1977 Series Length (in days): 29
Series Mean Sea Level (in feet): 6.49100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.308 277.4	0.157 299.8	0.224 275.6	0.136 169.9	0.037 117.6	0.107 161.2	0.084 260.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.003 31.6	0.000 0.0	0.043 275.8	0.002 328.9	0.031 231.5	0.030 273.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 178.6	0.009 287.8	0.000 0.0	0.008 165.6	0.008 174.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 157.5	0.021 156.9	0.009 298.9	0.001 300.7
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 152.5	0.045 169.3	0.000 0.0	0.000 0.0	0.037 279.2	0.000 0.0	0.043 301.7
M_8	MS_4					
0.004 182.4	0.000 0.0					

Jacksonville, Navy Fuel Depot, St. Johns River NOS/NOAA Station Number: 8720215
Series Start Date: 11/1/1977 Series Length (in days): 29
Series Mean Sea Level (in feet): 6.75300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.295 281.0	0.188 306.3	0.273 266.5	0.130 160.3	0.037 128.3	0.081 165.3	0.076 272.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.008 102.2	0.000 0.0	0.053 268.5	0.007 30.8	0.031 232.3	0.036 252.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 155.3	0.009 292.7	0.000 0.0	0.006 162.7	0.006 157.8	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 167.4	0.016 167.7	0.011 305.3	0.002 307.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 170.2	0.043 160.6	0.000 0.0	0.000 0.0	0.036 295.4	0.000 0.0	0.051 308.3
M_8	MS_4					
0.008 193.8	0.000 0.0					

Jacksonville, Navy Fuel Depot, St. Johns River NOS/NOAA Station Number: 8720215
Series Start Date: 12/1/1977 Series Length (in days): 29
Series Mean Sea Level (in feet): 6.29500

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.333 278.7	0.188 295.3	0.271 264.2	0.144 160.8	0.039 139.8	0.114 170.6	0.062 258.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.013 88.1	0.000 0.0	0.053 266.2	0.007 60.4	0.032 238.6	0.036 249.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 151.0	0.009 286.4	0.000 0.0	0.008 165.7	0.009 155.9	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 174.8	0.022 175.5	0.011 294.7	0.002 296.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 180.3	0.048 161.5	0.000 0.0	0.000 0.0	0.037 293.1	0.000 0.0	0.051 296.7
M_8	MS_4					
0.008 210.1	0.000 0.0					

Jacksonville, Navy Fuel Depot, St. Johns River NOS/NOAA Station Number: 8720215
Series Start Date: 2/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 6.33800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.261 272.4	0.202 329.0	0.280 232.4	0.106 172.9	0.034 130.5	0.131 151.0	0.050 246.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.027 126.8	0.000 0.0	0.054 237.8	0.004 323.3	0.030 192.4	0.037 192.4
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.006 194.8	0.009 298.7	0.000 0.0	0.009 162.0	0.010 183.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 141.6	0.025 140.1	0.012 326.8	0.002 331.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 129.3	0.035 171.2	0.000 0.0	0.000 0.0	0.035 312.4	0.000 0.0	0.055 333.6
M_8	MS_4					
0.012 184.5	0.000 0.0					

Table D8—*Continued*

Ribault River, Lake Forest — NOS/NOAA Station Number: 8720216
Series Start Date: 6/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.04800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.335 257.3	0.198 294.5	0.258 253.2	0.172 134.3	0.054 114.5	0.133 156.8	0.064 225.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.004 121.2	0.000 0.0	0.050 253.8	0.005 330.0	0.032 196.5	0.034 249.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.006 111.8	0.009 274.6	0.000 0.0	0.009 145.4	0.010 123.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 166.4	0.026 167.9	0.012 293.0	0.002 296.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 179.1	0.057 136.0	0.000 0.0	0.000 0.0	0.037 261.4	0.000 0.0	0.054 297.5
M_8	MS_4					
0.005 199.8	0.000 0.0					

Moncrief Creek Entrance — NOS/NOAA Station Number: 8720217
Series Start Date: 10/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.28600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.264 282.2	0.160 309.8	0.228 272.1	0.140 175.1	0.045 139.3	0.107 164.1	0.065 284.6
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.003 237.5	0.000 0.0	0.044 273.5	0.005 323.3	0.030 231.2	0.030 262.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 186.1	0.009 295.0	0.000 0.0	0.008 169.6	0.008 180.6	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 159.4	0.021 158.6	0.009 308.7	0.001 310.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 153.2	0.046 174.3	0.000 0.0	0.000 0.0	0.035 292.4	0.000 0.0	0.044 312.0
M_8	MS_4					
0.001 344.4	0.000 0.0					

Moncrief Creek Entrance — NOS/NOAA Station Number: 8720217
Series Start Date: 11/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.57700

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.270 283.5	0.186 302.5	0.243 274.5	0.132 165.8	0.045 151.9	0.084 166.1	0.067 288.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.005 92.3	0.000 0.0	0.047 275.7	0.004 37.8	0.031 241.0	0.032 265.5
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 165.5	0.009 292.3	0.000 0.0	0.006 165.9	0.007 165.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 166.2	0.016 166.2	0.011 301.7	0.002 303.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 166.4	0.044 165.8	0.000 0.0	0.000 0.0	0.036 292.4	0.000 0.0	0.051 304.0
M_8	MS_4					
0.004 186.8	0.000 0.0					

Moncrief Creek Entrance — NOS/NOAA Station Number: 8720217
Series Start Date: 12/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.08600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.305 287.8	0.217 306.2	0.225 284.2	0.140 167.1	0.058 161.5	0.111 178.1	0.062 293.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.014 93.7	0.000 0.0	0.044 284.7	0.006 75.5	0.031 245.8	0.030 280.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 156.2	0.009 296.3	0.000 0.0	0.008 172.6	0.009 161.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 182.8	0.021 183.5	0.013 305.5	0.002 306.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 189.0	0.046 168.0	0.000 0.0	0.000 0.0	0.037 291.3	0.000 0.0	0.059 307.7
M_8	MS_4					
0.005 233.1	0.000 0.0					

Table D8—*Continued*

Dames Point NOS/NOAA Station Number: 8720219
Series Start Date: 9/1/1977 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.63900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.593 264.7	0.185 282.5	0.274 255.0	0.239 161.5	0.033 31.9	0.152 150.0	0.074 222.0
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.015 76.7	0.000 0.0	0.053 256.3	0.008 231.3	0.038 223.6	0.037 245.3
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.006 172.9	0.011 272.9	0.000 0.0	0.011 155.8	0.012 167.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.006 145.1	0.029 144.3	0.011 281.8	0.002 283.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 138.7	0.079 160.6	0.000 0.0	0.000 0.0	0.045 274.4	0.000 0.0	0.050 283.9
M_8	MS_4					
0.006 166.4	0.000 0.0					

Dames Point NOS/NOAA Station Number: 8720219
Series Start Date: 10/1/1977 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.56900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.554 265.9	0.206 292.4	0.327 259.0	0.174 160.9	0.037 20.0	0.128 157.2	0.068 221.6
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.007 22.3	0.000 0.0	0.064 259.9	0.001 73.6	0.037 216.0	0.044 252.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 164.6	0.011 278.2	0.000 0.0	0.009 159.1	0.010 162.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 155.6	0.025 155.4	0.012 291.4	0.002 293.5
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 153.6	0.058 160.6	0.000 0.0	0.000 0.0	0.044 272.8	0.000 0.0	0.056 294.6
M_8	MS_4					
0.003 212.6	0.000 0.0					

Dames Point NOS/NOAA Station Number: 8720219
Series Start Date: 12/1/1977 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.35900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.599 265.6	0.240 283.1	0.317 253.7	0.180 152.4	0.019 27.8	0.132 167.0	0.055 219.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.014 58.2	0.000 0.0	0.062 255.3	0.006 26.4	0.038 224.8	0.042 241.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.006 137.8	0.011 273.8	0.000 0.0	0.009 159.6	0.010 145.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 173.2	0.026 174.2	0.014 282.5	0.002 283.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 181.4	0.060 153.5	0.000 0.0	0.000 0.0	0.045 277.6	0.000 0.0	0.065 284.6
M_8	MS_4					
0.009 216.3	0.000 0.0					

Dames Point NOS/NOAA Station Number: 8720219
Series Start Date: 1/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 4.90300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.617 264.2	0.262 288.3	0.307 255.0	0.162 156.1	0.012 86.0	0.112 178.1	0.064 212.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.024 36.0	0.000 0.0	0.060 256.2	0.008 13.0	0.039 216.8	0.041 245.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 134.1	0.011 275.4	0.000 0.0	0.008 167.0	0.009 145.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 187.6	0.022 189.0	0.016 287.3	0.002 289.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 199.9	0.054 157.8	0.000 0.0	0.000 0.0	0.045 273.4	0.000 0.0	0.071 290.2
M_8	MS_4					
0.005 220.5	0.000 0.0					

Table D8—*Continued*

Mayport NOS/NOAA Station Number: 8720220
Series Start Date: N/A Series Length (in days): N/A
Series Mean Sea Level (in feet): 2.46000

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.173 243.2	0.363 261.5	0.490 228.0	0.268 128.7	0.078 240.7	0.198 142.5	0.034 137.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.029 178.2	0.000 0.0	0.031 244.3	0.109 224.1	0.000 0.0	0.055 248.8	0.059 226.2
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.009 114.9	0.036 246.9	0.029 89.2	0.014 135.6	0.016 121.9	0.082 227.7	0.251 55.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.378 190.0	0.127 197.7	0.000 0.0	0.008 148.5	0.040 134.1	0.021 261.7	0.003 261.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.005 156.3	0.091 121.6	0.000 0.0	0.000 0.0	0.125 241.3	0.000 0.0	0.104 259.6
M_8	MS_4					
0.000 0.0	0.038 246.0					

Mayport NOS/NOAA Station Number: 8720220
Series Start Date: 1/1/1987 Series Length (in days): 365
Series Mean Sea Level (in feet): 4.11300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.206 241.0	0.346 260.2	0.478 228.2	0.275 127.0	0.085 232.9	0.189 141.0	0.037 132.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.027 165.8	0.015 344.1	0.030 244.4	0.110 220.9	0.003 255.5	0.048 251.7	0.074 218.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.010 147.4	0.039 245.9	0.038 85.1	0.011 169.2	0.016 120.0	0.051 116.3	0.206 27.4
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.133 252.4	0.058 177.9	0.042 325.0	0.009 116.3	0.038 132.6	0.033 250.5	0.011 146.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 99.3	0.095 125.8	0.015 283.4	0.029 297.2	0.070 242.6	0.026 183.6	0.088 258.0
M_8	MS_4					
0.012 125.8	0.039 244.3					

Mayport NOS/NOAA Station Number: 8720220
Series Start Date: 1/1/1989 Series Length (in days): 365
Series Mean Sea Level (in feet): 4.02600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.198 241.3	0.351 261.7	0.475 223.4	0.273 129.6	0.084 232.1	0.190 141.6	0.036 122.6
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.031 164.2	0.018 358.1	0.033 229.0	0.111 227.8	0.003 276.4	0.042 249.2	0.043 198.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.013 132.2	0.027 250.6	0.034 88.6	0.012 154.0	0.014 135.8	0.103 186.1	0.251 5.9
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.273 202.3	0.082 303.9	0.052 11.1	0.006 142.5	0.039 139.6	0.032 276.1	0.015 130.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.008 174.8	0.094 127.1	0.010 286.7	0.032 298.7	0.086 262.7	0.016 201.8	0.084 262.4
M_8	MS_4					
0.010 118.5	0.037 243.9					

Mayport NOS/NOAA Station Number: 8720220
Series Start Date: 1/1/1990 Series Length (in days): 274
Series Mean Sea Level (in feet): 3.96100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.225 240.5	0.360 262.0	0.489 221.2	0.266 127.6	0.086 233.3	0.192 143.8	0.035 122.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.032 161.7	0.013 359.7	0.027 236.1	0.112 225.6	0.002 287.4	0.055 249.9	0.065 185.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.007 151.6	0.038 244.0	0.038 94.2	0.012 178.9	0.014 154.9	0.069 103.5	0.261 6.5
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.258 139.4	0.088 213.6	0.047 324.8	0.010 112.2	0.038 142.7	0.038 249.8	0.028 140.6
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 227.5	0.091 126.0	0.011 267.1	0.021 301.0	0.077 255.3	0.024 206.6	0.086 261.0
M_8	MS_4					
0.011 127.4	0.040 248.0					

Table D8—*Continued*

Mayport — NOS/NOAA Station Number: 8720220
Series Start Date: 1/1/1991 — Series Length (in days): 365
Series Mean Sea Level (in feet): 4.31400

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.156 241.8	0.341 260.9	0.486 223.5	0.268 128.9	0.092 235.8	0.192 141.5	0.035 128.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.032 166.3	0.016 359.9	0.030 237.3	0.119 219.4	0.004 258.0	0.050 249.7	0.078 204.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.010 141.9	0.033 250.0	0.030 100.3	0.009 120.0	0.013 143.5	0.073 56.4	0.224 67.4
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.381 172.1	0.036 224.8	0.042 296.4	0.007 137.6	0.036 147.1	0.042 239.3	0.024 150.7
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.011 149.0	0.092 126.6	0.003 247.1	0.018 317.2	0.099 264.8	0.024 207.1	0.078 257.9
M_8	MS_4					
0.010 117.6	0.036 247.5					

Mayport — NOS/NOAA Station Number: 8720220
Series Start Date: 1/1/1992 — Series Length (in days): 219
Series Mean Sea Level (in feet): 4.09500

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.187 240.9	0.320 265.6	0.492 223.0	0.290 129.9	0.087 233.0	0.197 141.7	0.037 118.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.031 176.1	0.011 356.2	0.035 224.3	0.103 219.6	0.001 297.6	0.045 254.3	0.072 214.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.014 122.7	0.030 236.4	0.046 60.8	0.015 136.2	0.015 167.9	0.112 236.2	0.461 159.2
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.305 7.2	0.023 73.4	0.053 70.0	0.009 160.9	0.048 134.3	0.015 200.7	0.055 155.5
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.011 180.2	0.085 131.7	0.024 268.8	0.016 324.7	0.109 262.7	0.025 210.0	0.075 242.6
M_8	MS_4					
0.009 125.0	0.038 250.3					

Mayport — NOS/NOAA Station Number: 8720220
Series Start Date: 1/1/1982 — Series Length (in days): 365
Series Mean Sea Level (in feet): 4.03700

M_2	S_2	N_2	K_1	M_4	O_1	M_6
2.171 241.0	0.350 259.8	0.481 222.7	0.276 127.4	0.088 232.2	0.199 139.6	0.035 133.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.029 164.8	0.016 359.4	0.026 223.7	0.109 220.3	0.002 228.3	0.045 259.8	0.070 202.3
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.018 125.6	0.031 277.8	0.033 94.6	0.007 191.2	0.023 158.8	0.055 250.7	0.382 78.9
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.380 190.7	0.039 145.2	0.049 268.9	0.009 117.4	0.033 142.4	0.030 247.3	0.016 124.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.009 130.7	0.096 125.7	0.008 273.9	0.020 299.7	0.091 259.3	0.019 194.5	0.095 259.9
M_8	MS_4					
0.009 116.2	0.038 243.5					

Fulton, St. Johns River — NOS/NOAA Station Number: 8720221
Series Start Date: 10/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.39300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.754 257.5	0.276 282.9	0.359 241.5	0.210 151.6	0.026 328.8	0.153 150.9	0.052 189.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.011 354.3	0.000 0.0	0.070 243.7	0.002 183.9	0.042 208.9	0.048 225.5
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.007 152.3	0.012 269.3	0.000 0.0	0.011 151.3	0.012 151.9	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.006 150.6	0.030 150.6	0.016 281.9	0.002 283.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 150.3	0.070 151.6	0.000 0.0	0.000 0.0	0.049 273.5	0.000 0.0	0.075 285.0
M_8	MS_4					
0.005 57.9	0.000 0.0					

Table D8—*Continued*

Fulton, St. Johns River — NOS/NOAA Station Number: 8720221
Series Start Date: 11/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.65400

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.741 260.2	0.270 273.2	0.375 248.6	0.197 144.1	0.025 312.5	0.129 149.6	0.048 192.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.008 19.4	0.000 0.0	0.073 250.2	0.004 312.8	0.042 224.0	0.050 237.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 138.7	0.012 266.3	0.000 0.0	0.009 146.8	0.010 141.4	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 151.9	0.025 152.3	0.016 272.7	0.002 273.7
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 155.0	0.065 144.5	0.000 0.0	0.000 0.0	0.049 271.8	0.000 0.0	0.073 274.3
M_8	MS_4					
0.002 337.6	0.000 0.0					

Fulton, St. Johns River — NOS/NOAA Station Number: 8720221
Series Start Date: 1/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.69200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.855 253.5	0.311 276.0	0.340 244.3	0.198 147.3	0.021 261.3	0.133 164.6	0.043 170.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.034 31.0	0.000 0.0	0.066 245.5	0.011 317.7	0.045 207.8	0.045 235.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.006 130.0	0.013 263.9	0.000 0.0	0.009 155.9	0.010 138.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 172.1	0.026 173.2	0.018 275.1	0.003 276.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.004 181.8	0.065 148.6	0.000 0.0	0.000 0.0	0.052 262.7	0.000 0.0	0.085 277.8
M_8	MS_4					
0.002 100.1	0.000 0.0					

Fulton, St. Johns River — NOS/NOAA Station Number: 8720221
Series Start Date: 2/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.25400

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.774 263.1	0.337 288.6	0.361 250.7	0.151 159.1	0.021 301.6	0.182 149.1	0.045 202.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.024 95.7	0.000 0.0	0.070 252.4	0.005 158.3	0.043 214.4	0.048 238.3
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.008 169.1	0.012 274.9	0.000 0.0	0.013 154.1	0.014 164.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.007 144.8	0.035 144.1	0.020 287.6	0.003 289.6
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.005 139.2	0.050 158.3	0.000 0.0	0.000 0.0	0.050 275.4	0.000 0.0	0.092 290.7
M_8	MS_4					
0.007 216.3	0.000 0.0					

Phoenix Park — NOS/NOAA Station Number: 8720225
Series Start Date: 9/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.01800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.271 277.6	0.144 290.7	0.226 280.8	0.192 170.8	0.059 134.9	0.129 154.5	0.084 264.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.014 115.1	0.000 0.0	0.044 280.3	0.009 265.6	0.031 241.1	0.030 283.9
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 187.2	0.009 283.7	0.000 0.0	0.009 162.7	0.010 178.9	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.005 147.4	0.025 146.3	0.008 290.2	0.001 291.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 138.2	0.064 169.6	0.000 0.0	0.000 0.0	0.036 274.4	0.000 0.0	0.039 291.7
M_8	MS_4					
0.012 169.7	0.000 0.0					

Table D8—*Continued*

Phoenix Park NOS/NOAA Station Number: 8720225
Series Start Date: 10/1/1977 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.97200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.239 276.5	0.170 303.0	0.250 270.7	0.133 171.5	0.051 129.7	0.103 162.3	0.074 258.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.001 15.9	0.000 0.0	0.049 271.5	0.003 258.9	0.030 226.7	0.033 264.9
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 180.6	0.009 288.8	0.000 0.0	0.007 166.9	0.008 176.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 158.4	0.020 157.8	0.010 301.9	0.001 304.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 153.3	0.044 170.8	0.000 0.0	0.000 0.0	0.035 282.4	0.000 0.0	0.046 305.1
M_8	MS_4					
0.005 159.8	0.000 0.0					

Phoenix Park NOS/NOAA Station Number: 8720225
Series Start Date: 12/1/1977 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.68600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.281 276.6	0.210 292.2	0.246 263.0	0.141 161.0	0.053 133.8	0.106 172.6	0.065 249.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.010 82.2	0.000 0.0	0.048 264.8	0.005 40.2	0.031 237.6	0.033 249.4
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 149.4	0.009 283.8	0.000 0.0	0.007 166.8	0.008 155.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 177.6	0.021 178.4	0.012 291.6	0.002 292.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 184.2	0.047 161.9	0.000 0.0	0.000 0.0	0.036 290.2	0.000 0.0	0.057 293.4
M_8	MS_4					
0.008 194.7	0.000 0.0					

Phoenix Park NOS/NOAA Station Number: 8720225
Series Start Date: 1/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.21300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.305 275.6	0.211 300.7	0.240 262.5	0.127 165.9	0.066 136.7	0.091 189.3	0.064 241.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.017 67.9	0.000 0.0	0.047 264.3	0.008 67.3	0.031 227.0	0.032 249.5
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 142.5	0.009 287.2	0.000 0.0	0.006 177.5	0.007 154.3	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 199.4	0.018 201.0	0.012 299.7	0.002 301.7
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 212.6	0.042 167.7	0.000 0.0	0.000 0.0	0.037 288.6	0.000 0.0	0.058 302.8
M_8	MS_4					
0.008 147.9	0.000 0.0					

Pablo Creek Entrance NOS/NOAA Station Number: 8720232
Series Start Date: 9/1/1977 Series Length (in days): 29
Series Mean Sea Level (in feet): 6.49500

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.883 254.2	0.234 271.7	0.337 244.6	0.298 151.8	0.046 293.9	0.192 142.4	0.041 145.8
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.015 33.4	0.000 0.0	0.065 245.9	0.004 181.9	0.045 213.7	0.045 235.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.008 161.3	0.013 262.3	0.000 0.0	0.014 147.1	0.015 156.5	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.007 138.3	0.037 137.7	0.014 271.0	0.002 272.4
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.005 133.0	0.099 151.1	0.000 0.0	0.000 0.0	0.053 263.8	0.000 0.0	0.064 273.1
M_8	MS_4					
0.013 101.7	0.000 0.0					

Table D8—*Continued*

Long Branch, USACE Dredge Depot — NOS/NOAA Station Number: 8720242
Series Start Date: 1/1/1961 — Series Length (in days): 365
Series Mean Sea Level (in feet): 4.22200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.047 279.6	0.143 303.7	0.186 267.0	0.107 155.9	0.043 132.3	0.090 166.7	0.060 275.0
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.017 253.6	0.004 119.0	0.017 114.6	0.046 252.7	0.001 232.4	0.030 21.9	0.025 268.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.007 127.4	0.030 264.7	0.025 121.9	0.005 181.4	0.005 240.7	0.036 324.1	0.243 41.7
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.413 208.8	0.056 65.8	0.043 78.1	0.004 135.9	0.016 167.3	0.012 282.6	0.017 194.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.005 57.3	0.038 156.7	0.005 72.1	0.012 1.8	0.065 286.2	0.023 238.5	0.040 293.4
M_8	MS_4					
0.008 195.4	0.003 146.9					

Long Branch, USACE Dredge Depot — NOS/NOAA Station Number: 8720242
Series Start Date: 9/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.14000

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.145 280.3	0.138 293.4	0.200 277.4	0.173 174.9	0.050 119.1	0.110 162.1	0.070 271.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.013 114.2	0.000 0.0	0.039 277.8	0.005 284.2	0.028 243.8	0.027 274.5
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 187.7	0.008 286.4	0.000 0.0	0.008 168.5	0.009 181.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 156.6	0.021 155.7	0.008 292.9	0.001 293.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 149.4	0.057 173.9	0.000 0.0	0.000 0.0	0.032 283.2	0.000 0.0	0.038 294.5
M_8	MS_4					
0.005 165.1	0.000 0.0					

Long Branch, USACE Dredge Depot — NOS/NOAA Station Number: 8720242
Series Start Date: 10/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.03800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.118 283.9	0.146 310.4	0.229 283.3	0.117 178.9	0.042 118.3	0.088 168.6	0.064 279.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.002 88.7	0.000 0.0	0.044 283.4	0.004 297.5	0.027 234.1	0.030 282.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 189.2	0.008 296.2	0.000 0.0	0.006 173.7	0.007 184.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 164.1	0.017 163.4	0.009 309.4	0.001 311.5
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 158.3	0.039 178.1	0.000 0.0	0.000 0.0	0.031 284.6	0.000 0.0	0.040 312.6
M_8	MS_4					
0.002 190.4	0.000 0.0					

Long Branch, USACE Dredge Depot — NOS/NOAA Station Number: 8720242
Series Start Date: 11/1/1977 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.31100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.129 284.0	0.168 303.1	0.227 270.6	0.111 165.4	0.040 120.1	0.069 169.8	0.067 281.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.007 108.6	0.000 0.0	0.044 272.4	0.004 43.1	0.027 241.5	0.030 257.2
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 161.0	0.008 292.9	0.000 0.0	0.005 167.6	0.005 163.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 171.7	0.013 172.0	0.010 302.3	0.001 303.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 174.1	0.037 165.7	0.000 0.0	0.000 0.0	0.032 297.4	0.000 0.0	0.046 304.7
M_8	MS_4					
0.006 189.6	0.000 0.0					

Table D8—*Continued*

Long Branch, USACE Dredge Depot NOS/NOAA Station Number: 8720242
Series Start Date: 1/1/1967 Series Length (in days): 365
Series Mean Sea Level (in feet): 4.32400

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.076 278.9	0.139 306.8	0.214 265.0	0.115 156.8	0.040 130.9	0.085 169.1	0.061 272.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.022 248.3	0.000 0.0	0.018 96.6	0.040 272.3	0.000 0.0	0.028 9.3	0.017 305.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.000 0.0	0.022 266.8	0.027 122.0	0.000 0.0	0.000 0.0	0.086 72.6	0.240 46.9
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.378 191.8	0.051 345.6	0.000 0.0	0.000 0.0	0.019 184.9	0.022 266.2	0.016 170.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.005 162.5	0.032 159.2	0.000 0.0	0.000 0.0	0.134 270.6	0.028 254.1	0.035 314.4
M_8	MS_4					
0.000 0.0	0.000 0.0					

Long Branch, USACE Dredge Depot NOS/NOAA Station Number: 8720242
Series Start Date: 1/1/1966 Series Length (in days): 365
Series Mean Sea Level (in feet): 4.47300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.077 279.9	0.147 305.3	0.224 265.3	0.109 154.1	0.047 133.8	0.083 162.9	0.058 275.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.019 251.2	0.006 125.8	0.019 103.0	0.057 260.2	0.001 202.9	0.026 4.4	0.035 286.9
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 184.4	0.024 269.9	0.024 125.2	0.005 162.9	0.004 189.1	0.070 114.2	0.095 104.6
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.180 169.3	0.011 88.8	0.089 353.1	0.009 122.1	0.019 170.2	0.015 343.0	0.012 149.6
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.007 235.9	0.033 155.7	0.005 320.0	0.006 127.7	0.106 310.4	0.023 257.2	0.036 313.1
M_8	MS_4					
0.008 189.7	0.006 177.2					

Jacksonville, Acosta Bridge NOS/NOAA Station Number: 8720268
Series Start Date: 8/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 6.92400

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.815 292.4	0.102 319.4	0.133 274.5	0.113 161.2	0.023 128.8	0.085 174.4	0.043 307.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.004 205.4	0.000 0.0	0.026 276.9	0.003 218.0	0.020 241.9	0.018 256.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 147.9	0.006 304.9	0.000 0.0	0.006 167.7	0.007 154.6	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 180.1	0.017 181.0	0.006 318.3	0.001 320.4
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 187.5	0.037 162.2	0.000 0.0	0.000 0.0	0.023 310.3	0.000 0.0	0.028 321.5
M_8	MS_4					
0.004 168.5	0.000 0.0					

Jacksonville, Acosta Bridge NOS/NOAA Station Number: 8720268
Series Start Date: 9/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 7.42500

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.735 293.1	0.116 319.8	0.127 280.9	0.117 198.5	0.016 104.5	0.048 164.1	0.041 309.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.008 146.0	0.000 0.0	0.025 282.5	0.002 136.3	0.018 243.0	0.017 268.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 232.8	0.005 305.5	0.000 0.0	0.003 181.4	0.004 215.5	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 149.4	0.009 147.1	0.007 318.7	0.001 320.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 130.1	0.039 195.9	0.000 0.0	0.000 0.0	0.021 305.4	0.000 0.0	0.032 322.0
M_8	MS_4					
0.005 169.9	0.000 0.0					

Table D8—*Continued*

Jacksonville, Acosta Bridge — NOS/NOAA Station Number: 8720268
Series Start Date: 10/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 7.60000

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.708 294.5	0.086 316.3	0.117 283.6	0.072 209.4	0.019 113.8	0.050 181.1	0.038 311.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.014 76.4	0.000 0.0	0.023 285.1	0.003 42.6	0.017 249.3	0.016 272.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 237.7	0.005 304.6	0.000 0.0	0.004 195.4	0.004 223.5	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 168.9	0.010 167.0	0.005 315.4	0.001 317.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 153.0	0.024 207.3	0.000 0.0	0.000 0.0	0.020 305.5	0.000 0.0	0.023 318.1
M_8	MS_4					
0.006 173.7	0.000 0.0					

Jacksonville, Acosta Bridge — NOS/NOAA Station Number: 8720268
Series Start Date: 11/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 7.58200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.688 295.3	0.083 321.2	0.130 286.1	0.058 180.9	0.014 105.5	0.055 178.9	0.040 320.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.007 93.1	0.000 0.0	0.025 287.3	0.006 104.2	0.017 246.0	0.017 276.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 182.9	0.005 307.3	0.000 0.0	0.004 179.9	0.004 181.9	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 178.1	0.011 178.0	0.005 320.2	0.001 322.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 177.0	0.019 180.8	0.000 0.0	0.000 0.0	0.019 304.6	0.000 0.0	0.023 323.3
M_8	MS_4					
0.003 211.0	0.000 0.0					

Little Pottsburg Creek — NOS/NOAA Station Number: 8720274
Series Start Date: 7/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.96100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.030 284.5	0.120 296.6	0.211 278.9	0.138 153.1	0.057 170.0	0.099 177.5	0.052 271.2
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.012 19.2	0.000 0.0	0.041 279.6	0.005 94.3	0.025 249.1	0.028 273.2
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 128.8	0.007 290.1	0.000 0.0	0.007 165.2	0.008 141.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 187.9	0.019 189.5	0.007 296.1	0.001 297.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 201.6	0.046 154.9	0.000 0.0	0.000 0.0	0.029 290.2	0.000 0.0	0.033 297.6
M_8	MS_4					
0.012 219.6	0.000 0.0					

Little Pottsburg Creek — NOS/NOAA Station Number: 8720274
Series Start Date: 8/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.08300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.094 285.6	0.143 299.5	0.213 276.5	0.150 154.0	0.060 155.7	0.114 162.3	0.051 273.2
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.008 192.0	0.000 0.0	0.041 277.7	0.005 296.4	0.026 248.3	0.028 267.5
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.005 145.8	0.008 292.0	0.000 0.0	0.008 158.1	0.009 149.9	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.004 165.9	0.022 166.4	0.008 298.9	0.001 300.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 170.5	0.050 154.7	0.000 0.0	0.000 0.0	0.031 294.6	0.000 0.0	0.039 300.6
M_8	MS_4					
0.010 171.6	0.000 0.0					

Table D8—*Continued*

Little Pottsburg Creek NOS/NOAA Station Number: 8720274
Series Start Date: 9/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.58300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.995 285.7	0.162 309.1	0.181 276.0	0.140 186.0	0.035 154.3	0.075 156.1	0.060 278.8
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.011 147.9	0.000 0.0	0.035 277.3	0.000 321.3	0.024 239.1	0.024 266.3
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 215.9	0.007 296.6	0.000 0.0	0.005 171.2	0.006 200.8	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 143.3	0.015 141.3	0.009 308.1	0.001 310.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 126.5	0.047 183.8	0.000 0.0	0.000 0.0	0.028 295.5	0.000 0.0	0.044 311.0
M_8	MS_4					
0.005 216.7	0.000 0.0					

Little Pottsburg Creek NOS/NOAA Station Number: 8720274
Series Start Date: 10/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.78800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.967 288.8	0.127 309.0	0.166 286.4	0.090 188.9	0.037 157.9	0.076 170.3	0.058 281.2
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.021 65.6	0.000 0.0	0.032 286.8	0.004 356.0	0.023 245.2	0.022 284.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 207.6	0.007 298.2	0.000 0.0	0.005 179.7	0.006 198.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 162.3	0.015 161.0	0.007 308.2	0.001 309.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 151.7	0.030 187.5	0.000 0.0	0.000 0.0	0.027 291.2	0.000 0.0	0.035 310.7
M_8	MS_4					
0.005 206.3	0.000 0.0					

Little Pottsburg Creek NOS/NOAA Station Number: 8720274
Series Start Date: 11/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.77200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.955 287.9	0.113 315.4	0.179 278.6	0.089 162.4	0.035 159.3	0.083 166.8	0.062 285.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.011 83.2	0.000 0.0	0.035 279.8	0.008 68.1	0.023 237.1	0.024 269.3
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.004 158.0	0.007 300.7	0.000 0.0	0.006 164.5	0.006 160.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 168.7	0.016 168.9	0.007 314.3	0.001 316.5
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 171.1	0.030 162.7	0.000 0.0	0.000 0.0	0.027 297.3	0.000 0.0	0.031 317.6
M_8	MS_4					
0.005 210.0	0.000 0.0					

Ortega River Entrance NOS/NOAA Station Number: 8720296
Series Start Date: 9/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 7.39300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.558 302.0	0.079 330.2	0.088 297.1	0.110 203.5	0.028 222.4	0.038 170.6	0.045 345.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.004 178.9	0.000 0.0	0.017 297.8	0.003 132.7	0.013 250.3	0.012 292.2
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 236.3	0.004 315.1	0.000 0.0	0.003 187.2	0.003 219.8	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 156.5	0.007 154.3	0.005 329.1	0.001 331.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 138.0	0.036 201.0	0.000 0.0	0.000 0.0	0.016 306.9	0.000 0.0	0.022 332.5
M_8	MS_4					
0.006 267.1	0.000 0.0					

Table D8—*Continued*

Ortega River Entrance NOS/NOAA Station Number: 8720296
Series Start Date: 10/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 7.62600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.534 304.7	0.067 325.3	0.078 280.3	0.071 219.4	0.028 222.8	0.040 191.9	0.042 353.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.012 105.1	0.000 0.0	0.015 283.6	0.002 59.5	0.013 260.5	0.010 256.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 246.9	0.004 314.2	0.000 0.0	0.003 205.7	0.003 233.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 180.1	0.008 178.2	0.004 324.5	0.001 326.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 164.6	0.024 217.3	0.000 0.0	0.000 0.0	0.015 329.0	0.000 0.0	0.018 327.0
M_8	MS_4					
0.005 243.5	0.000 0.0					

Ortega River Entrance NOS/NOAA Station Number: 8720296
Series Start Date: 11/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 7.57600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.517 307.0	0.057 338.7	0.085 296.6	0.046 202.0	0.026 238.0	0.047 185.5	0.043 4.2
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.008 96.0	0.000 0.0	0.017 298.0	0.006 123.1	0.012 251.8	0.011 286.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 218.5	0.004 321.7	0.000 0.0	0.003 193.8	0.004 210.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 178.4	0.009 177.3	0.003 337.4	0.001 340.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 169.2	0.015 200.8	0.000 0.0	0.000 0.0	0.014 317.5	0.000 0.0	0.016 341.2
M_8	MS_4					
0.007 288.1	0.000 0.0					

Ortega River Entrance NOS/NOAA Station Number: 8720296
Series Start Date: 1/1/1979 Series Length (in days): 29
Series Mean Sea Level (in feet): 6.36200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.572 304.7	0.084 328.2	0.111 289.2	0.078 182.7	0.034 226.7	0.055 192.7	0.028 340.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.002 51.8	0.000 0.0	0.022 291.3	0.002 151.8	0.014 257.7	0.015 273.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 172.8	0.004 315.6	0.000 0.0	0.004 187.7	0.004 177.8	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 197.0	0.011 197.6	0.005 327.3	0.001 329.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 202.6	0.026 183.5	0.000 0.0	0.000 0.0	0.016 320.3	0.000 0.0	0.023 330.1
M_8	MS_4					
0.005 284.0	0.000 0.0					

Piney Point, St. Johns River NOS/NOAA Station Number: 8720333
Series Start Date: 10/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 6.10100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.437 319.5	0.055 343.1	0.070 304.1	0.061 238.2	0.020 217.0	0.037 202.4	0.032 31.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.009 125.7	0.000 0.0	0.014 306.1	0.003 110.3	0.010 272.3	0.009 288.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 274.0	0.003 330.4	0.000 0.0	0.003 220.4	0.003 256.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 187.0	0.007 184.6	0.003 342.2	0.000 344.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 166.9	0.020 235.5	0.000 0.0	0.000 0.0	0.012 334.8	0.000 0.0	0.015 345.0
M_8	MS_4					
0.005 246.0	0.000 0.0					

Table D8—*Continued*

Piney Point, St. Johns River — NOS/NOAA Station Number: 8720333
Series Start Date: 11/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 6.05200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.422 320.3	0.051 351.9	0.069 309.0	0.040 215.8	0.019 229.4	0.041 194.1	0.034 33.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.006 108.0	0.000 0.0	0.013 310.5	0.002 132.2	0.010 265.2	0.009 297.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 237.5	0.003 334.9	0.000 0.0	0.003 205.1	0.003 226.6	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 184.8	0.008 183.4	0.003 350.6	0.000 353.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 172.6	0.013 214.2	0.000 0.0	0.000 0.0	0.012 331.5	0.000 0.0	0.014 354.4
M_8	MS_4					
0.006 285.8	0.000 0.0					

Orange Park — NOS/NOAA Station Number: 8720374
Series Start Date: 7/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 3.84700

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.366 340.5	0.050 350.5	0.071 341.1	0.064 199.5	0.035 283.3	0.053 219.4	0.026 84.2
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.006 144.2	0.000 0.0	0.014 341.0	0.001 266.8	0.009 307.1	0.009 341.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 179.6	0.003 345.1	0.000 0.0	0.004 209.4	0.004 189.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 228.0	0.010 229.3	0.003 350.1	0.000 350.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 239.2	0.021 201.0	0.000 0.0	0.000 0.0	0.010 340.0	0.000 0.0	0.013 351.3
M_8	MS_4					
0.005 16.4	0.000 0.0					

Orange Park — NOS/NOAA Station Number: 8720374
Series Start Date: 9/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.19200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.388 341.3	0.048 360.0	0.046 333.6	0.087 229.8	0.029 278.5	0.036 209.2	0.033 91.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.005 270.0	0.000 0.0	0.009 334.7	0.003 195.3	0.009 299.1	0.006 326.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 250.3	0.003 350.0	0.000 0.0	0.003 219.6	0.003 240.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 200.4	0.007 199.0	0.003 359.3	0.000 0.7
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 188.8	0.029 228.2	0.000 0.0	0.000 0.0	0.011 349.0	0.000 0.0	0.013 1.5
M_8	MS_4					
0.005 11.5	0.000 0.0					

Doctors Lake, Peoria Point — NOS/NOAA Station Number: 8720406
Series Start Date: 6/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.69900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.396 334.0	0.035 334.9	0.079 332.3	0.061 191.5	0.029 278.3	0.060 212.4	0.045 76.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.003 352.1	0.000 0.0	0.015 332.5	0.002 138.2	0.009 309.4	0.010 330.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 170.7	0.003 334.4	0.000 0.0	0.004 201.9	0.005 181.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 221.4	0.012 222.8	0.002 334.9	0.000 334.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 233.1	0.020 193.1	0.000 0.0	0.000 0.0	0.011 335.6	0.000 0.0	0.009 335.0
M_8	MS_4					
0.004 28.1	0.000 0.0					

Table D8—*Continued*

Doctors Lake, Peoria Point NOS/NOAA Station Number: 8720406
Series Start Date: 7/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.73600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.396 346.3	0.051 24.5	0.066 346.7	0.066 199.1	0.047 297.9	0.063 236.4	0.051 111.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.004 153.8	0.000 0.0	0.013 346.6	0.001 180.0	0.009 284.4	0.009 347.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 161.9	0.003 4.0	0.000 0.0	0.004 217.6	0.005 180.6	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 252.4	0.012 254.9	0.003 22.9	0.000 26.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 273.3	0.022 201.9	0.000 0.0	0.000 0.0	0.011 345.9	0.000 0.0	0.014 27.6
M_8	MS_4					
0.014 81.8	0.000 0.0					

Doctors Lake, Peoria Point NOS/NOAA Station Number: 8720406
Series Start Date: 10/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 6.60300

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.392 343.1	0.051 13.1	0.053 322.8	0.074 230.5	0.031 266.4	0.042 211.0	0.052 103.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.011 180.0	0.000 0.0	0.010 325.5	0.001 270.1	0.009 289.5	0.007 302.5
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 250.0	0.003 357.0	0.000 0.0	0.003 220.8	0.003 240.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 202.6	0.008 201.3	0.003 11.9	0.000 14.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 191.6	0.024 229.0	0.000 0.0	0.000 0.0	0.011 3.4	0.000 0.0	0.014 15.5
M_8	MS_4					
0.009 45.9	0.000 0.0					

Julington Creek NOS/NOAA Station Number: 8720409
Series Start Date: 5/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 7.05100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.357 344.8	0.040 3.1	0.065 339.0	0.058 211.4	0.035 289.8	0.069 222.7	0.036 88.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.003 225.9	0.000 0.0	0.013 339.8	0.002 142.6	0.009 303.1	0.009 333.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 200.0	0.003 353.3	0.000 0.0	0.005 217.0	0.005 205.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 227.6	0.013 228.4	0.002 2.4	0.000 3.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 234.0	0.019 212.2	0.000 0.0	0.000 0.0	0.010 350.6	0.000 0.0	0.011 4.6
M_8	MS_4					
0.006 36.5	0.000 0.0					

Julington Creek NOS/NOAA Station Number: 8720409
Series Start Date: 6/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 7.16100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.351 353.8	0.048 15.1	0.058 346.8	0.071 210.3	0.030 306.4	0.057 228.7	0.033 115.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.003 346.5	0.000 0.0	0.011 347.7	0.001 77.4	0.008 309.0	0.008 339.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 192.0	0.003 3.7	0.000 0.0	0.004 219.4	0.004 201.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 236.5	0.011 237.8	0.003 14.3	0.000 16.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 246.9	0.024 211.7	0.000 0.0	0.000 0.0	0.010 0.8	0.000 0.0	0.013 16.8
M_8	MS_4					
0.005 71.2	0.000 0.0					

Table D8—*Continued*

Julington Creek — NOS/NOAA Station Number: 8720409
Series Start Date: 8/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 7.36800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.359 354.9	0.029 33.2	0.043 329.0	0.066 207.0	0.054 310.3	0.059 211.6	0.038 118.8
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.004 39.0	0.000 0.0	0.008 332.4	0.001 151.6	0.009 293.3	0.006 303.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 202.5	0.003 12.7	0.000 0.0	0.004 209.3	0.005 204.8	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 213.5	0.011 213.8	0.002 31.6	0.000 34.7
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 216.1	0.022 207.4	0.000 0.0	0.000 0.0	0.010 20.9	0.000 0.0	0.008 36.3
M_8	MS_4					
0.010 85.9	0.000 0.0					

Julington Creek — NOS/NOAA Station Number: 8720409
Series Start Date: 9/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 7.81600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.360 351.2	0.043 358.3	0.056 333.5	0.090 233.6	0.035 285.1	0.035 217.1	0.036 107.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.004 253.5	0.000 0.0	0.011 335.8	0.003 241.6	0.009 320.6	0.007 315.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 250.0	0.003 354.5	0.000 0.0	0.003 225.4	0.003 241.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 210.0	0.007 208.9	0.003 358.0	0.000 358.6
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 200.8	0.030 232.3	0.000 0.0	0.000 0.0	0.010 8.8	0.000 0.0	0.012 358.9
M_8	MS_4					
0.007 43.0	0.000 0.0					

Black Creek, SCL RR Bridge — NOS/NOAA Station Number: 8720434
Series Start Date: 8/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.21900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.390 13.0	0.034 52.2	0.074 356.8	0.062 207.0	0.051 323.2	0.063 218.0	0.030 178.8
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.001 98.6	0.000 0.0	0.014 359.0	0.003 145.1	0.009 310.1	0.010 340.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 196.1	0.003 31.2	0.000 0.0	0.004 212.5	0.005 201.6	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 222.7	0.012 223.4	0.002 50.6	0.000 53.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 228.9	0.020 207.8	0.000 0.0	0.000 0.0	0.011 29.2	0.000 0.0	0.009 55.4
M_8	MS_4					
0.007 143.6	0.000 0.0					

Black Creek, SCL RR Bridge — NOS/NOAA Station Number: 8720434
Series Start Date: 9/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.63800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.405 17.3	0.053 36.9	0.073 5.1	0.088 219.2	0.020 324.4	0.042 229.5	0.025 181.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.010 305.2	0.000 0.0	0.014 6.7	0.002 288.9	0.010 334.1	0.010 352.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 208.9	0.003 26.4	0.000 0.0	0.003 224.3	0.003 214.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 233.9	0.008 234.6	0.003 36.1	0.000 37.6
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 239.7	0.029 219.9	0.000 0.0	0.000 0.0	0.011 29.6	0.000 0.0	0.014 38.4
M_8	MS_4					
0.004 87.2	0.000 0.0					

Table D8—*Continued*

Black Creek, SCL RR Bridge — NOS/NOAA Station Number: 8720434
Series Start Date: 10/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.88100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.400 21.0	0.042 54.1	0.057 12.2	0.070 244.9	0.011 352.6	0.049 222.5	0.023 181.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.009 238.5	0.000 0.0	0.011 13.4	0.001 356.0	0.010 324.3	0.008 3.4
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 267.3	0.003 36.3	0.000 0.0	0.004 233.7	0.004 256.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 212.8	0.009 211.3	0.003 52.7	0.000 55.4
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 200.2	0.023 243.2	0.000 0.0	0.000 0.0	0.011 29.8	0.000 0.0	0.011 56.7
M_8	MS_4					
0.004 106.7	0.000 0.0					

Green Cove Springs, St. Johns River — NOS/NOAA Station Number: 8720496
Series Start Date: 4/1/1978 — Series Length (in days): 244
Series Mean Sea Level (in feet): 4.23200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.365 22.0	0.045 47.6	0.064 9.7	0.059 223.2	0.028 320.3	0.052 232.7	0.029 163.7
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.000 0.0	0.010 293.8	0.018 7.3	0.000 0.0	0.011 170.7	0.000 0.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.000 0.0	0.010 27.3	0.011 205.8	0.000 0.0	0.000 0.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.000 0.0	0.010 217.8	0.000 0.0	0.000 0.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.000 0.0	0.012 220.2	0.000 0.0	0.000 0.0	0.029 35.4	0.011 9.5	0.013 36.2
M_8	MS_4					
0.000 0.0	0.000 0.0					

Green Cove Springs, St. Johns River — NOS/NOAA Station Number: 8720496
Series Start Date: 8/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.12400

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.363 21.2	0.042 50.7	0.060 4.7	0.065 214.6	0.042 324.7	0.063 225.8	0.031 159.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.003 10.9	0.000 0.0	0.012 6.9	0.001 159.3	0.009 328.3	0.008 348.2
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 203.4	0.003 34.9	0.000 0.0	0.004 220.1	0.005 209.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 230.6	0.012 231.3	0.003 49.5	0.000 51.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 236.8	0.022 215.4	0.000 0.0	0.000 0.0	0.010 37.7	0.000 0.0	0.011 53.1
M_8	MS_4					
0.009 121.1	0.000 0.0					

Green Cove Springs, St. Johns River — NOS/NOAA Station Number: 8720496
Series Start Date: 9/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.60500

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.366 20.2	0.039 48.8	0.060 9.6	0.081 224.6	0.025 307.0	0.039 230.2	0.031 159.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.006 274.4	0.000 0.0	0.012 11.0	0.002 289.0	0.009 328.2	0.008 359.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 219.0	0.003 33.5	0.000 0.0	0.003 227.4	0.003 221.8	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 232.6	0.008 233.0	0.002 47.6	0.000 49.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 235.8	0.027 225.0	0.000 0.0	0.000 0.0	0.010 30.9	0.000 0.0	0.011 51.1
M_8	MS_4					
0.007 89.2	0.000 0.0					

Table D8—*Continued*

Green Cove Springs, St. Johns River — NOS/NOAA Station Number: 8720496
Series Start Date: 10/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.83600

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.356	21.6	0.045	41.4	0.047	4.0	0.058	249.1	0.020	308.7	0.051	222.1	0.031	165.6
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.007	216.5	0.000	0.0	0.009	6.3	0.002	324.5	0.009	338.4	0.006	346.3
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.002	276.0	0.003	30.8	0.000	0.0	0.004	235.7	0.004	262.4	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.002	210.6	0.010	208.8	0.003	40.6	0.000	42.2
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.001	195.4	0.019	247.0	0.000	0.0	0.000	0.0	0.010	39.3	0.000	0.0	0.012	43.0
M_8		MS_4											
0.005	91.1	0.000	0.0										

St. Johns County Pier, St. Augustine — NOS/NOAA Station Number: 8720587
Series Start Date: N/A — Series Length (in days): N/A
Series Mean Sea Level (in feet): 2.44000

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
2.172	229.4	0.369	245.7	0.536	212.7	0.330	121.8	0.042	119.0	0.241	132.7	0.020	6.7
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.012	252.4	0.018	324.2	0.018	114.6	0.098	214.5	0.000	0.0	0.069	216.8	0.070	200.5
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.011	142.2	0.021	247.5	0.033	116.5	0.015	132.9	0.026	123.8	0.000	0.0	0.217	60.5
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.361	199.5	0.000	0.0	0.000	0.0	0.019	121.8	0.044	123.4	0.040	247.2	0.024	104.7
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.012	98.8	0.119	114.4	0.015	242.9	0.010	252.0	0.093	224.1	0.016	264.3	0.088	245.5
M_8		MS_4											
0.000	0.0	0.036	168.3										

East Tocoi, St. Johns River — NOS/NOAA Station Number: 8720596
Series Start Date: 9/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.15900

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.444	58.4	0.045	99.4	0.069	41.0	0.074	245.6	0.026	22.8	0.044	253.4	0.029	252.4
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.004	307.1	0.000	0.0	0.013	43.3	0.001	97.6	0.011	354.2	0.009	23.6
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.002	237.9	0.003	77.4	0.000	0.0	0.003	249.5	0.004	241.8	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.002	256.7	0.009	257.3	0.003	97.8	0.000	101.0
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.001	261.1	0.024	246.2	0.000	0.0	0.000	0.0	0.012	75.8	0.000	0.0	0.012	102.7
M_8		MS_4											
0.005	222.4	0.000	0.0										

East Tocoi, St. Johns River — NOS/NOAA Station Number: 8720596
Series Start Date: 10/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.42500

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.427	58.8	0.051	77.9	0.044	42.6	0.049	271.8	0.026	27.8	0.056	230.5	0.026	250.2
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.004	303.1	0.000	0.0	0.008	44.8	0.002	50.0	0.010	16.6	0.006	26.3
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.002	313.0	0.003	67.7	0.000	0.0	0.004	251.3	0.004	292.2	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.002	212.8	0.011	210.1	0.003	77.1	0.000	78.6
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.002	189.6	0.016	268.7	0.000	0.0	0.000	0.0	0.012	75.1	0.000	0.0	0.014	79.4
M_8		MS_4											
0.006	208.8	0.000	0.0										

Table D8—*Continued*

East Tocoi, St. Johns River — NOS/NOAA Station Number: 8720596
Series Start Date: 11/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 5.36700

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.433 61.8	0.046 84.1	0.067 60.7	0.043 244.4	0.025 34.2	0.037 229.8	0.024 262.6
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.002 23.8	0.000 0.0	0.013 60.8	0.002 49.2	0.010 16.2	0.009 59.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 258.9	0.003 72.1	0.000 0.0	0.003 237.1	0.003 251.6	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 223.5	0.007 222.6	0.003 83.2	0.000 85.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 215.3	0.014 243.3	0.000 0.0	0.000 0.0	0.012 62.9	0.000 0.0	0.012 85.9
M_8	MS_4					
0.006 241.1	0.000 0.0					

Palmetto Bluff, St. Johns River — NOS/NOAA Station Number: 8720653
Series Start Date: 9/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.30700

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.496 70.7	0.060 112.8	0.071 54.5	0.066 243.0	0.030 58.6	0.047 261.9	0.031 310.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.002 234.0	0.000 0.0	0.014 56.7	0.003 156.7	0.012 5.4	0.009 38.3
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 224.2	0.004 90.2	0.000 0.0	0.003 252.4	0.004 233.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.002 270.0	0.009 271.2	0.004 111.1	0.001 114.4
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 280.6	0.022 244.4	0.000 0.0	0.000 0.0	0.014 86.9	0.000 0.0	0.016 116.2
M_8	MS_4					
0.006 299.3	0.000 0.0					

Palmetto Bluff, St. Johns River — NOS/NOAA Station Number: 8720653
Series Start Date: 11/2/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.53800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.497 70.6	0.051 91.3	0.075 60.2	0.043 248.5	0.030 53.5	0.034 245.2	0.029 312.2
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.003 6.4	0.000 0.0	0.015 61.6	0.003 92.6	0.012 26.7	0.010 49.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.001 251.8	0.004 80.2	0.000 0.0	0.002 246.8	0.003 250.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 243.7	0.006 243.5	0.003 90.5	0.000 92.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 241.9	0.014 248.2	0.000 0.0	0.000 0.0	0.014 81.1	0.000 0.0	0.014 93.0
M_8	MS_4					
0.007 274.0	0.000 0.0					

Palmetto Bluff, St. Johns River — NOS/NOAA Station Number: 8720653
Series Start Date: 1/1/1979 — Series Length (in days): 29
Series Mean Sea Level (in feet): 3.37900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.487 73.4	0.072 99.8	0.086 52.2	0.060 242.8	0.029 81.9	0.071 242.0	0.022 302.2
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.003 319.8	0.000 0.0	0.017 55.1	0.002 244.2	0.012 23.7	0.011 31.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.003 243.6	0.003 85.6	0.000 0.0	0.005 242.4	0.006 243.2	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.003 241.7	0.014 241.6	0.004 98.7	0.001 100.9
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.002 241.2	0.020 242.8	0.000 0.0	0.000 0.0	0.014 94.5	0.000 0.0	0.020 101.9
M_8	MS_4					
0.006 296.6	0.000 0.0					

Table D8—*Continued*

Palmetto Bluff, St. Johns River NOS/NOAA Station Number: 8720653
Series Start Date: 2/1/1979 Series Length (in days): 29
Series Mean Sea Level (in feet): 3.57600

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.486	69.4	0.064	101.1	0.094	51.5	0.057	247.7	0.029	71.7	0.055	239.7	0.023	293.4
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.006	52.6	0.000	0.0	0.018	53.9	0.001	64.0	0.012	14.4	0.012	33.6
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.002	255.7	0.003	84.1	0.000	0.0	0.004	243.7	0.004	251.7	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.002	236.2	0.011	235.7	0.004	99.8	0.001	102.4
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.001	231.7	0.019	247.1	0.000	0.0	0.000	0.0	0.014	87.3	0.000	0.0	0.017	103.7
M_8		MS_4											
0.005	266.1	0.000	0.0										

Palmetto Bluff, St. Johns River NOS/NOAA Station Number: 8720653
Series Start Date: 3/1/1979 Series Length (in days): 29
Series Mean Sea Level (in feet): 3.46100

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.517	70.3	0.064	97.4	0.092	58.5	0.099	205.8	0.030	71.4	0.048	236.1	0.027	298.5
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.004	16.6	0.000	0.0	0.018	60.1	0.002	359.1	0.012	19.8	0.012	46.8
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.002	175.4	0.004	82.9	0.000	0.0	0.003	220.8	0.004	190.7	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.002	249.1	0.009	251.2	0.004	96.3	0.001	98.5
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.001	266.2	0.033	208.1	0.000	0.0	0.000	0.0	0.014	82.0	0.000	0.0	0.017	99.6
M_8		MS_4											
0.007	295.6	0.000	0.0										

Buffalo Bluff, St. Johns River NOS/NOAA Station Number: 8720767
Series Start Date: 11/2/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 3.20600

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.435	107.7	0.041	119.2	0.074	104.0	0.032	270.2	0.021	160.2	0.018	268.8	0.039	116.7
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.006	50.6	0.000	0.0	0.014	104.5	0.003	9.5	0.010	72.8	0.010	100.3
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.001	271.6	0.003	113.0	0.000	0.0	0.001	269.5	0.001	270.9	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.001	268.2	0.004	268.1	0.002	118.7	0.000	119.6
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.001	267.4	0.011	270.1	0.000	0.0	0.000	0.0	0.012	111.4	0.000	0.0	0.011	120.1
M_8		MS_4											
0.007	154.6	0.000	0.0										

Palatka NOS/NOAA Station Number: 8720774
Series Start Date: 10/1/1978 Series Length (in days): 29
Series Mean Sea Level (in feet): 5.65700

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.515	89.2	0.050	113.3	0.055	92.1	0.045	256.7	0.033	82.2	0.054	239.5	0.042	33.2
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.009	7.5	0.000	0.0	0.011	91.7	0.004	190.8	0.012	41.7	0.007	95.0
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.002	273.9	0.004	100.4	0.000	0.0	0.004	248.2	0.004	265.3	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.002	232.1	0.010	231.0	0.003	112.4	0.000	114.3
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.001	222.4	0.015	255.4	0.000	0.0	0.000	0.0	0.014	86.4	0.000	0.0	0.014	115.3
M_8		MS_4											
0.012	28.4	0.000	0.0										

Table D8—*Continued*

Palatka — NOS/NOAA Station Number: 8720774
Series Start Date: 1/1/1979 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.38000

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.549	88.6	0.073	129.1	0.086	64.2	0.046	255.6	0.063	137.5	0.061	239.3	0.027	42.7
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.009	7.5	0.000	0.0	0.017	67.5	0.003	21.5	0.013	24.8	0.011	39.8
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.003	271.9	0.004	107.4	0.000	0.0	0.004	247.5	0.005	263.7	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.002	232.3	0.012	231.2	0.004	127.4	0.001	130.7
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.002	223.1	0.015	254.4	0.000	0.0	0.000	0.0	0.015	113.0	0.000	0.0	0.020	132.3
M_8		MS_4											
0.009	67.8	0.000	0.0										

Palatka — NOS/NOAA Station Number: 8720774
Series Start Date: 2/1/1979 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.61300

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.556	85.3	0.077	120.6	0.100	71.0	0.056	253.1	0.065	133.3	0.046	242.8	0.035	39.4
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.010	131.3	0.000	0.0	0.019	72.9	0.003	152.5	0.013	26.6	0.013	56.6
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.002	263.4	0.004	101.7	0.000	0.0	0.003	248.0	0.004	258.2	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.002	238.4	0.009	237.7	0.005	119.2	0.001	122.0
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.001	232.7	0.018	252.3	0.000	0.0	0.000	0.0	0.016	99.7	0.000	0.0	0.021	123.5
M_8		MS_4											
0.009	49.1	0.000	0.0										

Palatka — NOS/NOAA Station Number: 8720774
Series Start Date: 3/1/1979 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.48300

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.588	84.3	0.070	120.6	0.101	66.8	0.104	206.5	0.071	127.8	0.032	235.9	0.037	38.7
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.009	87.0	0.000	0.0	0.020	69.2	0.001	110.0	0.014	24.6	0.013	49.3
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.001	177.1	0.004	101.1	0.000	0.0	0.002	221.1	0.003	191.9	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.001	248.5	0.006	250.5	0.004	119.1	0.001	122.0
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.001	265.1	0.034	208.7	0.000	0.0	0.000	0.0	0.017	101.8	0.000	0.0	0.019	123.5
M_8		MS_4											
0.009	57.0	0.000	0.0										

Sutherlands Still, Dunns Creek — NOS/NOAA Station Number: 8720782
Series Start Date: 1/1/1979 — Series Length (in days): 29
Series Mean Sea Level (in feet): 3.78500

M_2		S_2		N_2		K_1		M_4		O_1		M_6	
0.402	101.2	0.051	132.8	0.069	83.3	0.031	263.6	0.062	163.9	0.042	248.9	0.026	104.7
MK_3		S_4		MN_4		Nu_2		S_6		Mu_2		$2N_2$	
0.000	0.0	0.006	16.1	0.000	0.0	0.013	85.7	0.008	44.0	0.010	46.1	0.009	65.4
OO_1		Lambda		S_1		M_1		J_1		M_m		S_{sa}	
0.002	278.3	0.003	115.9	0.000	0.0	0.003	256.3	0.003	270.9	0.000	0.0	0.000	0.0
S_a		MS_f		M_f		Rho_1		Q_1		T_2		R_2	
0.000	0.0	0.000	0.0	0.000	0.0	0.002	242.6	0.008	241.6	0.003	131.5	0.000	134.0
$2Q_1$		P_1		$2SM_2$		M_3		L_2		$2MK_3$		K_2	
0.001	234.4	0.010	262.5	0.000	0.0	0.000	0.0	0.011	119.1	0.000	0.0	0.014	135.3
M_8		MS_4											
0.013	171.3	0.000	0.0										

Table D8—*Continued*

Sutherlands Still, Dunns Creek — NOS/NOAA Station Number: 8720782
Series Start Date: 2/1/1979 — Series Length (in days): 29
Series Mean Sea Level (in feet): 3.96900

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.408 98.6	0.053 134.0	0.073 82.4	0.040 260.2	0.065 162.9	0.032 248.9	0.028 90.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.012 156.9	0.000 0.0	0.014 84.6	0.004 191.2	0.010 39.8	0.010 66.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.001 271.5	0.003 115.0	0.000 0.0	0.002 254.6	0.003 265.8	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 244.1	0.006 243.3	0.003 132.6	0.000 135.4
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 237.7	0.013 259.4	0.000 0.0	0.000 0.0	0.011 114.9	0.000 0.0	0.014 136.9
M_8	MS_4					
0.013 149.7	0.000 0.0					

Sutherlands Still, Dunns Creek — NOS/NOAA Station Number: 8720782
Series Start Date: 3/1/1979 — Series Length (in days): 29
Series Mean Sea Level (in feet): 3.85100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.439 97.5	0.048 129.6	0.077 80.2	0.081 216.2	0.071 155.8	0.021 253.0	0.036 88.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.012 99.7	0.000 0.0	0.015 82.5	0.002 301.3	0.010 41.9	0.010 62.9
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.001 179.3	0.003 112.4	0.000 0.0	0.002 234.5	0.002 197.9	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 268.9	0.004 271.3	0.003 128.3	0.000 130.8
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 289.6	0.027 218.9	0.000 0.0	0.000 0.0	0.012 114.8	0.000 0.0	0.013 132.1
M_8	MS_4					
0.017 153.1	0.000 0.0					

Welaka — NOS/NOAA Station Number: 8720832
Series Start Date: 10/1/1978 — Series Length (in days): 29
Series Mean Sea Level (in feet): 4.47800

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.133 123.8	0.014 154.0	0.021 142.8	0.018 274.6	0.030 250.7	0.014 274.2	0.022 203.8
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.010 78.2	0.000 0.0	0.004 140.3	0.002 300.3	0.003 70.2	0.003 161.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.001 275.0	0.001 137.8	0.000 0.0	0.001 274.4	0.001 274.8	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 274.1	0.003 274.0	0.001 152.8	0.000 155.2
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.000 273.8	0.006 274.6	0.000 0.0	0.000 0.0	0.004 104.9	0.000 0.0	0.004 156.4
M_8	MS_4					
0.002 2.9	0.000 0.0					

Welaka — NOS/NOAA Station Number: 8720832
Series Start Date: 1/1/1979 — Series Length (in days): 29
Series Mean Sea Level (in feet): 3.29600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.146 113.1	0.022 103.6	0.021 82.9	0.005 238.5	0.046 214.3	0.009 305.6	0.020 222.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.003 98.6	0.000 0.0	0.004 87.0	0.002 259.8	0.004 99.1	0.003 52.7
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.000 171.3	0.001 108.7	0.000 0.0	0.001 271.8	0.001 205.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.000 334.4	0.002 338.9	0.001 104.0	0.000 103.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.000 12.3	0.002 243.5	0.000 0.0	0.000 0.0	0.004 143.3	0.000 0.0	0.006 102.9
M_8	MS_4					
0.005 330.5	0.000 0.0					

Table D8—*Continued*

Welaka
Series Start Date: 3/1/1979
Series Mean Sea Level (in feet): 3.33900
NOS/NOAA Station Number: 8720832
Series Length (in days): 29

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.160 106.3	0.026 117.8	0.032 87.3	0.027 267.2	0.056 202.7	0.020 322.8	0.026 200.4
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.002 143.8	0.000 0.0	0.006 89.9	0.007 48.6	0.004 71.4	0.004 68.3
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.001 211.7	0.001 111.7	0.000 0.0	0.001 294.8	0.002 239.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.001 346.6	0.004 350.3	0.002 117.4	0.000 118.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.001 17.9	0.009 271.4	0.000 0.0	0.000 0.0	0.004 125.4	0.000 0.0	0.007 118.8
M_8	MS_4					
0.009 309.3	0.000 0.0					

Welaka
Series Start Date: 4/1/1979
Series Mean Sea Level (in feet): 3.03800
NOS/NOAA Station Number: 8720832
Series Length (in days): 29

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.191 109.3	0.023 143.9	0.042 87.3	0.022 289.3	0.041 210.0	0.011 298.8	0.036 196.9
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.005 185.6	0.000 0.0	0.008 90.3	0.005 301.5	0.005 51.2	0.005 65.4
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.001 279.8	0.001 125.4	0.000 0.0	0.001 294.0	0.001 284.6	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.000 302.9	0.002 303.6	0.001 142.5	0.000 145.3
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.000 308.3	0.007 290.0	0.000 0.0	0.000 0.0	0.005 131.3	0.000 0.0	0.006 146.7
M_8	MS_4					
0.007 313.5	0.000 0.0					

Welaka
Series Start Date: 9/1/1978
Series Mean Sea Level (in feet): 3.70000
NOS/NOAA Station Number: 8720832
Series Length (in days): 242

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.152 113.5	0.023 141.1	0.024 93.7	0.012 274.0	0.037 216.3	0.013 296.1	0.025 201.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.000 0.0	0.011 180.6	0.008 103.5	0.000 0.0	0.006 251.1	0.000 0.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.000 0.0	0.005 116.7	0.007 66.6	0.000 0.0	0.000 0.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.000 0.0	0.000 0.0	0.006 14.0	0.000 0.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.000 0.0	0.000 0.0	0.000 0.0	0.000 0.0	0.014 126.7	0.006 161.2	0.000 0.0
M_8	MS_4					
0.005 324.2	0.009 269.7					

Georgetown, St. Johns River
Series Start Date: 1/1/1974
Series Mean Sea Level (in feet): 2.08500
NOS/NOAA Station Number: 8720877
Series Length (in days): 29

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.027 206.8	0.003 203.2	0.003 158.2	0.003 327.8	0.004 228.1	0.008 329.3	0.009 214.5
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.001 147.9	0.000 0.0	0.001 164.7	0.001 32.9	0.001 187.0	0.000 109.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.000 326.3	0.000 205.1	0.000 0.0	0.001 328.5	0.001 327.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.000 329.9	0.002 330.0	0.000 203.4	0.000 203.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.000 330.7	0.001 327.9	0.000 0.0	0.000 0.0	0.001 255.4	0.000 0.0	0.001 202.9
M_8	MS_4					
0.005 323.8	0.000 0.0					

Table D8—*Continued*

Georgetown, St. Johns River — NOS/NOAA Station Number: 8720877
Series Start Date: 10/1/1974 — Series Length (in days): 29
Series Mean Sea Level (in feet): 3.91700

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.019 226.2	0.005 10.7	0.005 266.8	0.005 331.9	0.002 79.5	0.004 56.3	0.002 286.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.000 150.0	0.000 0.0	0.001 261.3	0.002 43.4	0.000 58.3	0.001 307.3
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.000 247.4	0.000 293.2	0.000 0.0	0.000 13.7	0.000 290.0	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.000 92.5	0.001 98.2	0.000 4.9	0.000 16.4
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.000 140.1	0.002 338.2	0.000 0.0	0.000 0.0	0.001 185.6	0.000 0.0	0.001 22.4
M_8	MS_4					
0.001 111.2	0.000 0.0					

Georgetown, St. Johns River — NOS/NOAA Station Number: 8720877
Series Start Date: 4/1/1975 — Series Length (in days): 29
Series Mean Sea Level (in feet): 2.28100

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.027 228.6	0.003 342.6	0.007 176.3	0.014 12.6	0.006 245.1	0.002 70.0	0.007 311.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.001 248.9	0.000 0.0	0.001 183.3	0.001 350.3	0.001 91.2	0.001 124.0
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.000 315.2	0.000 281.5	0.000 0.0	0.000 41.1	0.000 344.1	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.000 94.6	0.001 98.5	0.000 338.0	0.000 347.1
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.000 126.9	0.005 16.9	0.000 0.0	0.000 0.0	0.001 280.9	0.000 0.0	0.001 351.8
M_8	MS_4					
0.006 80.1	0.000 0.0					

Georgetown, St. Johns River — NOS/NOAA Station Number: 8720877
Series Start Date: 5/1/1975 — Series Length (in days): 29
Series Mean Sea Level (in feet): 2.46600

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.029 231.8	0.012 306.1	0.001 87.9	0.007 80.6	0.001 299.0	0.009 3.8	0.014 294.8
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.004 189.1	0.000 0.0	0.000 107.2	0.002 295.0	0.001 134.1	0.000 304.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.000 157.4	0.000 266.2	0.000 0.0	0.001 42.5	0.001 118.7	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.000 330.9	0.002 325.7	0.001 303.1	0.000 309.0
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.000 287.6	0.002 74.9	0.000 0.0	0.000 0.0	0.001 15.6	0.000 0.0	0.003 312.1
M_8	MS_4					
0.004 46.5	0.000 0.0					

Daytona Beach — NOS/NOAA Station Number: 8721120
Series Start Date: 1/1/1982 — Series Length (in days): 365
Series Mean Sea Level (in feet): 4.25000

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.855 225.5	0.312 241.6	0.426 206.7	0.330 121.0	0.032 143.4	0.256 131.0	0.010 266.0
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.007 264.7	0.016 294.6	0.011 132.3	0.090 196.4	0.003 91.5	0.055 218.6	0.063 191.6
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.020 123.9	0.026 306.3	0.028 90.4	0.006 157.1	0.025 131.2	0.052 282.9	0.375 73.5
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.390 205.1	0.035 99.6	0.060 274.9	0.014 126.5	0.046 135.2	0.031 230.3	0.019 72.5
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.009 131.2	0.104 121.5	0.013 261.8	0.012 224.3	0.052 256.7	0.011 264.0	0.084 245.8
M_8	MS_4					
0.001 276.4	0.034 163.8					

Table D8—*Continued*

Daytona Beach — NOS/NOAA Station Number: 8721120
Series Start Date: N/A — Series Length (in days): N/A
Series Mean Sea Level (in feet): 4.66700

M_2	S_2	N_2	K_1	M_4	O_1	M_6
1.853 227.7	0.278 239.9	0.445 205.3	0.385 128.9	0.036 166.5	0.228 127.7	0.007 266.1
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.000 0.0	0.033 287.7	0.000 0.0	0.086 208.3	0.007 101.7	0.044 193.4	0.059 182.8
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.010 130.1	0.013 233.4	0.000 0.0	0.016 128.3	0.018 129.5	0.000 0.0	0.000 0.0
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.000 0.0	0.000 0.0	0.000 0.0	0.009 127.2	0.044 127.1	0.016 240.1	0.002 239.7
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.006 126.5	0.127 129.3	0.000 0.0	0.000 0.0	0.052 250.1	0.000 0.0	0.076 239.5
M_8	MS_4					
0.001 267.7	0.000 0.0					

Titusville — NOS/NOAA Station Number: 8721456
Series Start Date: 1/1/1983 — Series Length (in days): 365
Series Mean Sea Level (in feet): 3.99200

M_2	S_2	N_2	K_1	M_4	O_1	M_6
0.014 143.3	0.005 150.3	0.003 105.0	0.004 36.2	0.001 135.1	0.005 334.6	0.001 346.3
MK_3	S_4	MN_4	Nu_2	S_6	Mu_2	$2N_2$
0.001 119.1	0.000 57.2	0.001 85.8	0.001 88.9	0.000 19.9	0.001 185.8	0.001 197.1
OO_1	Lambda	S_1	M_1	J_1	M_m	S_{sa}
0.002 141.3	0.001 142.7	0.013 165.8	0.002 283.9	0.003 257.1	0.075 22.7	0.209 20.8
S_a	MS_f	M_f	Rho_1	Q_1	T_2	R_2
0.181 232.7	0.034 146.2	0.042 84.5	0.002 42.2	0.002 353.1	0.000 88.8	0.000 224.5
$2Q_1$	P_1	$2SM_2$	M_3	L_2	$2MK_3$	K_2
0.003 198.0	0.002 75.2	0.000 331.1	0.000 180.0	0.000 176.9	0.000 257.5	0.001 191.0
M_8	MS_4					
0.000 112.5	0.000 140.7					

Note: N/A = not available

The symbol of each constituent is centered above the corresponding amplitude and phase of that constituent (see Table 3.13 for name of most constituents). For example, under Little St. Marys River, constituent M_2 has an amplitude of 1.881 feet (NGVD) and a phase of 312.7 degrees relative to local meridian.

Table D9. Ratios of harmonic constituents (1992 analysis)

Station Number*	Station Name	River Mile**	Amplitude Ratios			Phase Expression
			$\frac{K_1+O_1}{M_2+S_2}$	$\frac{M_4}{M_2}$	$\frac{M_6}{M_2}$	$M_2-K_1-O_1$
8720194	Little Talbot Island	†	0.207	0.019	0.008	-014.7
8720220	Mayport	2.4	0.186	0.037	0.014	-028.0
8720232	Pablo Creek entrance	5.0	0.227	0.027	0.021	-040.0
8720221	Fulton	7.8	0.164	0.011	0.028	-038.7
8720198	Clapboard Creek	8.7	0.185	0.017	0.034	-038.0
8720203	Blount Island Bridge	10.8	0.223	0.017	0.034	-037.6
8720219	Dame Point	10.8	0.184	0.019	0.044	-050.8
8720215	Jacksonville, Navy Fuel Depot	15.6	0.176	0.031	0.061	-049.3
8720225	Phoenix Park	16.9	0.189	0.040	0.056	-054.0
8720242	USACE dredge depot	19.0	0.172	0.035	0.062	-057.1
8720274	Little Pottsburg Creek	22.6	0.190	0.039	0.049	-052.6
8720268	Jacksonville, Acosta Bridge	24.0	0.188	0.027	0.053	-069.5
8720296	Ortega River entrance	28.0	0.200	0.057	0.075	-085.4
8720333	Piney Point (NAS)	31.0	0.167	0.047	0.070	-105.1
8720374	Orange Park	36.0	0.279	0.079	0.079	-087.9
8720409	Julington Creek	40.5	0.300	0.111	0.111	-079.4
8720496	Green Cove Springs	47.0	0.275	0.083	0.083	-073.7
8720596	East Tocoi	60.5	0.234	0.070	0.070	-072.1
8720653	Palmetto Bluff (Bridgeport)	66.5	0.216	0.061	0.061	-062.8
8720774	Palatka	79.5	0.164	0.093	0.056	-047.9
8720767	Buffalo Bluff	90.0	0.104	0.045	0.091	-071.2
8720832	Welaka	100.4	0.118	0.267	0.133	-096.7
8720877	Georgetown	109.4	——	——	——	——

Note: —— = negligible values

*See Figure 3.10a–d for location of stations
**River miles taken from file used to create Figures 3.1a–d
†Station not located directly on the St. Johns River

See Table 3.13 for name of constituents

Source: USACE Jacksonville 1994b, 12, Table 3

Table D10. Relationships of tidal datums to National Geodetic Vertical Datum (1992 analysis)

Station Number*	Station Name	River Mile**	MSL NGVD	MHW NGVD	MTL NGVD	MLLW NGVD
8720194	Little Talbot Island	†	0.48	3.28	0.53	-2.41
8720220	Mayport	2.4	0.36	2.56	0.31	-2.10
8720232	Pablo Creek entrance	5.0	0.41	2.36	0.41	-1.64
8720221	Fulton@	7.8	0.46	2.26	0.43	-1.51
8720198	Clapboard Creek	8.7	0.47	2.29	0.47	-1.47
8720203	Blount Island Bridge	10.8	0.55	2.18	0.43	-1.44
8720219	Dame Point	10.8	0.48	2.04	0.45	-1.25
8720215	Jacksonville, Navy Fuel Depot	15.6	0.56	1.87	0.56	-0.84
8720225	Phoenix Park@	16.9	0.56	1.83	0.56	-0.80
8720242	USACE dredge depot	19.0	0.72	1.77	0.73	-0.39
8720274	Little Pottsburg Creek@	22.6	0.76	1.80	0.77	-0.35
8720268	Jacksonville, Acosta Bridge@	24.0	0.77	1.51	0.75	-0.09
8720296	Ortega River entrance@	28.0	0.81	1.40	0.85	0.22
8720333	Piney Point (NAS)@	31.0	0.76	1.23	0.79	0.28
8720374	Orange Park@	36.0	0.68	1.05	0.68	0.23
8720409	Julington Creek@	40.5	0.80	1.16	0.81	0.38
8720496	Green Cove Springs	47.0	0.70	1.06	0.69	0.25
8720596	East Tocoi@	60.5	0.69	1.13	0.68	0.16
8720653	Palmetto Bluff@ (Bridgeport)	66.5	0.65	1.19	0.67	0.08
8720774	Palatka	79.5	0.62	1.19	0.65	0.17
8720767	Buffalo Bluff@	90.0	0.86	1.37	0.90	0.38
8720832	Welaka@	100.4	0.90	1.09	0.92	0.70

Note: MSL = mean sea level
NGVD = feet, National Geodetic Vertical Datum
MHW = mean high water
MTL = mean tide level
MLLW = mean lower low water

*See Figure 3.10a–d for location of stations
**River miles taken from file used to create Figures 3.1a–d
†Station not located directly on the St. Johns River
@NGVD elevations are preliminary and may be adjusted later

Source: USACE Jacksonville 1994b, 12, Table 5

APPENDIX E: MAINSTEM FLOW

LONG-TERM MEAN DISCHARGE/DRAINAGE COEFFICIENT CALCULATION

An approximate measure of the relationship between total runoff and mainstem flow is traditionally obtained by dividing the measured mean discharge at a location by the upstream surface drainage area. It is reasonable to assume that the accuracy of the statistical calculation will increase as more stations are included. The available means of annual flow in the river are shown in Table E1, for data collected to 1993, where available.

Table E1. Drainage areas and long-term mean discharge to the main stem

Reference Water Year	Location of Discharge	Number of Years of Record	Drainage Surface Area (mi^2)	Mean Discharge (cfs)	Cumulative Discharge/Drainage Area Coefficient (cfs/mi^2)
1993	Big Davis Creek	28	13.6	10.6	0.779
1993	Ortega River	29	30.9	36.8	1.191
1993	Middle Haw Creek	19	78.3	69.4	0.886
1993	Little Haw Creek	43	93.0	80.9	0.870
1986	Dunns Creek	8	585.0	455.0	0.778
1993	Near Melbourne	54	968.0	660.0	0.682
1993	Near Cocoa	40	1,331.0	967.0	0.727
1993	Near Christmas	60	1,539.0	1281.0	0.832
1993	Rodman Dam	25	2,097.0*	1353.0	0.645
1993	De Land	60	3,066.0	3039.0	0.991
1994	Buffalo Bluff	1	5,930.0	5360.0	0.904
1982	Palatka	13	6,444.0*	5945.0	0.923
1993	Jacksonville	23	8,200.0*	6105.0	0.745

Note: cfs/mi^2 = cubic feet per second per square mile

*Indicates that, for this table, the area of Paynes Prairie has been omitted from USGS-tabulated drainage area of this basin, because Paynes Prairie is a controlled part of the watershed and does not contribute to drainage from this basin to the St. Johns River.

Source: USGS, Water Year (see Reference Water Year column)

EXPLANATION OF THE MINIMUM, MEAN, AND MAXIMUM DAILY VALUE TABLES

The monthly means of the daily values and the minimum and maximum daily values for each month in the period of record for which USGS data are available through WY 1992 for De Land, Rodman Dam, Buckman Lock, Dunns Creek, Palatka, and Jacksonville are tabulated in this appendix. The minimum, mean, and maximum values for each month enable a summary and comparison to be made of the monthly fluctuations over the period of record. It should be noted that the extremes of the daily fluctuations are listed.

The three rightmost columns (YR MIN, YR MEAN, YR MAX, not counting the far righthand column for YEAR) in Tables E2–E22 provide the minimum, mean, and maximum monthly flows for the year. The three sets of values (ANN MIN, ANN MEAN, ANN MAX) for each of these three columns below the last year of record (e.g., 1992) are the minimum, mean, and maximum values for each column directly above. The last three lines (MO MIN, MO MEAN, MO MAX) are the monthly statistics of the minimums, means, and maximums of the monthly values (last three rightmost columns) on the same line.

MINIMUM DAILY FLOW

Table E2. Station 02236000, De Land. Minimum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1934	2360	1440	1560	1260	1450	4260	7820	5660	4120	2680	510	1240	510	2863	7820	1934
1935	250	30	420	430	60	340	950	1230	2160	5610	4340	3170	30	1583	5610	1935
1936	2870	2590	4900	2930	870	1430	3230	1930	1340	1310	2400	1520	870	2277	4900	1936
1937	370	740	540	1150	470	800	680	940	530	410	4440	5200	370	1356	5200	1937
1938	3770	2250	1020	10	180	20	510	1420	620	265	690	780	10	961	3770	1938
1939	475	580	295	750	745	665	2180	2600	3020	3860	2530	1970	295	1639	3860	1939
1940	1270	1070	930	905	240	490	1260	2310	2440	2590	883	535	240	1244	2590	1940
1941	1960	3810	3530	3520	1870	750	3230	6780	4980	4530	5870	4860	750	3808	6780	1941
1942	4040	2330	2790	3070	1100	883	2700	2100	2130	1690	774	556	556	2014	4040	1942
1943	728	850	446	454	410	412	613	3390	3930	6600	3350	1880	410	1922	6600	1943
1944	1220	890	448	811	1010	880	1440	3880	4650	3200	5110	3100	448	2220	5110	1944
1945	2360	1440	969	440	862	852	3000	5780	5260	6980	4320	2660	440	2910	6980	1945
1946	2370	1490	590	897	678	758	1750	4610	4590	4060	2440	1610	590	2154	4610	1946
1947	1090	542	1770	3340	1530	1390	4520	5210	4850	7210	7360	4590	542	3617	7360	1947
1948	3390	3480	2330	835	1270	1060	1480	2690	3260	10300	5260	2650	835	3167	10300	1948
1949	2170	1060	1260	1350	1250	1110	2060	1550	4790	7690	5670	3200	1060	2763	7690	1949
1950	1800	980	800	775	700	392	450	600	850	1800	6670	3420	392	1603	6670	1950
1951	1510	1440	1020	1000	1200	900	1300	1800	2100	5500	4480	3120	900	2114	5500	1951
1952	1820	1500	1600	1460	897	700	700	620	1700	3000	5950	3300	620	1937	5950	1952
1953	1690	1560	1140	2830	681	700	658	2110	6990	13900	9140	6930	658	4027	13900	1953
1954	4360	2460	1600	1180	900	1480	3570	2400	1640	2600	2250	2900	900	2278	4360	1954
1955	1900	1930	1210	1190	1400	1140	1860	1880	2090	2860	2200	1170	1140	1736	2860	1955
1956	980	1310	220	890	700	1060	1180	820	1190	-640	7250	3940	-640	1575	7250	1956
1957	1920	-1920	510	1140	960	1660	1900	-3030	5010	5240	2560	1100	-3030	1421	5240	1957
1958	-1880	3580	4370	4000	-960	-1820	960	-360	-3020	-1620	1460	-1300	-3020	284	4370	1958
1959	2450	-1510	810	6920	3270	2550	4240	4180	3680	5540	4960	3370	-1510	3372	6920	1959
1960	2430	2240	3120	6670	3070	60	3350	8910	8720	12700	7590	3720	60	5215	12700	1960
1961	1760	1840	792	949	303	-1260	844	-294	1350	1240	-486	-918	-1260	510	1840	1961
1962	-1320	-789	-2650	-771	-1210	-986	-803	1000	2730	4030	196	-1180	-2650	-146	4030	1962
1963	1380	-1160	3570	1500	-1710	-1380	850	424	-221	3480	3850	4350	-1710	1244	4350	1963
1964	3950	5590	3660	-1810	-2320	-1730	-1080	1080	5860	6580	3140	2570	-2320	2124	6580	1964
1965	596	365	1520	698	756	-662	1060	3110	855	1270	2870	1370	-662	1151	3110	1965
1966	1240	1470	4500	3620	1220	1560	5690	5440	4050	5180	1770	2260	1220	3167	5690	1966
1967	639	-1220	-379	-498	-2230	-1140	1920	4350	4120	2390	750	-200	-2230	709	4350	1967
1968	-510	-1020	730	-490	0	0	10200	1840	1360	1480	5430	2800	-1020	1818	10200	1968
1969	1410	0	200	2370	760	510	1300	1620	4250	4380	6880	6220	0	2492	6880	1969
1970	6110	5930	3810	2730	500	380	760	1310	190	790	-1410	-380	-1410	1727	6110	1970
1971	-380	620	-1920	-1140	-1190	-620	370	1020	-910	200	800	-400	-1920	-296	1020	1971
1972	-1660	-520	500	-510	-640	780	910	1400	2300	-311	-634	1630	-1660	270	2300	1972
1973	-313	2210	1070	484	293	451	1340	2850	3370	3460	3450	1860	-313	1710	3460	1973
1974	1410	-1040	-1220	-930	-831	-1240	4350	7380	5900	5790	1470	836	-1240	1823	7380	1974
1975	-292	-1320	-1550	-717	-597	0	1970	3020	2340	3110	2850	1020	-1550	820	3110	1975
1976	234	-669	-1330	-1990	-562	271	3530	3290	4120	3210	1990	1350	-1990	1120	4120	1976
1977	1430	1450	271	442	-419	1050	583	1200	1380	997	498	1080	-419	830	1450	1977
1978	2440	1390	4480	730	877	1140	1650	5190	4600	1840	1660	1150	730	2262	5190	1978
1979	1950	2480	3190	1060	1130	723	1740	3050	2330	7770	5020	2060	723	2709	7770	1979
1980	657	66	775	64	0	-435	-373	-1330	-833	-1160	-1620	-2320	-2320	-542	775	1980
1981	0	-1790	-66	-795	-2060	-2440	-1750	-788	968	-2340	-1530	-486	-2440	-1090	968	1981
1982	-89	-761	-1240	1590	540	1180	7030	7030	5720	4730	2950	543	-1240	2435	7030	1982
1983	533	2560	5620	7310	2890	1120	1720	2120	728	1390	2550	2440	533	2582	7310	1983
1984	2640	3110	1590	798	917	855	2340	2960	2300	2320	67	1730	67	1802	3110	1984
1985	765	62	-869	-62	-1130	1110	881	448	4130	4880	5230	4130	-1130	1631	5230	1985
1986	2700	2380	274	369	-132	-466	804	658	486	596	738	696	-466	759	2700	1986
1987	652	135	2200	3020	1110	856	549	328	823	288	2350	2320	135	1219	3020	1987
1988	3360	3190	2920	1850	959	835	673	1270	2020	806	792	1750	673	1702	3360	1988
1989	203	910	-91	-786	232	252	47	98	-208	483	1920	796	-786	321	1920	1989
1990	1730	732	661	492	0	69	-214	311	181	729	1060	1210	-214	580	1730	1990
1991	-60	212	-63	1090	742	846	4320	5900	3630	2080	3090	2030	-63	1985	5900	1991
1992	1020	-593	170	978	720	1060	1500	1680	4500				-593	1226	4500	1992
MIN													-3030	-1090	775	ANN
MEAN													-392	1741	5177	ANN
MAX													1220	5215	13900	ANN
MO MIN	-1880	-1920	-2650	-1990	-2320	-2440	-1750	-3030	-3020	-2340	-1620	-2320	-3030	-2273	-1620	MO MIN
MO MEAN	1421	1084	1209	1218	436	468	1903	2389	2679	3303	2899	1957	436	1747	3303	MO MEAN
MO MAX	6110	5930	5620	7310	3270	4260	10200	8910	8720	13900	9140	6930	3270	7525	13900	MO MAX

Table E3. Station 02243960, Rodman Dam. Minimum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1969	1740	1290	0	1800	1920	150	180	1400	1900	2810	2160	2230	0	1465	2810	1969
1970	2810	3290	3490	3020	1480	1010	1300	900	1800	1040	423	904	423	1789	3490	1970
1971	1130	1420	1440	1080	995	643	663	995	872	846	854	1060	643	1000	1440	1971
1972	926	1220	1070	983	967	789	1060	1490	1300	977	985	1090	789	1071	1490	1972
1973	1190	411	948	1480	703	946	698	1220	1410	545	468	896	411	910	1480	1973
1974	585	705	705	585	585	697	1750	1750	1490	955	896	964	585	972	1750	1974
1975	978	978	429	585	581	645	585	585	955	955	826	630	429	728	978	1975
1976	598	665	606	473	473	1230	955	705	955	705	642	705	473	726	1230	1976
1977	1230	1010	955	517	389	473	427	473	353	473	473	668	353	620	1230	1977
1978	705	559	1330	955	705	874	1090	1850	1230	630	705	585	559	935	1850	1978
1979	705	705	705	585	826	826	705	399	1780	1370	344	1040	344	833	1780	1979
1980	1310	1070	797	1230	748	705	473	533	585	770	662	707	473	799	1310	1980
1981	402	412	468	353	348	353	241	349	478	385	476	291	241	380	478	1981
1982	383	353	357	614	705	1230	2120	1620	1110	954	826	785	353	921	2120	1982
1983	826	1090	1860	2350	1040	1230	1350	1230	1490	955	826	1090	826	1278	2350	1983
1984	2020	944	1620	1390	705	955	955	1090	473	585	478	539	473	980	2020	1984
1985	498	473	461	448	353	357	473	585	605	700	874	710	353	545	874	1985
1986	808	1000	1000	275	187	353	353	473	488	353	539	592	187	535	1000	1986
1987	665	565	1070	1870	1090	705	479	473	473	429	426	427	426	723	1870	1987
1988	573	715	861	575	429	479	576	719	895	618	919	1170	429	711	1170	1988
1989	335	827	601	728	345	420	598	568	852	429	570	570	335	570	852	1989
1990	713	572	428	426	570	571	572	565	429	430	570	522	426	531	713	1990
1991	569	427	281	356	574	807	576	569	430				281	510	807	1991
													0	380	478	ANN MIN
													427	849	1526	ANN MEAN
													826	1789	3490	ANN MAX
MO MIN	335	353	0	275	187	150	180	349	353	353	344	291	0	264	353	MO MIN
MO MEAN	943	900	934	986	727	715	790	893	972	814	725	826	715	852	986	MO MEAN
MO MAX	2810	3290	3490	3020	1920	1230	2120	1850	1900	2810	2160	2230	1230	2403	3490	MO MAX

Table E4. Station 02244032, Buckman Lock. Minimum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1970
1971	0	15	0	0	0	0	0	0	0	0	0	0	0	1	15	1971
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1972
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1973
1974	24	13	25	14	16	0	0	0	0	0	0	0	0	8	25	1974
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1975
1976	0	12	11	29	0	0	0	0	0	0	0	0	0	4	29	1976
1977	0	0	0	0	16	0	0	0	0	0	0	0	0	1	16	1977
1978	0	0	20	0	0	0	0	0	0	0	0	0	0	2	20	1978
1979	0	0	0	0	0	0	0	0	0	13	0	0	0	1	13	1979
1980	9	0	0	13	0	0	0	0	0	9	0	0	0	3	13	1980
1981	0	0	0	13	0	0	0	0	0	0	0	0	0	1	13	1981
1982	0	0	11	0	0	0	0	0	0	0	0	0	0	1	11	1982
1983	0	0	0	0	0	0	5	0	0	0	14	0	0	2	14	1983
1984	0	0	0	0	0	0	0	0	0	10	0	16	0	2	16	1984
1985	0	0	33	38	0	0	0	0	0	0	0	0	0	6	38	1985
1986	0	12	0	0	0	0	0	0	0	0	14	0	0	2	14	1986
1987	0	11	0	0	0	0	0	0	0	13	11	0	0	3	13	1987
1988	0	21	0	0	0	0	11	0	0	11	0	0	0	4	21	1988
1989	0	0	0	0	0	0	0	0	6	0	0	0	0	1	6	1989
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1990
1991	0	0	12	0	0	0	0	0	0	0	0	0	0	1	12	1991
1992	0	16	0	0	0	0	0	0	0				0	2	16	1992
													0	0	0	ANN MIN
													0	2	13	ANN MEAN
													0	8	38	ANN MAX
MO MIN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MO MIN
MO MEAN	1	4	5	5	1	0	1	0	0	3	2	1	0	2	5	MO MEAN
MO MAX	24	21	33	38	16	0	11	0	6	13	14	16	0	16	38	MO MAX

Table E5. Station 02244440, Dunns Creek. Minimum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1978	-459	-3160	-742	-1950	-1530	-750	-2680	-1590	-1660	-2780	-1560	-2420	-3160	-1773	-459	1978
1979	-621	-3800	-579			-955	-150	-774	-1310	-151	-910	-965	-3800	-1022	-150	1979
1980	-483	-430	-1420	-521	-1230	-853		-650	-701	-1590	-838	-1530	-1590	-931	-430	1980
1981	-391	-340			-97	-800	-173	-1280	-355	-2740	-1630	-1610	-2740	-942	-97	1981
1982	-690	-2410	-1460	-1010	-486	-842	-275	-463	-913	-2310	-584	-1400	-2410	-1070	-275	1982
1983	-1140	1420	-680	-124	-966	-1620	-1110	-1020	-1720	-833	-188	-395	-1720	-698	1420	1983
1984	-1240	-446	-508	-894	-1190	-1100	-665	-1290	533		-2970	-449	-2970	-929	533	1984
1985	-1110	-1450	-1230	-1730	-1730	-1770	-1340				-753	-1350	-1770	-1385	-753	1985
1986	-3480	-2060	-3970	-1730	-4520	-2550	-1320	-3670	-1960				-4520	-2807	-1320	1986
													-4520	-2807	-1320	ANN MIN
													-2742	-1284	-170	ANN MEAN
													-1590	-698	1420	ANN MAX
MO MIN	-3480	-3800	-3970	-1950	-4520	-2550	-2680	-3670	-1960	-2780	-2970	-2420	-4520	-3063	-1950	MO MIN
MO MEAN	-1068	-1408	-1324	-1137	-1469	-1249	-964	-1342	-1011	-1734	-1179	-1265	-1734	-1262	-964	MO MEAN
MO MAX	-391	1420	-508	-124	-97	-750	-150	-463	533	-151	-188	-395	-750	-105	1420	MO MAX

Table E6. Summation of De Land, Rodman Dam, Buckman Lock, and Dunns Creek station data. Minimum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1969	3150	1290	200	4170	2680	660	1480	3020	6150	7190	9040	8450	200	3957	9040	1969
1970	8920	9220	7300	5750	1980	1390	2060	2210	1990	1830	-987	524	-987	3516	9220	1970
1971	750	2055	-480	-60	-195	23	1033	2015	-38	1046	1654	660	-480	705	2055	1971
1972	-734	700	1570	473	327	1569	1970	2890	3600	666	351	2720	-734	1342	3600	1972
1973	877	2621	2018	1964	996	1397	2038	4070	4780	4005	3918	2756	877	2620	4780	1973
1974	2019	-322	-490	-331	-230	-543	6100	9130	7390	6745	2366	1800	-543	2803	9130	1974
1975	686	-342	-1121	-132	-16	645	2555	3605	3295	4065	3676	1650	-1121	1547	4065	1975
1976	832	8	-713	-1488	-89	1501	4485	3995	5075	3915	2632	2055	-1488	1851	5075	1976
1977	2660	2460	1226	959	-14	1523	1010	1673	1733	1470	971	1748	-14	1452	2660	1977
1978	2686	-1211	5088	-265	52	1264	60	5450	4170	-310	805	-685	-1211	1425	5450	1978
1979	2034	-615	3316	1645	1956	594	2295	2675	2800	9002	4454	2135	-615	2691	9002	1979
1980	1493	706	152	786	-482	-583	100	-1447	-949	-1971	-1796	-3143	-3143	-595	1493	1980
1981	11	-1718	402	-429	-1809	-2887	-1682	-1719	1091	-4695	-2684	-1805	-4695	-1494	1091	1981
1982	-396	-2818	-2332	1194	759	1568	8875	8187	5917	3374	3192	-72	-2818	2287	8875	1982
1983	219	5070	6800	9536	2964	730	1965	2330	498	1512	3202	3135	219	3163	9536	1983
1984	3420	3608	2702	1294	432	710	2630	2760	3306	2915	-2425	1836	-2425	1932	3608	1984
1985	153	-915	-1605	-1306	-2507	-303	14	1033	4735	5580	5351	3490	-2507	1143	5580	1985
1986	28	1332	-2696	-1086	-4465	-2663	-163	-2539	-986	949	1291	1288	-4465	-809	1332	1986
1987	1317	711	3270	4890	2200	1561	1028	801	1296	730	2787	2747	711	1945	4890	1987
1988	3933	3926	3781	2425	1388	1314	1260	1989	2915	1435	1711	2920	1260	2416	3933	1988
1989	538	1737	510	-58	577	672	645	666	650	912	2490	1366	-58	892	2490	1989
1990	2443	1304	1089	918	570	640	358	876	610	1159	1630	1732	358	1111	2443	1990
1991	509	639	230	1446	1316	1653	4896	6469	4060	2080	3090	2030	230	2368	6469	1991
1992	1020	-577	170	978	720	1060	1500	1680	4500				-577	921	4500	1992
													-4695	-1494	1091	ANN MIN
													-1001	1633	5013	ANN MEAN
													1260	3957	9536	ANN MAX
MO MIN	-734	-2818	-2696	-1488	-4465	-2887	-1682	-2539	-986	-4695	-2684	-3143	-4695	-2568	-734	MO MIN
MO MEAN	1607	1203	1266	1386	380	562	1938	2576	2858	2331	2031	1710	380	1654	2858	MO MEAN
MO MIN	8920	9220	7300	9536	2964	1653	8875	9130	7390	9002	9040	8450	1653	7623	9536	MO MAX

Table E7. Station 02244450, Palatka. Minimum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YRMAX	YEAR
1968	-11300	-10300	-4520	-9220	-9680	-20400	5310	-13700	-2510	-3150	7280	-2090	-20400	-6190	7280	1968
1969	-8590	-2250	657	-3260	-4230	-2210	-1640	-4210	-8230	2840	11500	3470	-8590	-1346	11500	1969
1970	6140	10200	-2470	4630	-5550	-6630	1320	-3280	-7120	-9380	-4310	-5610	-9380	-1838	10200	1970
1971	-8120	-2820	-6360	-1230	-9590	-6890	-1000	-3110	-9600	-11900	-5560	-14300	-14300	-6707	-1000	1971
1972	-11300	-11900	-5740	-12100	-10900	-2320	-4460	-2770	-3240	-11900	-5560	-6830	-12100	-7418	-2320	1972
1973	-7850	-17700	-437	1410	-2820	-1210	-3560	1930	3710	-753	-7650	-713	-17700	-2970	3710	1973
1974	3510	-4140	-9210	-6810	-5230	-7940	3320	10600	-4150	-8570	-11500	-4690	-11500	-3734	10600	1974
1975	-5430	-13900	-7810	-8420	-7920	-7680	-4890	-4880	-10200	-5780	1670	-4160	-13900	-6617	1670	1975
1976	-9030	-3480					1270	-7780	1040	-14900	-3100	-11500	-14900	-5935	1270	1976
1977	-8500	-5480	-4840	-5720	-12500	-1630	-6680	-2250	-1970	-9000	-10000	-5800	-12500	-6198	-1630	1977
1978	418	-10400	769	-2620	-1330	-3030	-7710	1580	985	-9240	-8580	-10700	-10700	-4155	1580	1978
1979	1860	-12800	342	-2730	-6460	-12700	-5970	-11100	-11400				-12800	-6096	1860	1979
1980									-11800	-7540	-12200					1980
1981	-9030	-11300	-4000	-6110	-11300	-6210	-2480	-2320	396	-6560	-528	-1610	-11300	-5088	396	1981
1982	-1270	-6530	-3410	-3030	174	-294	4360	8510	4640				-6530	350	8510	1982
													-20400	-7418	-2320	ANN MIN
													-12614	-4567	3830	ANN MEAN
													-6530	350	11500	ANN MAX
MO MIN	-11300	-17700	-9210	-12100	-12500	-20400	-7710	-13700	-11800	-14900	-12200	-14300	-20400	-13152	-7710	MO MIN
MO MEAN	-4892	-7343	-3618	-4247	-6718	-6088	-1629	-2341	-3963	-6845	-3734	-5378	-7343	-4733	-1629	MO MEAN
MO MAX	6140	10200	769	4630	174	-294	5310	10600	4640	2840	11500	3470	-294	4998	11500	MO MAX

Table E8. Station 02246500, Jacksonville. Minimum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1972	-28100	-51000	-41600	-55800	-37500	-24600	-4230	-16400	-15200	-62700	-40000	-24700	-62700	-33486	-4230	1972
1973	-26800	-35000	-25100	-31400	-29000	-23500	-20600	-10900	-12200	-30400	-41100	-52400	-52400	-28200	-10900	1973
1974	-49100	-41600	-31600	-24000	-22200	-39200	-15600	-6190	-48300	-37500	-42300	-32400	-49100	-32499	-6190	1974
1975	-35200	-61500	-31200	-26400	-16900	-5000	-647	-28800	-20600				-61500	-25139	-647	1975
1980									-29500		-15800	-472				1980
1981	-10200	-21400	-36600	-24900	-23100	-7260	-14700	-9570	-11700				-36600	-17714	-7260	1981
1987							-11400	-1640	-3740	-13900	-20500	-12600	-20500	-10630	-1640	1987
1988	-13300	-26000	-22400	-15800	-45400	-16700	-8820	-17700	-28600	-26800		-20400	-45400	-21993	-8820	1988
1989	-30500	-32000	-24200	-23000	-28100	-11300	-11600	-19200	-21600	-39500	-17600	-20100	-39500	-23225	-11300	1989
1990	1360	-23900	-21700	-28700	-21300	-8440	-24000	-9510	-9800	-10400	-7390	-12900	-28700	-14723	1360	1990
1991	-31100															1991
													-62700	-33486	-11300	ANN MIN
													-44044	-23068	-5514	ANN MEAN
													-20500	-10630	1360	ANN MAX
MO MIN	-49100	-61500	-41600	-55800	-45400	-39200	-24000	-28800	-48300	-62700	-42300	-52400	-62700	-45925	-24000	MO MIN
MO MEAN	-24771	-36550	-29300	-28750	-27938	-17000	-12400	-13323	-20124	-31600	-26384	-21997	-36550	-24178	-12400	MO MEAN
MO MAX	1360	-21400	-21700	-15800	-16900	-5000	-647	-1640	-3740	-10400	-7390	-472	-21700	-8644	1360	MO MAX

MEAN DAILY FLOW

Table E9. Station 02236000, De Land. Mean daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1934	2360	2003	2295	1857	2752	7004	9084	7326	4882	3302	2204	1678	1678	3896	9084	1934
1935	1212	1080	891	742	610	696	1281	2015	3558	6911	5701	3571	610	2356	6911	1935
1936	3334	3962	5534	4084	2054	2465	3608	2458	2380	2488	2754	2247	2054	3114	5534	1936
1937	1991	1631	1466	1786	1375	1097	919	1400	1532	4222	4934	5893	919	2354	5893	1937
1938	4453	3048	2009	941	600	1050	2710	2828	1188	1102	1579	1555	600	1922	4453	1938
1939	763	985	925	1107	1150	1399	2828	2999	3723	4629	3582	2927	763	2251	4629	1939
1940	1984	1530	1578	1919	719	1021	2209	3052	2966	3299	1812	1377	719	1956	3299	1940
1941	3266	4033	4490	4268	2613	1598	5504	8144	6031	5496	6456	5601	1598	4792	8144	1941
1942	4532	3043	4452	3951	2321	2372	3971	3145	2637	2362	1651	1335	1335	2981	4532	1942
1943	1119	943	1075	1048	931	1004	1877	4122	5422	7282	4681	2818	931	2694	7282	1943
1944	1809	1380	1081	1550	1292	1572	2421	4993	5100	5587	6855	4112	1081	3146	6855	1944
1945	2781	2070	1380	1137	1172	1333	5546	6935	8512	9530	5276	3272	1137	4079	9530	1945
1946	2950	2234	1621	1345	1068	1611	2542	5611	5385	4924	3070	2311	1068	2889	5611	1946
1947	1551	1698	2860	3598	2465	2333	5015	5666	5459	11522	9719	5896	1551	4815	11522	1947
1948	4048	4836	3532	2067	1606	1560	2039	3729	4500	12323	7856	4407	1560	4375	12323	1948
1949	3076	2013	1846	1703	1595	2114	3177	2828	6011	8835	6540	3950	1595	3641	8835	1949
1950	3717	1505	1171	1230	1160	962	504	1240	2110	4628	8632	4956	504	2651	8632	1950
1951	2445	2052	1273	1100	1252	1033	1506	2102	2696	6232	5040	4371	1033	2592	6232	1951
1952	2779	2117	2873	2396	1148	1114	908	1073	2150	4702	7688	4624	908	2798	7688	1952
1953	2491	2055	1931	3937	2306	1193	1390	3476	11177	15800	10675	8251	1193	5390	15800	1953
1954	6223	3270	1866	1342	1009	2582	3873	4083	2445	3819	4127	3839	1009	3207	6223	1954
1955	2375	2291	1695	1395	1400	1140	1932	1994	2798	3341	2997	1944	1140	2109	3341	1955
1956	1997	1993	785	890	700	1060	1180	1147	2163	4557	8911	5419	700	2567	8911	1956
1957	2716	1403	2111	2353	2484	2530	2405	2722	7108	6073	3944	2428	1403	3190	7108	1957
1958	2538	4013	5640	4967	2528	465	2378	1895	405	980	3318	1852	405	2582	5640	1958
1959	3301	2344	4587	7986	4996	3678	4738	4673	4654	6412	6120	5111	2344	4883	7986	1959
1960	3692	3587	6826	9811	4445	2623	6204	10276	12058	14906	9843	5189	2623	7455	14906	1960
1961	2659	2844	1850	1414	852	926	1249	1132	3050	2545	1101	1044	852	1722	3050	1961
1962	1042	594	542	614	62	229	926	1929	3651	4855	3555	2517	62	1710	4855	1962
1963	2105	3232	5224	2738	953	1020	1662	1541	1663	5229	4919	5450	953	2978	5450	1963
1964	5574	6441	4779	3079	1413	893	1955	2706	10670	8469	4429	3260	893	4472	10670	1964
1965	2193	1733	2739	1703	1257	1169	3116	3824	1877	3042	3359	2480	1169	2374	3824	1965
1966	2266	3412	6543	5100	2009	3908	6795	6604	5239	6208	4253	3086	2009	4619	6795	1966
1967	1854	1865	1633	830	513	1036	3556	5295	5010	3669	1600	985	513	2321	5295	1967
1968	909	962	1738	442	667	6603	11755	6707	3627	3678	6002	3861	442	3913	11755	1968
1969	2689	1976	2990	3348	1592	1853	1813	3349	4911	7015	8131	7252	1592	3910	8131	1969
1970	6750	6434	5230	3300	1667	1296	1635	2419	1681	1425	1631	880	880	2862	6750	1970
1971	1286	1916	782	888	407	617	1578	1786	693	1500	2030	2235	407	1310	2235	1971
1972	1478	2365	1700	2207	875	2110	2894	2536	3554	1792	1883	2887	875	2190	3554	1972
1973	2622	3826	2851	2188	1381	1146	2071	3486	4394	4347	4277	3116	1146	2975	4394	1973
1974	1936	868	670	701	202	875	6455	8041	6657	6760	3932	1758	202	3238	8041	1974
1975	921	622	577	599	847	1240	3037	3713	3536	3981	3650	2396	577	2093	3981	1975
1976	1816	1221	546	615	1213	3129	3959	4016	4836	4278	3216	2440	546	2607	4836	1976
1977	2774	2454	1577	1188	792	1419	1296	1813	2946	2272	1875	2678	792	1924	2946	1977
1978	3272	3850	5644	2772	1769	1952	3487	6429	5836	3907	2684	2324	1769	3661	6429	1978
1979	3968	4020	4157	1957	2438	2103	3139	3575	5730	8704	6392	3589	1957	4148	8704	1979
1980	2035	1945	2485	2060	1162	1164	800	644	870	480	251	234	234	1178	2485	1980
1981	1439	1124	1104	656	286	359	482	895	1643	446	1104	810	286	862	1643	1981
1982	1473	591	906	4285	2435	3995	7755	7273	6175	5861	4007	2644	591	3950	7755	1982
1983	1739	4571	6696	7697	5170	2665	2977	3085	2409	2533	3295	3473	1739	3859	7697	1983
1984	4503	4264	3203	3095	2649	1739	3389	3558	3697	3150	1844	2740	1739	3153	4503	1984
1985	2214	1817	859	1353	1003	2281	1425	2517	5746	6354	6191	4559	859	3027	6354	1985
1986	5112	4236	1775	1077	1136	1515	1988	1687	1742	1379	1945	1679	1077	2106	5112	1986
1987	2587	2167	2731	5519	2685	1674	1444	1327	1926	1741	3770	3357	1327	2577	5519	1987
1988	4176	3981	3666	3173	1910	1488	1639	2092	3372	2102	1909	2811	1488	2693	4176	1988
1989	2136	2978	1762	1313	1016	1070	1232	1456	1619	1782	3134	2261	1016	1813	3134	1989
1990	2440	1805	1487	1487	889	1259	1344	1351	864	1196	1824	2127	864	1506	2440	1990
1991	1425	1385	1766	2511	1287	3313	6546	6971	4617	4456	3750	2951	1287	3415	6971	1991
1992	2309	1090	1241	1583	1493	1523	2054	3453	5746				1090	2277	5746	1992
													62	862	1643	ANN MIN
													1080	3016	6477	ANN MEAN
													2623	7455	15800	ANN MAX
MO MIN	763	591	542	442	62	229	482	644	405	446	251	234	62	424	763	MO MIN
MO MEAN	2664	2470	2530	2407	1556	1800	3003	3545	4052	4746	4207	3213	1556	3016	4746	MO MEAN
MO MAX	6750	6441	6826	9811	5170	7004	11755	10276	12058	15800	10675	8251	5170	9235	15800	MO MAX

Table E10. Station 02243960, Rodman Dam. Mean daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1969	2097	1992	2183	2160	2167	875	966	2130	2524	3288	2982	2871	875	2186	3288	1969
1970	3746	5004	4400	4518	2807	2220	2165	2703	2375	1413	1280	1503	1280	2844	5004	1970
1971	1506	2594	1820	1615	1338	997	1239	1252	1179	1184	1050	1421	997	1433	2594	1971
1972	1271	1583	1425	2238	1283	1757	1944	2129	1582	1200	1324	1620	1200	1613	2238	1972
1973	1643	1856	1727	2349	1319	1418	1266	1792	2029	1133	929	1258	929	1560	2349	1973
1974	1034	964	1092	804	947	1338	3247	3080	2264	1239	1036	1075	804	1510	3247	1974
1975	1535	1106	599	766	709	789	1026	1186	1633	1347	1131	894	599	1060	1633	1975
1976	980	862	742	754	1395	1893	1590	947	1160	909	808	1154	742	1100	1893	1976
1977	1660	1512	1337	740	661	685	692	865	851	639	694	1059	639	950	1660	1977
1978	1411	1663	2556	1257	1061	1290	1387	3182	1582	1117	874	918	874	1525	3182	1978
1979	1303	1271	1281	1038	2126	1272	1076	1106	3651	2929	899	1547	899	1625	3651	1979
1980	2339	1725	1271	2141	1338	961	750	717	1069	1036	977	1021	717	1279	2339	1980
1981	744	589	644	501	391	425	402	635	984	600	702	479	391	591	984	1981
1982	423	531	742	2744	1093	3765	3093	2467	2483	2285	1132	1049	423	1817	3765	1982
1983	1160	2104	2959	3175	1905	1974	2282	1645	2335	1287	1183	1574	1160	1965	3175	1983
1984	3038	2226	2559	2600	1376	1173	1627	1738	1087	886	887	688	688	1657	3038	1984
1985	661	641	615	536	357	499	673	1369	1337	1050	1103	1397	357	853	1397	1985
1986	1749	1520	2118	778	388	829	797	912	956	492	647	826	388	1001	2118	1986
1987	919	1294	2354	3650	1553	940	893	731	738	699	889	722	699	1282	3650	1987
1988	965	1244	2439	1234	743	706	937	1087	2921	1360	1577	1831	706	1420	2921	1988
1989	1203	1164	1137	1084	563	774	1200	878	1085	805	769	924	563	966	1203	1989
1990	876	857	747	622	586	666	955	928	588	635	571	589	571	718	955	1990
1991	626	531	684	623	1023	1975	1602	1205	627				531	989	1975	1991
													357	591	955	ANN MIN
													741	1389	2533	ANN MEAN
													1280	2844	5004	ANN MAX
MO MIN	423	531	599	501	357	425	402	635	588	492	571	479	357	500	635	MO MIN
MO MEAN	1430	1514	1627	1649	1180	1270	1383	1508	1611	1252	1066	1201	1066	1391	1649	MO MEAN
MO MAX	3746	5004	4400	4518	2807	3765	3247	3182	3651	3288	2982	2871	2807	3622	5004	MO MAX

Table E11. Station 02244032, Buckman Lock. Mean daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1970	39	40	32	27	23	19	26	55	36	24	35	41	19	33	55	1970
1971	36	65	44	26	36	35	33	36	24	31	24	19	19	34	65	1971
1972	9	12	29	36	23	30	16	24	9	10	8	12	8	18	36	1972
1973	19	88	51	39	40	49	57	49	20	29	45	36	19	43	88	1973
1974	65	87	79	74	49	50	29	18	13	21	31	31	13	46	87	1974
1975	49	52	49	36	52	33	30	36	23	26	16	27	16	36	52	1975
1976	67	77	66	70	56	48	38	29	35	39	46	53	29	52	77	1976
1977	64	68	72	63	83	58	62	47	53	41	51	41	41	58	83	1977
1978	37	66	72	51	48	21	28	20	22	16	34	14	14	36	72	1978
1979	24	55	73	43	32	20	16	20	52	51	49	39	16	39	73	1979
1980	37	52	62	69	53	43	43	52	48	50	43	30	30	49	69	1980
1981	13	64	66	82	72	50	39	33	38	37	39	19	13	46	82	1981
1982	29	67	64	48	45	24	15	14	13	17	29	24	13	32	67	1982
1983	30	48	59	42	49	45	54	44	40	38	44	37	30	44	59	1983
1984	29	56	63	61	29	48	35	24	36	47	53	57	24	45	63	1984
1985	39	74	90	91	57	46	39	0	0	15	26	21	0	41	91	1985
1986	35	36	29	39	51	42	42	35	41	47	60	42	29	42	60	1986
1987	46	63	58	56	60	37	37	43	73	78	77	67	37	58	78	1987
1988	57	77	75	67	65	73	63	51	35	31	30	22	22	54	77	1988
1989	19	28	18	11	16	20	16	25	36	24	32	13	11	22	36	1989
1990	38	47	66	46	54	69	46	33	48	46	41	28	28	47	69	1990
1991	31	59	54	56	48	27	20	10	15	26	27	33	10	34	59	1991
1992	37	55	58	49	57	51	30	34	50							1992
													0	18	36	ANN MIN
													20	41	68	ANN MEAN
													41	58	91	ANN MIN
MO MIN	9	12	18	11	16	19	15	0	0	10	8	12	0	11	19	MO MIN
MO MEAN	37	58	58	51	48	41	36	32	33	34	38	32	32	41	58	MO MEAN
MO MAX	67	88	90	91	83	73	63	55	73	78	77	67	55	75	91	MO MAX

Table E12. Station 02244440, Dunns Creek. Mean daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1978	1076	850	480	-295	-267	89	631	1453	-600	-205	363	165	-600	312	1453	1978
1979	828	211	247			-807	471	482	1228	1229	279	208	-807	438	1229	1979
1980	335	446	179	264	-193	78		-129	-50	23	125	29	-193	101	446	1980
1981	528	660			473	224	275	-219	187	-213	365	-34	-219	225	660	1981
1982	434	-184	265	1444	265	885	798	640	125	645	389	230	-184	495	1444	1982
1983	2823	4431	2249	603	167	207	207	157	-161	552	-94	884	-161	1002	4431	1983
1984	1040	684	391	794	-19	48	160	74	683		343	253	-19	405	1040	1984
1985	124	-77	16	-151	-217	-418	-320				2098	775	-418	204	2098	1985
1986	1159	1167	705	133	42	526	866	465	791				42	651	1167	1986
													-807	101	446	ANN MIN
													-284	426	1552	ANN MEAN
													42	1002	4431	ANN MAX
MO MIN	124	-184	16	-295	-267	-807	-320	-219	-600	-213	-94	-34	-807	-241	124	MO MIN
MO MEAN	927	910	566	399	32	93	386	365	275	338	484	314	32	424	927	MO MEAN
MO MAX	2823	4431	2249	1444	473	885	866	1453	1228	1229	2098	884	473	1672	4431	MO MAX

Table E13. Summation of De Land, Rodman Dam, Buckman Lock, and Dunns Creek station data. Mean daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1969	4785	3968	5173	5508	3760	2728	2779	5479	7435	10302	11113	10123	2728	6096	11113	1969
1970	10535	11477	9662	7845	4498	3535	3827	5177	4092	2862	2945	2423	2423	5740	11477	1970
1971	2829	4575	2645	2529	1780	1648	2850	3075	1897	2716	3105	3675	1648	2777	4575	1971
1972	2758	3961	3154	4481	2182	3898	4854	4690	5145	3002	3215	4519	2182	3821	5145	1972
1973	4284	5770	4629	4576	2739	2613	3394	5327	6443	5508	5250	4411	2613	4579	6443	1973
1974	3036	1919	1841	1579	1199	2263	9731	11139	8933	8021	4999	2863	1199	4794	11139	1974
1975	2505	1779	1225	1401	1609	2062	4094	4935	5192	5354	4797	3316	1225	3189	5354	1975
1976	2863	2160	1354	1439	2664	5071	5586	4991	6032	5227	4069	3646	1354	3759	6032	1976
1977	4497	4034	2985	1991	1536	2161	2050	2725	3850	2952	2620	3778	1536	2932	4497	1977
1978	5796	6427	8753	3785	2611	3352	5534	11085	6841	4835	3955	3421	2611	5533	11085	1978
1979	6123	5557	5758	3038	4596	2589	4702	5183	10662	12913	7620	5382	2589	6177	12913	1979
1980	4746	4168	3996	4534	2361	2246	1593	1284	1937	1589	1396	1314	1284	2597	4746	1980
1981	2725	2437	1814	1239	1223	1057	1197	1345	2851	870	2210	1273	870	1687	2851	1981
1982	2359	1005	1977	8521	3838	8668	11661	10394	8795	8808	5558	3947	1005	6294	11661	1982
1983	5752	11154	11964	11517	7291	4891	5519	4929	4624	4410	4428	5967	4410	6870	11964	1983
1984	8611	7229	6215	6550	4035	3008	5211	5394	5503	4083	3128	3738	3008	5225	8611	1984
1985	3038	2456	1581	1829	1200	2408	1817	3886	7083	7419	9418	6751	1200	4074	9418	1985
1986	8054	6960	4628	2028	1617	2912	3693	3100	3530	1918	2652	2546	1617	3636	8054	1986
1987	3552	3524	5143	9225	4298	2650	2374	2102	2738	2519	4736	4147	2102	3917	9225	1987
1988	5199	5302	6180	4473	2719	2267	2638	3230	6329	3493	3516	4664	2267	4167	6329	1988
1989	3359	4171	2918	2408	1595	1864	2449	2359	2740	2612	3936	3197	1595	2801	4171	1989
1990	3354	2709	2300	2155	1529	1994	2346	2312	1500	1876	2437	2744	1500	2271	3354	1990
1991	2082	1976	2504	3190	2358	5315	8168	8186	5259	4482	3777	2984	1976	4190	8186	1991
1992	2346	1145	1299	1632	1550	1574	2084	3487	5796				1145	2324	5796	1992
													870	1687	2851	ANN MIN
													1920	4144	7672	ANN MEAN
													4410	6870	12913	ANN MAX
MO MIN	2082	1005	1225	1239	1199	1057	1197	1284	1500	870	1396	1273	870	1277	2082	MO MIN
MO MEAN	4383	4411	4154	4061	2699	3032	4173	4826	5217	4686	4386	3949	2699	4165	5217	MO MEAN
MO MAX	10535	11477	11964	11517	7291	8668	11661	11139	10662	12913	11113	10123	7291	10755	12913	MO MAX

Table E14. Station 02244450, Palatka. Mean daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1968	1920	2322	4114	603	1720	8035	14888	8954	15510	13349	12718	7030	603	7597	15510	1968
1969	4780	11086	10969	5590	7012	6481	4201	7102	10772	20115	19583	16222	4201	10326	20115	1969
1970	14459	18011	14022	12514	4605	5465	6376	6853	3616	3213	6212	3922	3213	8272	18011	1970
1971	5546	5979	3102	5179	2306	3264	5161	4227	1058	4562	6337	7678	1058	4533	7678	1971
1972	6347	7337	6337	6323	1636	7629	6666	4690	7757	4420	6897	8651	1636	6224	8651	1972
1973	8878	8605	7870	10133	4533	5308	8467	10200	12975	11010	11024	12021	4533	9252	12975	1973
1974	10114	5266	6767	5102	4293	6787	18488	19642	16449	9002	5487	4791	4293	9349	19642	1974
1975	4123	2698	2557	1650	556	1930	6191	5878	5701	5545	12333	4096	556	4438	12333	1975
1976	3622	2229					5149	4803	7559	3316	6478	3482	2229	4580	7559	1976
1977	3334	2990	1331	2232	-16	3067	795	2023	3604	1443	4873	5774	-16	2621	5774	1977
1978	7338	5684	9843	5827	3382	4255	6472	9240	6287	4448	4646	2838	2838	5855	9843	1978
1979	7433	5824	6276	2943	5364	-507	374	-2092	3833				-2092	3272	7433	1979
1980									1592	2104	1776					1980
1981	1475	1391	1163	810	-214	-1027	213	1497	4092	1034	2643	592	-1027	1139	4092	1981
1982	1720	1243	2083	5478	2252	4375	11240	13006	11676				1243	5897	13006	1982
													-2092	1139	4092	ANN MIN
													1662	5931	11616	ANN MEAN
													4533	10326	20115	ANN MAX
MO MIN	1475	1243	1163	603	-214	-1027	213	-2092	1058	1034	1776	592	-2092	485	1776	MO MIN
MO MEAN	5792	5762	5880	4953	2879	4236	6763	6859	7499	6428	7770	6425	2879	5937	7770	MO MEAN
MO MAX	14459	18011	14022	12514	7012	8035	18488	19642	16449	20115	19583	16222	7012	15379	20115	MO MAX

Table E15. Station 02246500, Jacksonville. Mean daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1971										20237	7075	-498				1971
1972	-136	1347	-2918	3603	242	10105	13228	7963	7990	1667	3555	9745	-2918	4699	13228	1972
1973	10392	10981	5855	8464	-10428	-8294	1868	6438	9347	11455	266	981	-10428	3944	11455	1973
1974	-4023	-1814	-4920	-1826	43	4523	22697	25515	13644	14483	5763	6333	-4920	6702	25515	1974
1975	1632	463	4760	11545	11896	19178	24351	18535	20943				463	12589	24351	1975
1980									10936		4080	8371				1980
1981	5142	14535	-1492	10399	12269	6434	3658	1755	-1208				-1492	5721	14535	1981
1987							6058	14790	10459	15785	6909	6821	6058	10137	15785	1987
1988	10716	7353	8401	6701	7986	9975	6595	6651	9563	7358		8340	6595	8149	10716	1988
1989	5487	3010	769	3845	3771	6678	9458	6927	9330	6382	8684	7865	769	6017	9458	1989
1990	9421	6991	4928	5461	1722	20247	10339	8510	4246	6792	6501	8320	1722	7790	20247	1990
1991	5770															1991
													-10428	3944	9458	ANN MIN
													-461	7305	16143	ANN MEAN
													6595	12589	25515	ANN MAX
MO MIN	-4023	-1814	-4920	-1826	-10428	-8294	1868	1755	-1208	1667	266	-498	-10428	-2288	1868	MO MIN
MO MEAN	4829	5358	1923	6024	3438	8606	10917	10787	9368	10566	5354	6253	1923	6952	10917	MO MEAN
MO MAX	10716	14535	8401	11545	12269	20247	24351	25515	20943	20237	8684	9745	8401	15599	25515	MO MAX

MAXIMUM DAILY FLOW

Table E16. Station 02236000, De Land. Maximum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1934	2360	2520	2880	2260	4290	10500	10600	7980	5460	4000	3190	2140	2140	4848	10600	1934
1935	2150	1630	1420	1180	860	1070	2000	2680	5380	7900	7400	4320	860	3166	7900	1935
1936	3880	5510	5950	4900	2880	3580	4070	3360	2800	3300	3190	2800	2800	3852	5950	1936
1937	2700	2290	2320	1980	1900	1410	1310	1940	2240	5550	5480	6290	1310	2951	6290	1937
1938	5320	3700	2480	1820	960	2640	3880	3800	1840	1880	2400	2340	960	2755	5320	1938
1939	960	1430	1590	1440	1680	2130	3250	3420	4480	5120	4280	3500	960	2773	5120	1939
1940	2340	2010	2070	2490	1420	2200	2740	3720	3710	3820	2700	2540	1420	2647	3820	1940
1941	4160	4300	5260	5020	3470	3360	7910	9020	6960	6860	6810	6100	3360	5769	9020	1941
1942	5210	3990	5370	4980	3110	2900	4580	4000	3180	2700	2180	1790	1790	3666	5370	1942
1943	1640	1170	1720	1330	1610	1580	3320	4930	7200	7800	6440	3500	1170	3520	7800	1943
1944	2310	1910	1650	1930	1540	2090	3770	5770	5620	8290	8240	4940	1540	4005	8290	1944
1945	3160	2580	1820	1610	1480	2840	7960	7800	14400	14200	6890	4140	1480	5740	14400	1945
1946	3400	2860	2050	1760	1400	1950	4550	6120	6230	5950	3990	2810	1400	3589	6230	1946
1947	2320	2510	4010	4000	3710	4260	5380	5920	5850	13400	12200	7220	2320	5898	13400	1947
1948	4710	5880	4280	3380	2140	1920	2870	4770	8700	13900	10400	5170	1920	5677	13900	1948
1949	4000	2680	2260	2120	1960	2570	4060	4480	7170	10000	8080	5900	1960	4607	10000	1949
1950	6130	1900	1760	2000	2270	1620	680	1870	3090	10600	10800	6510	680	4103	10800	1950
1951	3520	2750	1510	1200	1300	1200	1700	2360	4090	7500	5500	5190	1200	3152	7500	1951
1952	3770	3050	4020	3490	1430	1940	1200	2100	3500	7200	8560	5800	1200	3838	8560	1952
1953	3200	2390	3820	5480	4890	1490	1970	6540	13700	17100	14400	9250	1490	7019	17100	1953
1954	7530	4210	2220	1520	1100	3660	4400	5210	3070	4490	5360	5000	1100	3981	7530	1954
1955	2990	2550	2390	1600	1400	1140	2000	2100	4180	3690	3480	2650	1140	2514	4180	1955
1956	2520	2710	1870	890	700	1060	1180	1740	3490	9660	9910	7280	700	3584	9910	1956
1957	3840	2690	3150	3480	3080	3010	2970	4690	8410	6650	5320	3690	2690	4248	8410	1957
1958	4190	4530	6390	5780	4220	2110	3270	2700	2470	3160	4220	3180	2110	3852	6390	1958
1959	3880	3120	8380	9060	7170	5040	5170	5140	5940	7810	7380	6090	3120	6182	9060	1959
1960	4380	4720	13000	12900	6380	3290	10700	11700	15000	16000	12400	7150	3290	9802	16000	1960
1961	3660	4120	3920	2000	1250	1850	1550	2480	4730	4210	2500	1960	1250	2853	4730	1961
1962	1880	1670	2170	1770	1260	1150	2040	2730	5050	5660	4320	3630	1150	2778	5660	1962
1963	2600	4940	6000	3710	1960	2420	2320	2190	5170	6530	6100	6510	1960	4204	6530	1963
1964	6920	6920	5670	4940	2600	1850	2690	5260	13400	11100	6010	3960	1850	5943	13400	1964
1965	2920	4060	4380	2390	1720	2240	4300	4380	2920	4010	3810	3220	1720	3363	4380	1965
1966	3250	4170	7540	6160	3310	5570	7880	7340	7520	7660	5340	4620	3250	5863	7880	1966
1967	2580	3630	2950	1630	1300	3180	4510	6030	6010	5290	2500	2070	1300	3473	6030	1967
1968	1890	2520	2980	1350	1280	11800	12800	9720	4610	6340	6440	5290	1280	5585	12800	1968
1969	3390	2950	4690	4420	2750	2430	2510	4580	5240	7710	9050	7980	2430	4808	9050	1969
1970	7240	6990	5910	3670	2820	2060	2270	3530	3000	2350	3110	1560	1560	3709	7240	1970
1971	2660	3520	2220	2080	1720	1540	3070	3070	1850	3080	3260	3620	1540	2641	3620	1971
1972	2580	4060	2630	3770	1660	3410	3730	3820	4290	3020	3630	3760	1660	3363	4290	1972
1973	4400	4670	3910	3300	2060	1950	2880	4080	4920	4800	5190	3810	1950	3831	5190	1973
1974	3190	1710	2220	2310	1760	3880	7410	8680	8040	7590	5750	2990	1710	4628	8680	1974
1975	1780	1640	1380	1720	1650	2100	3720	4350	4030	4670	4340	3210	1380	2883	4670	1975
1976	2950	2500	1530	1820	2380	4200	4170	4710	5440	5390	4200	3370	1530	3555	5440	1976
1977	3540	2940	2090	1800	1870	2190	1890	2300	3800	3110	2870	3450	1800	2654	3800	1977
1978	3900	6030	6550	4420	2690	2640	5650	7210	6630	4960	3750	3120	2640	4796	7210	1978
1979	5310	4710	4950	3330	3480	3130	4250	4170	7890	9500	7760	5140	3130	5302	9500	1979
1980	3160	3110	3450	3110	2140	2280	2310	1820	2100	1840	2450	2990	1820	2563	3450	1980
1981	2850	2480	2140	1920	1360	1120	1820	2050	2550	2170	2700	2020	1120	2098	2850	1981
1982	2610	1690	2290	5890	4110	7640	8930	7550	6880	6370	5450	3840	1690	5271	8930	1982
1983	2840	6090	7650	8570	7640	3650	3730	3750	3550	4090	3840	4720	2840	5010	8570	1983
1984	5360	5180	4700	4810	3910	2480	4200	4010	4480	3950	2940	3550	2480	4131	5360	1984
1985	2870	3280	2040	2420	2280	3470	2180	4370	7490	7340	6670	5730	2040	4178	7490	1985
1986	7070	5930	3070	1780	2100	2810	2830	2140	4030	3230	2490	2880	1780	3363	7070	1986
1987	3660	3270	3760	7870	4030	2540	1900	1830	2550	2600	4900	5040	1830	3663	7870	1987
1988	5430	5340	4450	4090	2410	2360	2410	3320	4040	3090	2710	3310	2360	3580	5430	1988
1989	3880	4220	2710	2100	1870	1870	2350	2440	2810	2610	3980	3290	1870	2844	4220	1989
1990	3030	2510	2250	2160	1870	2130	2380	1830	1570	2030	2480	2730	1570	2248	3030	1990
1991	2090	2090	3150	3000	2660	4930	8200	8180	5840	7280	4470	4040	2090	4661	8200	1991
1992	3260	1900	1710	2560	2040	1960	2540	5920	6480				1710	3152	6480	1992
													680	2098	2850	ANN MIN
													1803	4073	7592	ANN MEAN
													3360	9802	17100	ANN MAX
MO MIN	960	1170	1380	890	700	1060	680	1740	1570	1840	2180	1560	680	1311	2180	MO MIN
MO MEAN	3582	3431	3605	3330	2479	2905	3948	4503	5374	6219	5418	4192	2479	4082	6219	MO MEAN
MO MAX	7530	6990	13000	12900	7640	11800	12800	11700	15000	17100	14400	9250	6990	11676	17100	MO MAX

Table E17. Station 02243960, Rodman Dam. Maximum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1969	2900	2320	4500	2580	2700	2020	1780	4400	3500	4320	3960	4750	1780	3311	4750	1969
1970	5400	9560	6750	8300	4250	4320	2950	4100	2950	1810	2030	2450	1810	4573	9560	1970
1971	1900	3190	2560	3210	1640	1460	1820	1790	1620	1780	1290	2100	1290	2030	3210	1971
1972	1650	2080	2410	2870	1500	2820	2810	2690	2350	1410	2020	3230	1410	2320	3230	1972
1973	2380	2730	2620	2660	2010	2590	2290	2580	2610	1750	1490	1650	1490	2280	2730	1973
1974	1750	1230	2070	1060	1230	3230	4510	4310	3430	1960	1100	1100	1060	2248	4510	1974
1975	2560	1450	1040	1390	835	1240	2010	1800	2900	2040	1370	1230	835	1655	2900	1975
1976	1370	1210	886	1100	2770	2470	2210	1240	1770	1150	955	2370	886	1625	2770	1976
1977	2700	2180	1640	1040	987	1300	966	1370	1630	955	1370	1400	955	1462	2700	1977
1978	2390	2560	4710	2130	1840	1900	2360	4590	2040	1620	1230	1280	1230	2388	4710	1978
1979	2420	2440	1770	1500	4020	1770	1500	2500	8530	5530	1660	2040	1500	2973	8530	1979
1980	4170	3200	2040	3340	2070	1280	1670	896	2250	1450	1900	1320	896	2132	4170	1980
1981	988	1640	1090	835	478	478	966	1090	1450	1030	1120	672	478	986	1640	1981
1982	551	966	1240	8610	1910	7020	4350	3680	4210	3390	1360	1510	551	3233	8610	1982
1983	1640	4230	3720	4560	2700	3700	4010	2210	3430	1620	1640	3170	1620	3053	4560	1983
1984	3970	4340	3710	5110	1690	1640	2460	3180	2580	1390	1640	966	966	2723	5110	1984
1985	821	966	966	966	357	1630	1380	2290	2860	1320	1140	2170	357	1406	2860	1985
1986	2810	1870	4290	1530	484	1470	1630	1640	1630	854	854	1260	484	1694	4290	1986
1987	1240	2320	7580	7480	2400	1240	1380	1300	1320	864	1750	1010	864	2490	7580	1987
1988	1820	2130	4200	2000	1190	1160	1700	1620	5200	2280	3460	2560	1160	2443	5200	1988
1989	1740	1440	2090	1360	727	1220	1850	1140	1850	1290	860	1150	727	1393	2090	1989
1990	1280	1150	1150	1430	716	718	1290	1280	714	1140	575	717	575	1013	1430	1990
1991	858	761	1860	1010	1980	4030	3110	1780	855				761	1805	4030	1991
													357	986	1430	ANN MIN
													1030	2228	4399	ANN MEAN
													1810	4573	9560	ANN MAX
MO MIN	551	761	886	835	357	478	966	896	714	854	575	672	357	712	966	MO MIN
MO MEAN	2144	2433	2821	2873	1760	2205	2217	2325	2682	1862	1581	1823	1581	2227	2873	MO MEAN
MO MAX	5400	9560	7580	8610	4250	7020	4510	4590	8530	5530	3960	4750	3960	6191	9560	MO MAX

Table E18. Station 02244032, Buckman Lock. Maximum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1970	134	111	100	98	79	74	89	111	134	85	100	111	74	102	134	1970
1971	99	112	110	104	89	119	111	104	113	110	76	61	61	101	119	1971
1972	55	46	120	98	125	94	52	78	50	40	48	64	40	73	125	1972
1973	67	171	110	107	94	124	129	142	68	79	99	128	67	110	171	1973
1974	116	149	122	140	116	100	82	59	60	84	87	121	59	103	149	1974
1975	127	97	121	110	153	98	112	106	106	96	60	125	60	109	153	1975
1976	154	127	112	109	116	121	87	68	138	85	114	118	68	112	154	1976
1977	145	188	131	131	171	118	120	110	146	153	138	93	93	137	188	1977
1978	104	188	137	114	199	71	116	94	131	58	150	56	56	118	199	1978
1979	71	179	132	117	154	74	106	83	132	109	126	107	71	116	179	1979
1980	76	126	113	159	135	114	104	123	147	117	96	86	76	116	159	1980
1981	71	152	186	131	134	124	115	87	111	97	93	79	71	115	186	1981
1982	121	152	156	127	141	100	57	47	58	83	116	68	47	102	156	1982
1983	179	108	162	105	144	156	134	116	143	120	102	117	102	132	179	1983
1984	84	138	126	161	116	133	118	80	118	94	154	115	80	120	161	1984
1985	95	120	139	141	119	109	108	0	0	59	65	65	0	85	141	1985
1986	73	73	66	102	125	153	121	110	132	132	112	111	66	109	153	1986
1987	123	129	131	122	124	108	93	146	154	157	152	133	93	131	157	1987
1988	171	158	163	166	154	182	150	129	138	82	160	46	46	142	182	1988
1989	68	110	85	31	56	46	45	88	99	81	81	74	31	72	110	1989
1990	91	144	144	99	147	181	126	134	150	133	96	86	86	128	181	1990
1991	76	135	183	144	171	76	64	64	74	116	87	77	64	106	183	1991
1992	107	112	129	133	202	162	104	114	182				104	138	202	1992
													0	72	110	ANN MIN
													66	112	162	ANN MEAN
													104	142	202	ANN MAX
MO MIN	55	46	66	31	56	46	45	0	0	40	48	46	0	40	66	MO MIN
MO MEAN	105	132	129	120	133	115	102	95	112	99	105	93	93	112	133	MO MEAN
MO MAX	179	188	186	166	202	182	150	146	182	157	160	133	133	169	202	MO MAX

Table E19. Station 02244440, Dunns Creek. Maximum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1978	2710	4360	3510	1120	1290	1230	2510	3650	647	1400	2100	1560	647	2174	4360	1978
1979	2590	1390	738			-658	998	3140	3690	3850	1490	1170	-658	1840	3850	1979
1980	1440	1140	962	845	445	1000		275	593	819	1370	814	275	882	1440	1980
1981	908	1300			1090	826	672	319	650	1250	1570	1120	319	971	1570	1981
1982	1290	848	1370	4090	1450	2700	2530	2170	1280	1920	1150	1240	848	1837	4090	1982
1983	6360	6650	5880	1790	917	1060	1150	797	1300	1940	1	1700	1	2462	6650	1983
1984	2600	2520	1990	2740	769	1130	848	1030	1010		1850	1100	769	1599	2740	1984
1985	1290	817	981	421	626	207	464				5410	2990	207	1467	5410	1985
1986	6400	3940	3740	2130	1920	2840	2370	2770	4440				1920	3394	6400	1986
													-658	882	1440	ANN MIN
													481	1847	4057	ANN MEAN
													1920	3394	6650	ANN MIN
MO MIN	908	817	738	421	445	-658	464	275	593	819	1	814	-658	470	908	MO MIN
MO MEAN	2843	2552	2396	1877	1063	1148	1443	1769	1701	1863	1868	1462	1063	1832	2843	MO MEAN
MO MAX	6400	6650	5880	4090	1920	2840	2530	3650	4440	3850	5410	2990	1920	4221	6650	MO MAX

Table E20. Summation of De Land, Rodman Dam, Buckman Lock, and Dunns Creek station data. Maximum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1969	6290	5270	9190	7000	5450	4450	4290	8980	8740	12030	13010	12730	4290	8119	13010	1969
1970	12774	16661	12760	12068	7149	6454	5309	7741	6084	4245	5240	4121	4121	8384	16661	1970
1971	4659	6822	4890	5394	3449	3119	5001	4964	3583	4970	4626	5781	3119	4772	6822	1971
1972	4285	6186	5160	6738	3285	6324	6592	6588	6690	4470	5698	7054	3285	5756	7054	1972
1973	6847	7571	6640	6067	4164	4664	5299	6802	7598	6629	6779	5588	4164	6221	7598	1973
1974	5056	3089	4412	3510	3106	7210	12002	13049	11530	9634	6937	4211	3089	6979	13049	1974
1975	4467	3187	2541	3220	2638	3438	5842	6256	7036	6806	5770	4565	2541	4647	7036	1975
1976	4474	3837	2528	3029	5266	6791	6467	6018	7348	6625	5269	5858	2528	5293	7348	1976
1977	6385	5308	3861	2971	3028	3608	2976	3780	5576	4218	4378	4943	2971	4253	6385	1977
1978	9104	13138	14907	7784	6019	5841	10636	15544	9448	8038	7230	6016	5841	9475	15544	1978
1979	10391	8719	7590	4947	7654	4316	6854	9893	20242	18989	11036	8457	4316	9924	20242	1979
1980	8846	7576	6565	7454	4790	4674	4084	3114	5090	4226	5816	5210	3114	5620	8846	1980
1981	4817	5572	3416	2886	3062	2548	3573	3546	4761	4547	5483	3891	2548	4009	5572	1981
1982	4572	3656	5056	18717	7611	17460	15867	13447	12428	11763	8076	6658	3656	10443	18717	1982
1983	11019	17078	17412	15025	11401	8566	9024	6873	8423	7770	5583	9707	5583	10657	17412	1983
1984	12014	12178	10526	12821	6485	5383	7626	8300	8188	5434	6584	5731	5383	8439	12821	1984
1985	5076	5183	4126	3948	3382	5416	4132	6660	10350	8719	13285	10955	3382	6769	13285	1985
1986	16353	11813	11166	5542	4629	7273	6951	6660	10232	4216	3456	4251	3456	7712	16353	1986
1987	5023	5719	11471	15472	6554	3888	3373	3276	4024	3621	6802	6183	3276	6284	15472	1987
1988	7421	7628	8813	6256	3754	3702	4260	5069	9378	5452	6330	5916	3702	6165	9378	1988
1989	5688	5770	4885	3491	2653	3136	4245	3668	4759	3981	4921	4514	2653	4309	5770	1989
1990	4401	3804	3544	3689	2733	3029	3796	3244	2434	3303	3151	3533	2434	3388	4401	1990
1991	3024	2986	5193	4154	4811	9036	11374	10024	6769	7396	4557	4117	2986	6120	11374	1991
1992	2197	2202	3279	3133	2862	5092	8304	8294	6022				2197	4598	8304	1992
													2197	3388	4401	ANN MIN
													3526	6597	11186	ANN MEAN
													5841	10657	20242	ANN MAX
MO MIN	2197	2202	2528	2886	2638	2548	2976	3114	2434	3303	3151	3533	2197	2793	3533	MO MIN
MO MEAN	6883	7123	7080	6888	4831	5642	6578	7158	7781	6830	6522	6087	4831	6617	7781	MO MEAN
MO MAX	16353	17078	17412	18717	11401	17460	15867	15544	20242	18989	13285	12730	11401	16257	20242	MO MAX

Table E21. Station 02244450, Palatka. Maximum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1968	13300	15900	17900	8660	6970	18200	21600	14800	27800	27000	22700	15300	6970	17511	27800	1968
1969	13100	16600	17400	12700	18400	14600	11900	15800	20300	29200	31300	26200	11900	18958	31300	1969
1970	22100	29600	26200	22800	14400	12100	12600	16200	12500	14300	18800	9740	9740	17612	29600	1970
1971	17000	19300	12100	15900	14300	7380	11000	13900	11300	15600	22500	20800	7380	15090	22500	1971
1972	16200	23300	14700	21700	10900	17300	14600	11800	20800	20200	21000	15400	10900	17325	23300	1972
1973	24200	21900	16700	18700	10300	12300	15200	18700	23700	28200	20100	20700	10300	19225	28200	1973
1974	16700	13600	17700	14900	15100	19900	23800	25200	27900	16800	15700	14100	13600	18450	27900	1974
1975	12100	11100	12000	13500	9260	10600	14200	13400	17400	18800	14500	12500	9260	13280	18800	1975
1976	11800	7800					6430	13400	17700	12700	14000	10600	6430	11804	17700	1976
1977	11100	7220	4600	7200	8700	6070	5380	5300	12400	6400	9530	11300	4600	7933	12400	1977
1978	13000	15600	16000	11400	9930	10500	12400	13600	11700	11100	12700	9920	9920	12321	16000	1978
1979	13700	15100	12900	11500	12100	11300	8450	3070	15000				3070	11458	15100	1979
1980									7430	11700	7180					1980
1981	7770	7200	5320	4750	5140	2660	1490	7560	6380	5150	5490	2340	1490	5104	7770	1981
1982	3890	4330	6680	13300	5030	10700	17300	17100	16300				3890	10514	17300	1982
													1490	5104	7770	ANN MIN
													7818	14042	21119	ANN MEAN
													13600	19225	31300	ANN MAX
MO MIN	3890	4330	4600	4750	5030	2660	1490	3070	6380	5150	5490	2340	1490	4098	6380	MO MIN
MO MEAN	13997	14896	13862	13616	10810	11816	12596	13559	16574	16704	16577	14075	10810	14090	16704	MO MEAN
MO MAX	24200	29600	26200	22800	18400	19900	23800	25200	27900	29200	31300	26200	18400	25392	31300	MO MAX

Table E22. Station 02246500, Jacksonville. Maximum daily flow, cfs (USGS data), and summaries of means and extremes

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YR MIN	YR MEAN	YR MAX	YEAR
1972	31800	51500	16400	38700	31300	64000	41000	23800	28500	30200	46300	30000	16400	36125	64000	1972
1973	46300	47000	39600	45200	16400	15500	24700	34000	26900	56300	43700	59100	15500	37892	59100	1973
1974	31800	29300	27700	20900	52500	39000	45800	52200	43600	52900	37100	45400	20900	39850	52900	1974
1975	39500	38500	42000	37900	40500	46900	46600	52400	56600				37900	44544	56600	1975
1980									45500		18300	21700				1980
1981	11000	53000	28000	42300	37600	18800	10600	13900	10700				10600	25100	53000	1981
1987							25700	28600	26200	36200	28400	23100	23100	28033	36200	1987
1988	33400	37400	29600	33100	39000	28300	24500	22200	40600	29000		28600	22200	31427	40600	1988
1989	30800	17900	16200	26500	22200	23300	29900	18600	35100	37500	42500	18800	16200	26608	42500	1989
1990	15000	42100	26600	24000	21400	40700	28600	17900	21500	30900	21900	20900	15000	25958	42100	1990
1991	21100															1991
													10600	25100	36200	ANN MIN
													19756	32838	49667	ANN MEAN
													37900	44544	64000	ANN MAX
MO MIN	11000	17900	16200	20900	16400	15500	10600	13900	10700	29000	18300	18800	10600	16600	29000	MO MIN
MO MEAN	28967	39588	28263	33575	32613	34563	30822	29289	33520	39000	34029	30950	28263	32931	39588	MO MEAN
MO MAX	46300	53000	42000	45200	52500	64000	46600	52400	56600	56300	46300	59100	42000	51692	64000	MO MAX

APPENDIX F: WATER QUALITY SURVEYS

Table F1. Water quality intensive surveys analysis, FDER

WQTS	Date Measured	Tributary/Facility	Comments	Parameters	Facilities
1:11	6/4/79	Cedar River Basin	Non-tidal	Metals	Industries
1:12	8/6/79	East Br. Cedar R.	Non-tidal	Metals	Adcom Wire, Buffalo Tank Div., Cleaner Hangers Co., Fla. Steel Corp., Fla. Wire & Cable Co., Lewis Business Forms, Mike & Frank trailer park (TP), Murray Hill Lumber Co., Paramount Poultry, Pat & Mikes Restaurant, Paxon Prof. Center, Reichhold Chemicals, SCL RR Warrington, SCL RR West End, Simmons Co., Tire City
1:14	10/22/79	Rowell Creek	Non-tidal	Flow	NAS, Cecil Field stormwater treatment plant (STP)
1:16	10/8, 10/29/79	McGirts Creek	Non-tidal		
1:17	10/22/79	Baldwin STP	Non-tidal	Flow	Baldwin STP
1:19	11/13/79	Cedar River	Tidal	Height, velocity	
1:21	2/4/80	Baldwin STP	Non-tidal	Flow	Baldwin STP, part of stormwater
1:22	11/13/79	Ortega River	Tidal	Height, flow	
1:28	3/24, 4/21/80	Ribault River	Non-tidal	Flow	
1:56	10/12–13/81	Newcastle Creek	Tidal	Flow, travel time	Lucina Utilities STP
1:70	11/1/82	Wills Bridge	Non-tidal	Flow	Herlong Ortega Utilities, Lamplighter mobile home park (MHP), Normandy Village STP
	12/7/82	Wills Bridge	Non-tidal	Flow, travel time	Normandy Estates MHP
	1/26/83	Wills Bridge	Non-tidal	Flow, travel time	
1:71	1/19/82	McGirts Creek	Non-tidal	1st prelim. survey	Blair Road Apt., Coleman-Evans, Cole MHP, Colony MHP, Holiday MHP, Jax Youth Dev. Center, JCP-Oak Hill Park, Lake Forest MHP, Napoli MHP, Normandy Pines TP, Owen Steel Co., Paradise Village MHP, Park West MHP, Pine Breeze MHP, Sch. #51 Whitehouse Elem., Scott's MHP, Springtree Village S/D, Tylor's MHP, Town and Country MHP, West Meadows MHP, Westside Coin Laundry
	1/27–28/82	McGirts Creek	Non-tidal	2nd prelim. survey	
	2/8/82	McGirts Creek	Non-tidal	3rd prelim. survey	
	2/16–17/82	McGirts Creek	Non-tidal	4th prelim. survey	
	2/23–24/82	McGirts Creek	Non-tidal	Intensive survey	
	10/4–5/82	McGirts Creek	Non-tidal	Intensive survey	
	11/2–3/82	McGirts Creek	Non-tidal	Intensive survey	
1:73	11/16/82	Rowell Creek	Non-tidal	Dye study	NAS, Cecil Field
1:75	1/12/83	East Br. Cedar R.	Non-tidal	Prelim., dye, flow	Industrial
	2/10/83	East Br. Cedar R.	Non-tidal	Prelim., travel time, flow	
	2/23/83	East Br. Cedar R.	Non-tidal	Intensive survey	
1:76	3/14/83	Fishing Creek	Non-tidal	Prelim., travel time	Continuous: Jax Heights, Wesconnett Elem., Wil-Mar Apt., Thunderbird MHP Other: Big George's Tavern, Wares MHPs #1 & #2, Riecker MHP, Lynwood Shopping Center
	5/24/83	Fishing Creek	Non-tidal	Prelim., flow	
	6/28–29/83	Fishing Creek	Non-tidal	Intensive, time of travel, flow	
1:79	2/24/83	Upper Cedar River	Non-tidal	1st prelim.	Continuous: Ford Motor, Four Seasons MHP, Heckler Corp., JC Penney, JEA Westside, Kelly's TP, Thomas Jefferson Elem., U.S. post office Other: Kimwood warehouse, Montgomery warehouse, United Parcel Service
	3/9, 3/10/83	Upper Cedar River	Non-tidal	2nd prelim., travel time	
	4/6–7/83	Upper Cedar River	Non-tidal	Intensive, travel time	
1:82	4/6/83	Lower Cedar River	Non-tidal	1st prelim.	Continuous: Cedar Shores Apt., Colonial MHP, Crest Pontiac, Cross Creek Apt., Denny Moran's Restaurant, Duval Motors, JCP #33, Malibu Garden Apt., River City Chrysler, River Oyster Bar, Westside Dodge, Sch. #77 Hyde Park Elementary, Sch. #79 Ramona Blvd. Elementary, Tara Manor Apt., U-Haul International
	4/27–28/83	Lower Cedar River	Non-tidal	2nd prelim., travel time	
	5/25–26/83	Lower Cedar River	Non-tidal	Intensive, travel time	
1:83	9/12/83	Little Pottsburg	Non-tidal	Prelim.	Arbys, Atlantic Oaks Apt., Aunt Polly's Laundromat, Beach Bvld. S/C, Cajeco, Clearview Townhouses, Colonial Point Apt., Empress Garden Apt., Famous Amos, Harold House Apt., Jax Liquors, M. Poole & Assoc.
	10/10–11/83	Little Pottsburg	Non-tidal	2nd prelim.	
	10/12–18/83	Little Pottsburg	Non-tidal	Intensive	
1:88	11/28/84	L. Pottsburg Creek	Tidal	Tide, flow	Pottsburg Utilities, Sassy's Disco, Solar Office, Suntree MHP, Uncle John's Pancake House, Weight Watchers
	12/5/84	L. Pottsburg Creek	Tidal	Tide, flow	
1:93	12/11/85	Ribault River	Non-tidal		Biltmore Elem., Harborview S/D STP, Ideal TP, Jax-American Truck Plaza, Manna Provisions, Monterey Motel, Pickett Elem., Produce Terminal, Reynolds Lane Elem., Ricky Villa Apt., ZXT Inc.
	4/14/86	Ribault River	Tidal	Tide, flow	Burger King #1, Famous Amos #3, Deluxe Strip Stores, Don & Son Meat Market, Red Carpet Cleaners

Table F1—*Continued*

WQTS	Date Measured	Tributary/Facility	Comments	Parameters	Facilities
1:95	3/18/87	Baldwin WRP	Non-tidal	Flow, travel time, velocity	Baldwin water reclamation plant (WRP)
1:97	5/29/95	Strawberry Creek	Tidal	Flow, tide	Mill Creek Manor Apt., Steve Hyll Chevrolet, Kings Inn, Oaks Apt., Rivermont Apt.
1:101	2/24/87 4/87 12/7/87	Trout River	Tidal	Flow, tide Flow, tide Flow, tide	River Park Apt., Days Inn, Milligan Center, K-Mart, Victory Baptist, Northtown Square, Trout River MHP, Briarwood MHP, Shady Oaks MHP, Oak Crest MHP, Dinsmore Elementary

Note: WQTS = Water Quality Technical Series (volume no.:sequence no.)

Table F2. Reports on FDEP wasteload allocation studies and water quality based effluent limitations, the LSJR

WQTS	Year	County	Tributary/Facility	Model	Comments
2:18	1979	Duval	Fishing Creek	RIV1	Calibration, verification
2:19	1979	Duval	Wills Branch	RIV1	Calibration, design conditions
2:20	1979	Duval	Cedar	RIV1	Calibration, design conditions
2:33	1980	Duval	McGirts Creek	RIV1	Calibration, verification, design
2:34	1980	Duval	Cedar Creek (tidal)	DYNRIV	Calibration, design
2:35	1980	Duval	Ortega River (tidal)	DYNRIV	Calibration, verification, design
2:36	1980	Duval	Baldwin 201	RIVER	Calibration, verification, design
2:76	1984	Duval	Wills Branch	BRIV2	Calibration, design
2:78	1984	Duval	McGirts Creek	RIV2	Calibration, verification, design
2:81	1984	Duval	NAS, Cecil Field	SIMRIV	Calibration, design
2:83	1984	Duval	Fishing Creek	SIMRIV	Calibration, design
2:86	1984	Putnam	City of Palatka STP	RIV/River	Design
2:99	1986	Duval	Ortega River (tidal)	TIDAL PRISM	Calibration, design
2:105	1991	Duval	Silversmith Creek (Famous Amos rest.)	SIMRIV	Calibration, design
2:110	1989	Duval	Little Pottsburg Creek (tidal portion)	DYNRIV	Calibration, verification, design
			Little Pottsburg Creek (non-tidal portion)	SIMRIV	Calibration, verification, design
2:119	1990	Duval	Rowell Creek (NAS, Cecil Field)	SIMRIV	Calibration, verification, design
2:124	1992	Clay	Ridaught Landing WWTP	CORMIX2	
2:128	1994	St. Johns	Hastings STP	CORMIX1	

Note: FDEP = Florida Department of Environmental Protection (formerly Florida Department of Environmental Regulation)
WQTS = Water Quality Technical Series (volume no.:sequence no.)
STP = stormwater treatment plant
WWTP = wastewater treatment plant

APPENDIX G: MODEL GEOMETRY

Table G1. Channel (link) geometry used in the Edge (Clemson) and/or WRE (Stanley Consultants) models

Channel Number	Length (ft)	Width (ft)	Cross-Sectional Area (ft^2)	Mannings *n*	Junctions at Ends		Model
1	19500	5950	77918	0.047	23	24	Both
2	20840	5740	74178	0.047	22	23	Both
3	34100	9380	123576	0.047	21	22	Both
4	52800	11700	177776	0.047	20	21	Both
5	28700	11070	179602	0.047	19	20	Both
6	40500	12600	203743	0.047	18	19	Both
7	17670	4000	60909	0.047	16	17	Both
8	37200	13100	237179	0.047	15	17	Both
9	11900	4510	102570	0.022	12	13	Both
10	10500	2230	69858	0.022	11	12	Both
11	18640	3850	106420	0.022	10	11	Both
12	9770	3550	69501	0.022	9	10	Both
13	7260	2700	35118	0.025	9	26	Both
14	14060	2250	56187	0.018	8	9	Both
15	8350	1936	15453	0.018	7	9	Both
16	6470	1224	10922	0.018	7	8	Both
17	10090	1732	12009	0.025	8	28	Both
18	4390	2540	17660	0.025	8	29	Both
19	14660	2110	61023	0.018	5	8	Both
20	21900	5300	37151	0.018	6	7	Both
21	7040	927	7288	0.018	4	6	Both
22	7200	1740	46768	0.018	4	5	Both
23	15250	1464	34927	0.018	5	30	Both
24	8220	1516	39164	0.018	30	31	Both
25	4390	1634	47106	0.018	3	31	Both
26	4110	1148	34230	0.018	3	4	Both
27	7890	435	16620	0.018	3	32	Both
28	16440	2400	74531	0.018	2	3	Both
29	5540	963	12273	0.018	2	33	Both
30	12480	1992	63078	0.018	1	2	Both
31	5980	800	5432	0.025	30	34	Both
32	12500	900	11504	0.025	31	35	Both
33	6800	700	6823	0.025	31	36	Both
34	8300	800	10182	0.025	2	37	Both
35	9800	2000	10268	0.025	26	27	Both
36	15600	1400	12611	0.025	27	38	Both
37	5600	600	6005	0.025	27	39	Both
38	12400	300	2403	0.025	39	40	SC/W
39	9600	100	601	0.025	40	41	SC/W
40	5600	50	257	0.025	12	42	SC/W
41	4000	120	610	0.025	42	43	SC/W
42	6400	15	61	0.025	43	44	SC/W
43	5400	9000	92065	0.047	13	14	SC/W
44	8800	4200	72438	0.047	13	25	SC/W
45	8600	8600	86134	0.047	14	25	SC/W
46	12200	10600	193245	0.047	15	25	SC/W
47	6600	6400	58864	0.025	14	45	SC/W
48	4598	2000	26337	0.025	45	46	SC/W

Table G1—*Continued*

Channel Number	Length (ft)	Width (ft)	Cross-Sectional Area (ft^2)	Mannings *n*	Junctions at Ends		Model
49	4002	2000	16358	0.025	46	47	SC/W
50	3802	1500	12254	0.025	47	48	SC/W
51	4699	2000	14740	0.025	48	49	SC/W
52	5797	1000	5121	0.025	49	50	SC/W
53	14196	800	3296	0.025	50	51	SC/W
54	5143	120	675	0.025	51	52	SC/W
55	4599	50	209	0.025	52	53	SC/W
56	5988	200	1434	0.025	47	54	SC/W
57	5100	600	4902	0.025	47	55	SC/W
58	4499	500	5585	0.025	55	56	SC/W
59	8801	150	1443	0.025	56	57	SC/W
60	13600	9600	165512	0.047	17	58	SC/W
61	19000	12000	183048	0.047	18	58	SC/W
62	6600	12000	159266	0.025	58	59	SC/W
63	6800	3000	27817	0.025	59	60	SC/W
64	9600	2000	16545	0.025	60	61	SC/W
65	17800	300	1882	0.025	61	62	SC/W
66	13800	200	1155	0.025	61	63	SC/W

Edge/Clemson model: 36 junctions, 38 channels
Stanley Consultants/WRE (SC/W) model: 66 junctions, 63 channels

Source: WRE 1979, 67–71, Tables 3.1 and 3.2

Table G2. Junction (nodal) geometry used in the Edge (Clemson) and/or WRE (Stanley Consultants) models

Junction Number	Channels Entering the Junction					Model
	1	2	3	4	5	
1	30	0	0	0	0	Both
2	28	29	34	30	0	Both
3	25	26	27	28	0	Both
4	21	22	26	0	0	Both
5	19	23	22	0	0	Both
6	20	21	0	0	0	Both
7	15	16	20	0	0	Both
8	14	18	17	16	19	Both
9	12	13	14	15	0	Both
10	11	12	0	0	0	Both
11	10	11	0	0	0	Both
12	9	10	40	0	0	Both
13	9	43	44	0	0	Both
14	43	45	47	0	0	Both
15	8	46	0	0	0	Both
16	7	0	0	0	0	Both
17	8	7	60	0	0	Both
18	6	61	0	0	0	Both
19	5	6	0	0	0	Both
20	4	5	0	0	0	Both
21	3	4	0	0	0	Both
22	2	3	0	0	0	Both
23	1	2	0	0	0	Both
24	1	0	0	0	0	Both
25	44	45	46	0	0	Both
26	13	35	0	0	0	Both
27	35	36	37	0	0	Both
28	17	0	0	0	0	Both
29	18	0	0	0	0	Both
30	24	31	23	0	0	Both
31	33	24	25	0	0	E/C
31	32	33	24	25	0	SC/W
32	27	0	0	0	0	Both
33	29	0	0	0	0	Both
34	31	0	0	0	0	Both
35	32	0	0	0	0	SC/W
36	33	0	0	0	0	Both
37	34	0	0	0	0	Both
38	36	0	0	0	0	SC/W
39	37	38	0	0	0	SC/W
40	38	39	0	0	0	SC/W
41	39	0	0	0	0	SC/W
42	40	41	0	0	0	SC/W
43	41	42	0	0	0	SC/W
44	42	0	0	0	0	SC/W
45	47	48	0	0	0	SC/W
46	48	49	0	0	0	SC/W
47	49	50	56	57	0	SC/W

Table G2—*Continued*

Junction Number	Channels Entering the Junction 1	2	3	4	5	Model
48	50	51	0	0	0	SC/W
49	51	52	0	0	0	SC/W
50	52	53	0	0	0	SC/W
51	53	54	0	0	0	SC/W
52	54	55	0	0	0	SC/W
53	55	0	0	0	0	SC/W
54	56	0	0	0	0	SC/W
55	57	58	0	0	0	SC/W
56	58	59	0	0	0	SC/W
57	59	0	0	0	0	SC/W
58	60	61	62	0	0	SC/W
59	62	63	0	0	0	SC/W
60	63	64	0	0	0	SC/W
61	64	65	66	0	0	SC/W
62	65	0	0	0	0	SC/W
63	66	0	0	0	0	SC/W

Note: E/C = Edge/Clemson model
SC/W = Stanley Consultants/WRE model

Source: WRE 1979, 67–71