Simulation of groundwater-management scenarios in the Mullica and Great Egg Harbor River basins, New Jersey

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U.S. Department of the Interior
U.S. Geological Survey

Topics

- Description of Study and study area
- Overview of model
- Overview of scenarios
  - Approach
  - Base-flow depletion criteria
- Scenario results
  - Basic scenarios
  - Adjusted scenarios

Study by USGS in cooperation with the New Jersey Department of Environmental Protection

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Groundwater issues

Two major aquifers with different issues

- **Confined Atlantic City 800-Foot sand**

  Large cones of depression. Saltwater intrusion in Cape May

- **Unconfined Kirkwood-Cohansey aquifer**

  Base-flow depletion

Need to understand how to best use the two aquifers together and how they interact

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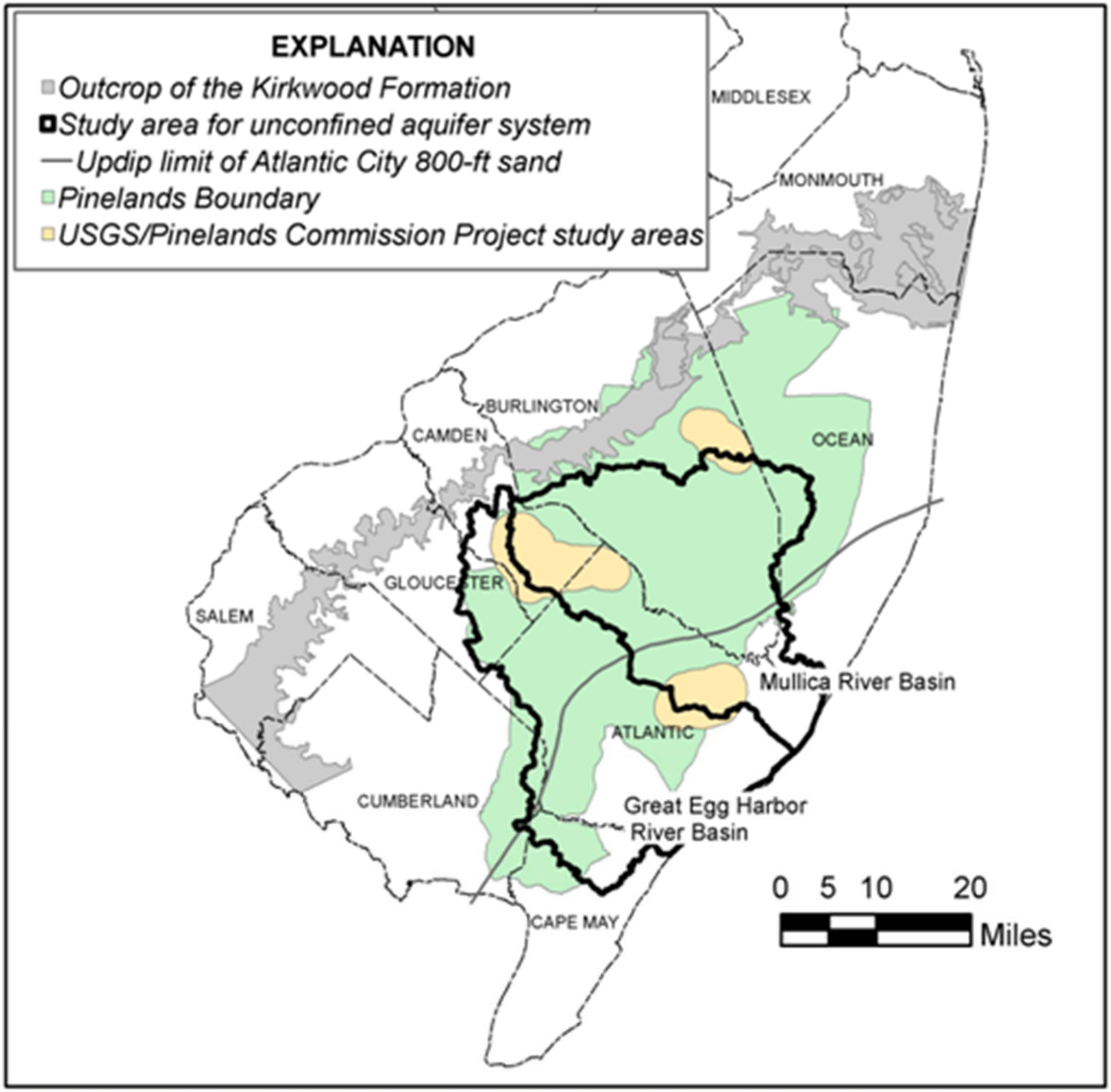
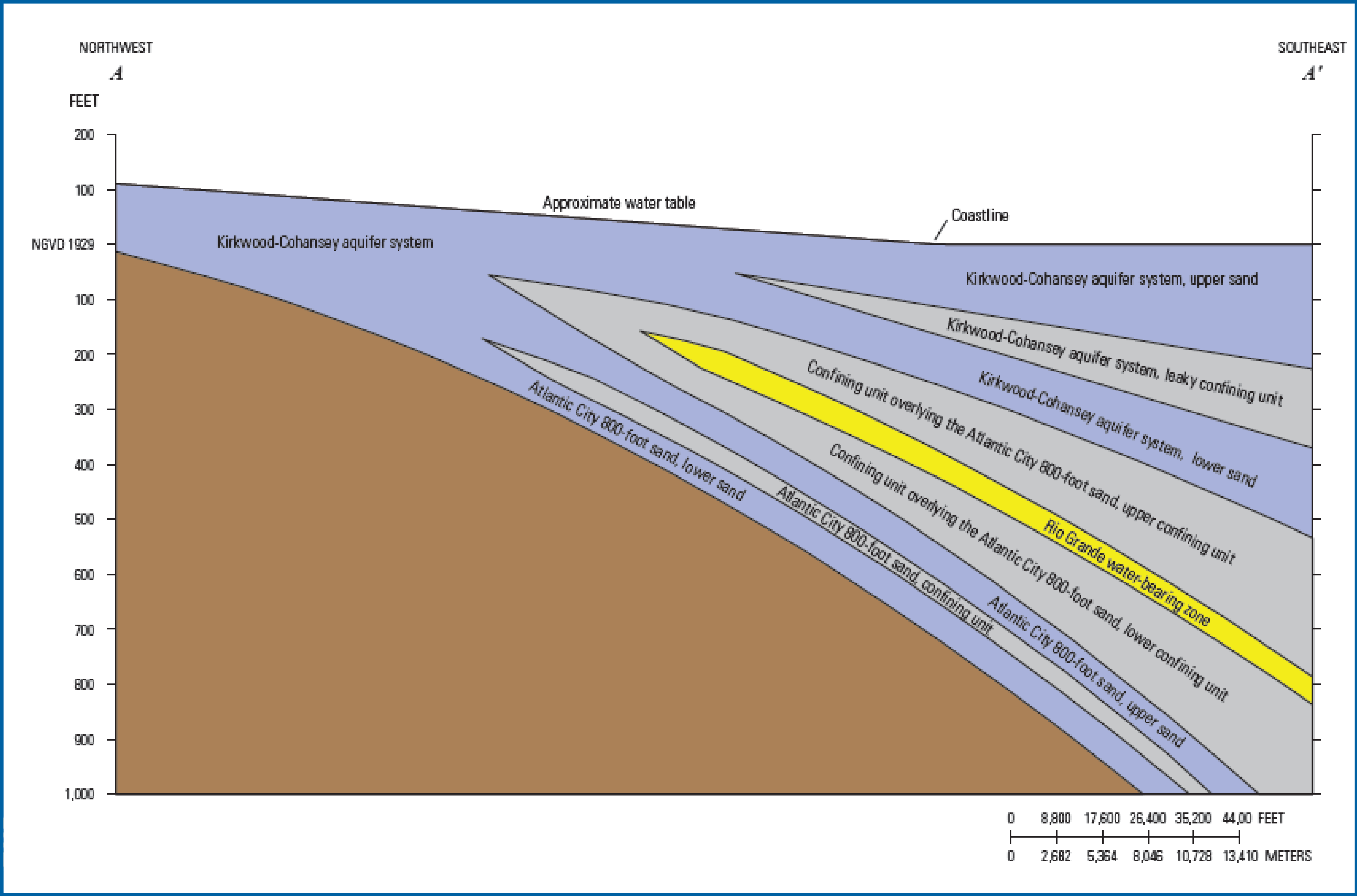
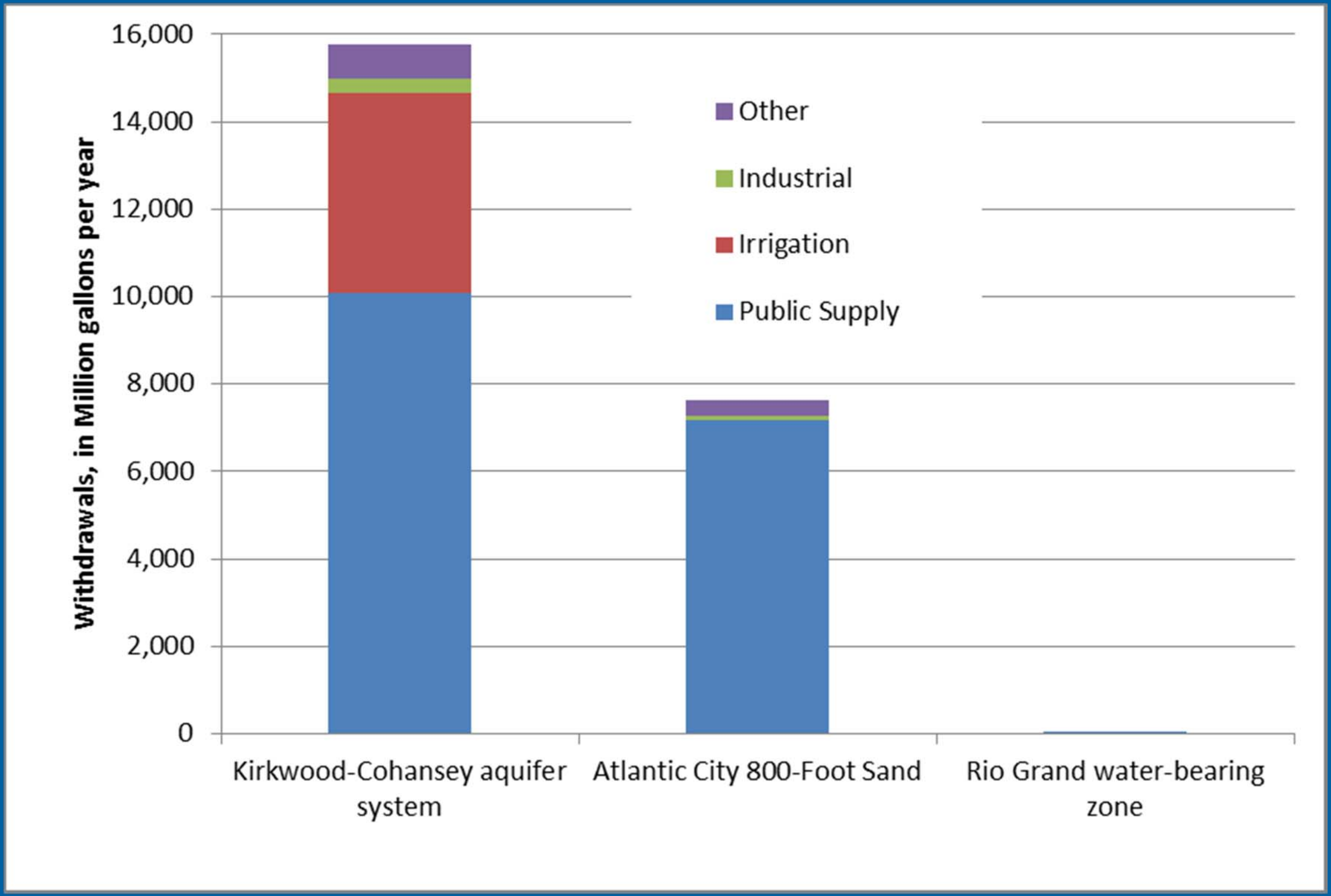

EXPLANATION
Outcrop of the Kirkwood Formation
Study area for unconfined aquifer system
Updip limit of Atlantic City 800-ft sand
Pinelands Boundary
USGS/Pinelands Commission Project study areas
MIDDLESEX
MONMOUTH
BURLINGTON
CAMDEN
OCEAN
GLOUCESTER
SALEM
Mullica River Basin
ATLANTIC
CUMBERLAND
Great Egg Harbor
River Basin
CAPE MAY
0 5 10 20
Miles

Hydrogeologic Section



Withdrawals by aquifer and use type



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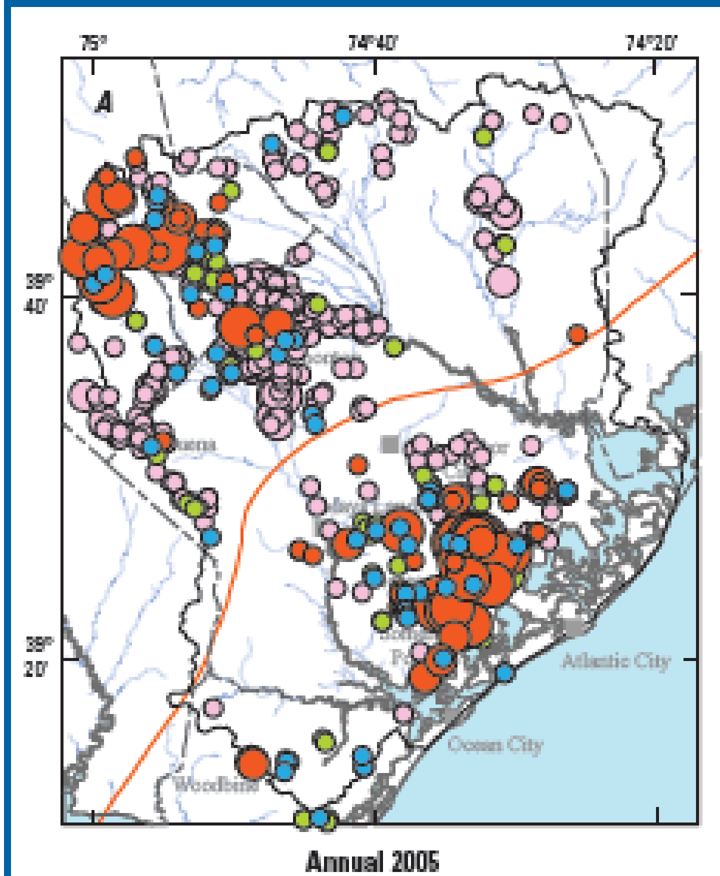
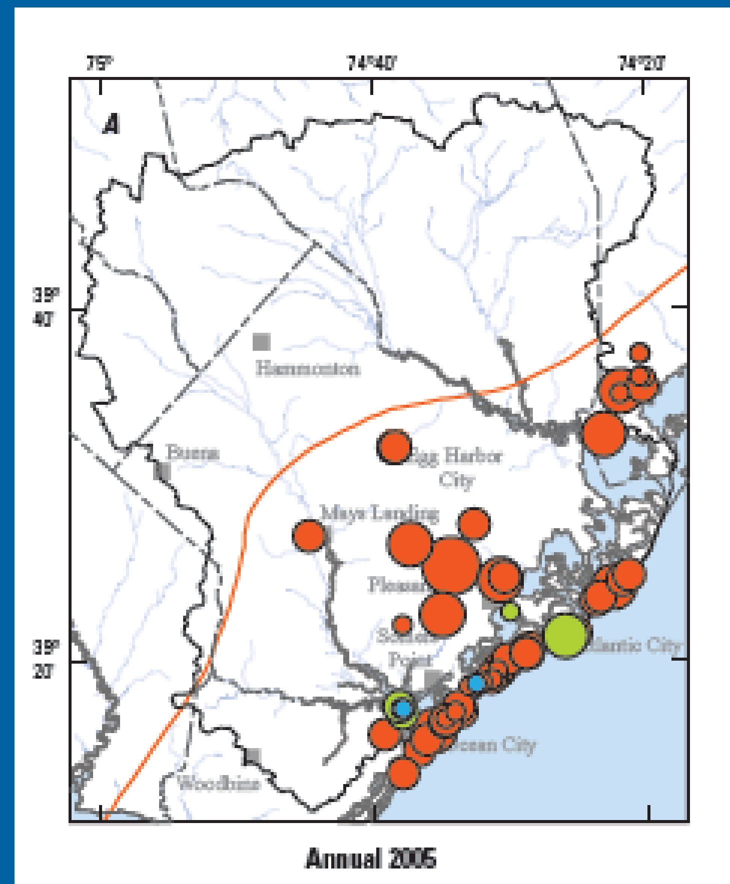
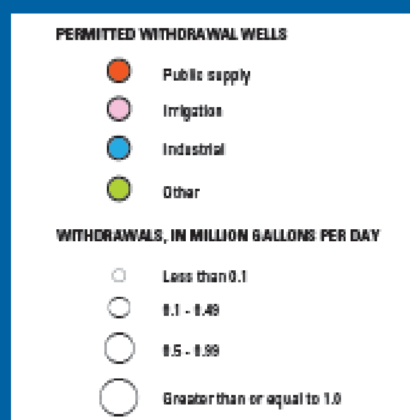
Water Use

Kirkwood Cohansey

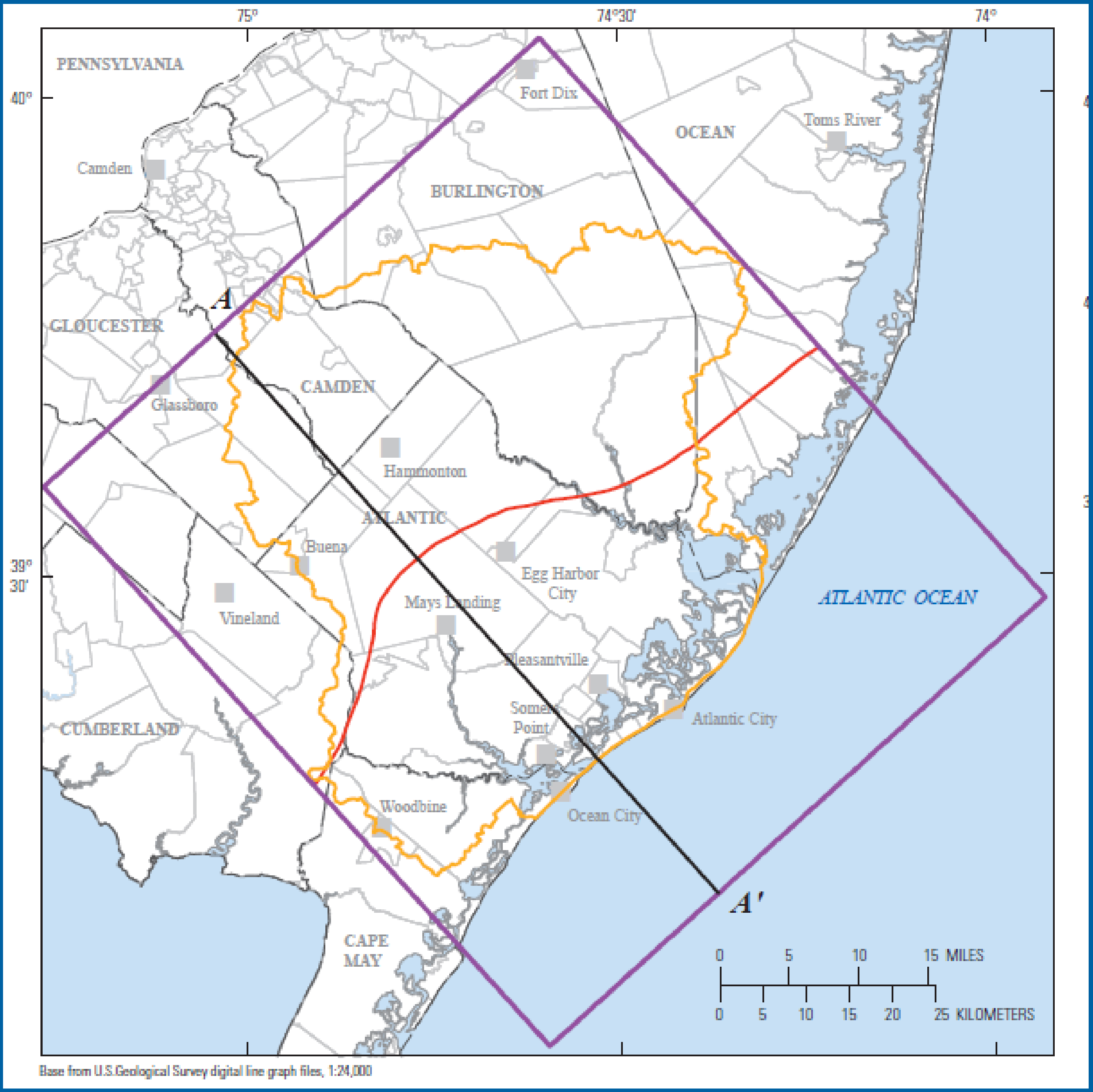


Atlantic City 800-Foot sand





Study Area



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Model Calibration

- Calibrated to water levels and base flow
- Synoptic water levels from Spring 2005 and Fall 2006
- Water levels from 14 long term monitoring wells
- Base flow from 1998-2006 at 6 gaging stations and 16 low-flow partial record stations

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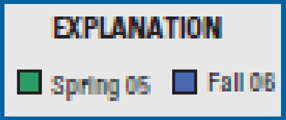
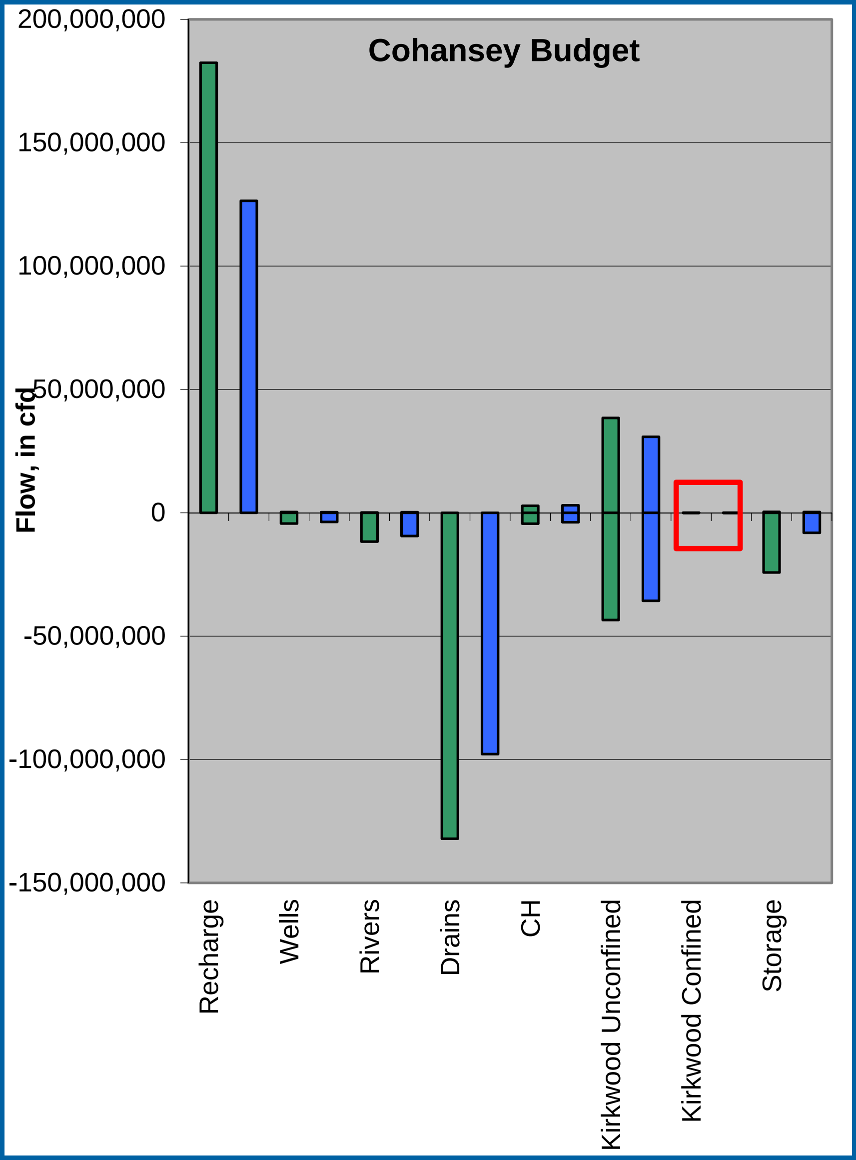
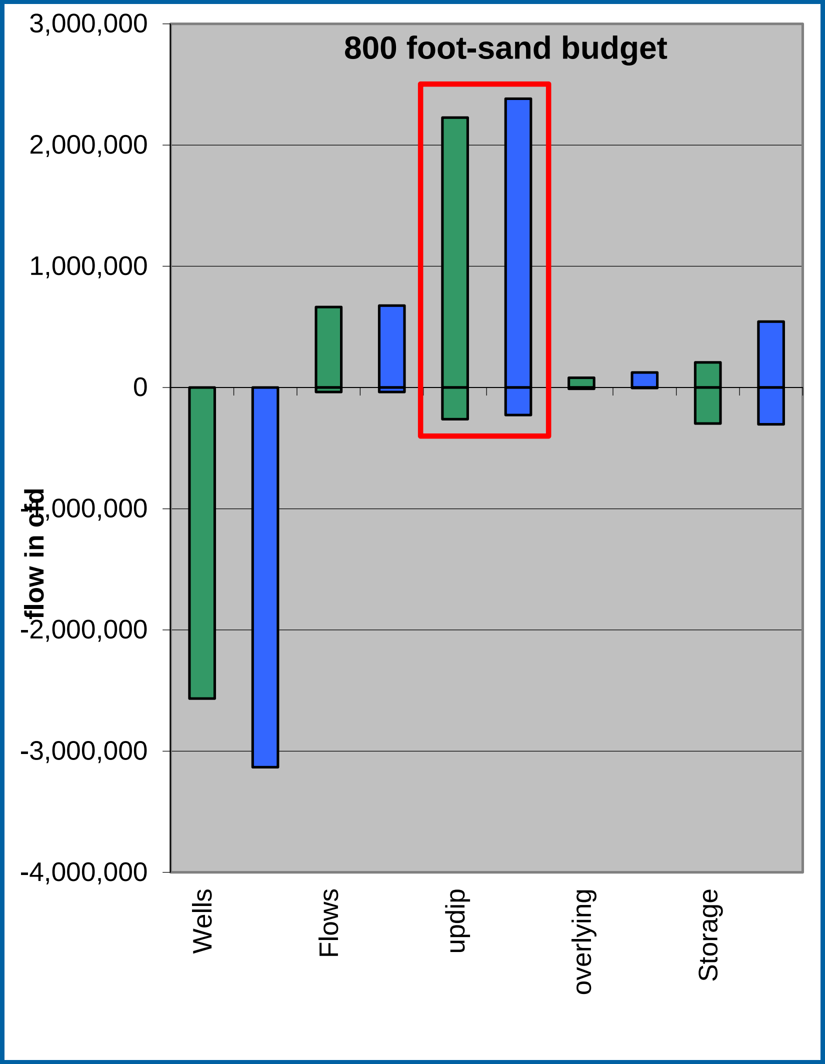
Simulated flow budgets







Scenarios

- Unstressed (no withdrawals)
- Basic Scenarios
  - Average 1998-2006 withdrawals
  - Full-allocation (FA) withdrawals
  - Year 2050 Demand withdrawals
- Withdrawals adjusted to eliminate deficits
  - Adjusted Average 1998-2006
  - Adjusted Full Allocation
  - Adjusted Year 2050 Demand

Used 3 Tier approach for adjusted scenarios

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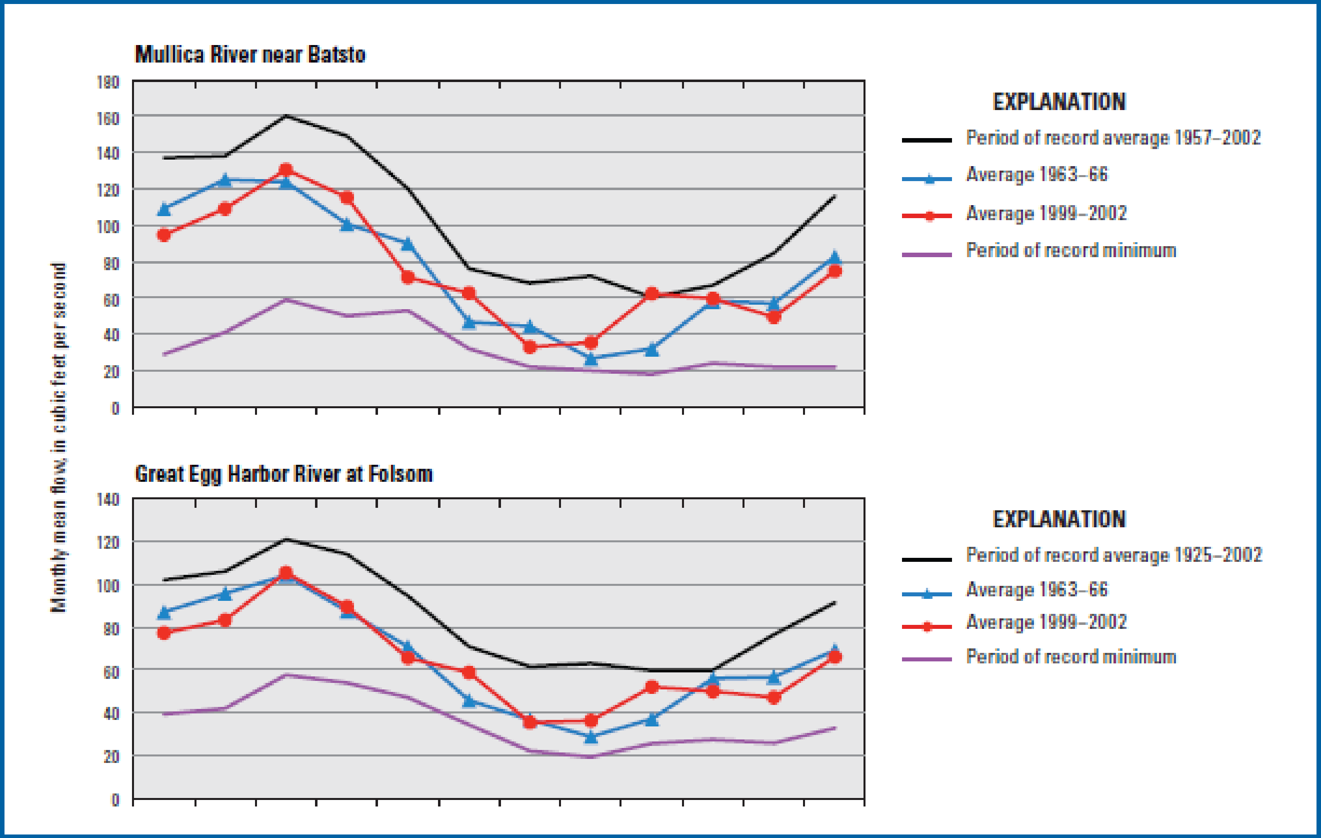
Approach to simulating scenarios

- **Simulated period from 1998-2006 which includes a dry period from 1999-2002 (comparable flows to 60's drought) and a wetter period from 2003-2006**



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Approach to simulating scenarios

- Scenarios will be simulated using the recharge conditions during the period 1998-2006
- Present results as ‘Scenario Years’ instead of dates to avoid confusion
- Scenario with no withdrawals is used as baseline
- Analyzed base-flow depletion at HUC 11 scale

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Year 2050 Demand Estimates

- Public Supply: based on 2050 Metropolitan Planning Organization population projection data
- Commercial/Industrial: 1.4 percent annual increase
- Registrations: 1.8 percent annual increase
- Agricultural: Same as Average Annual. Assumes increased irrigation balances decrease in available land

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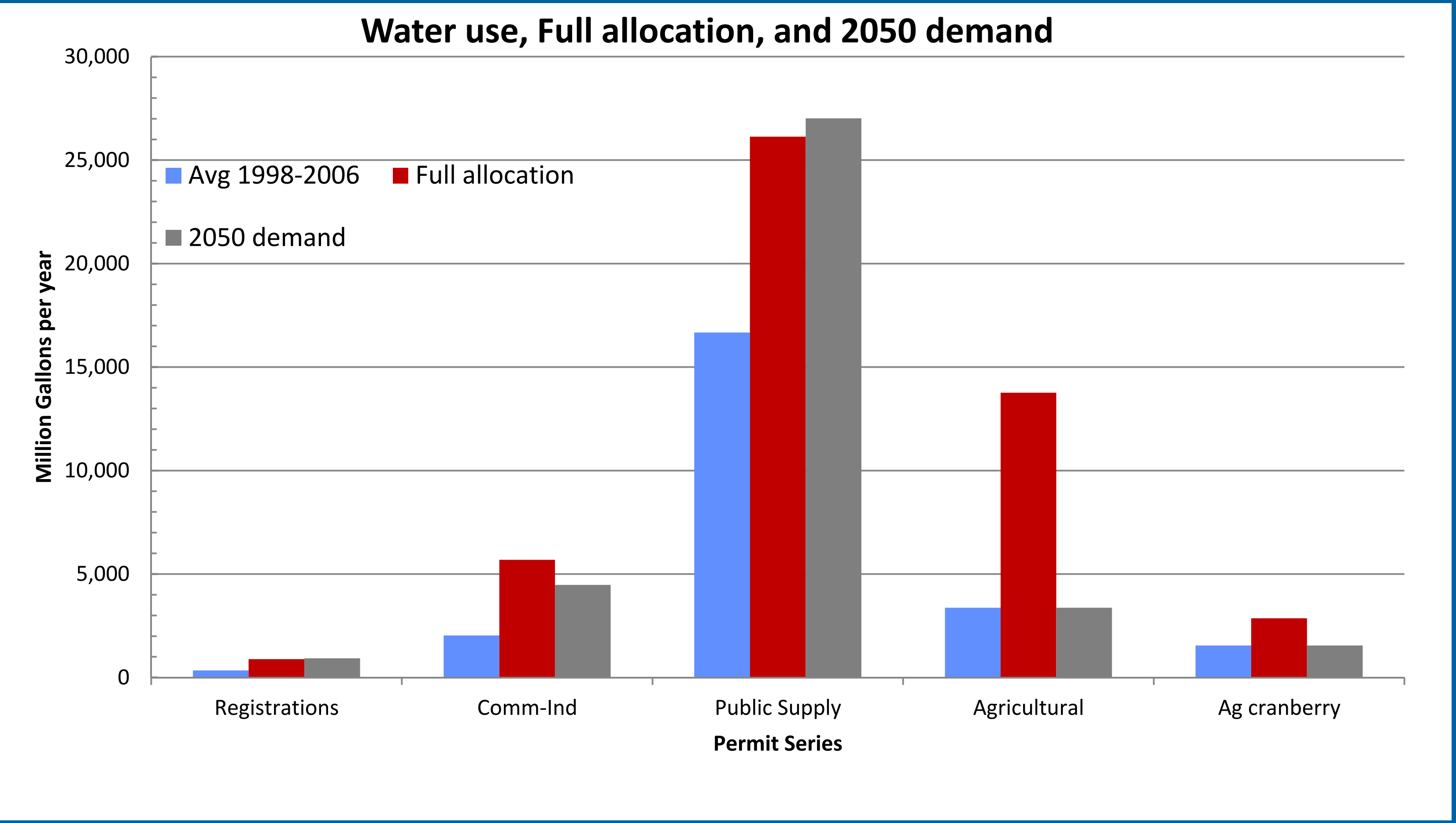
Water use data for scenarios



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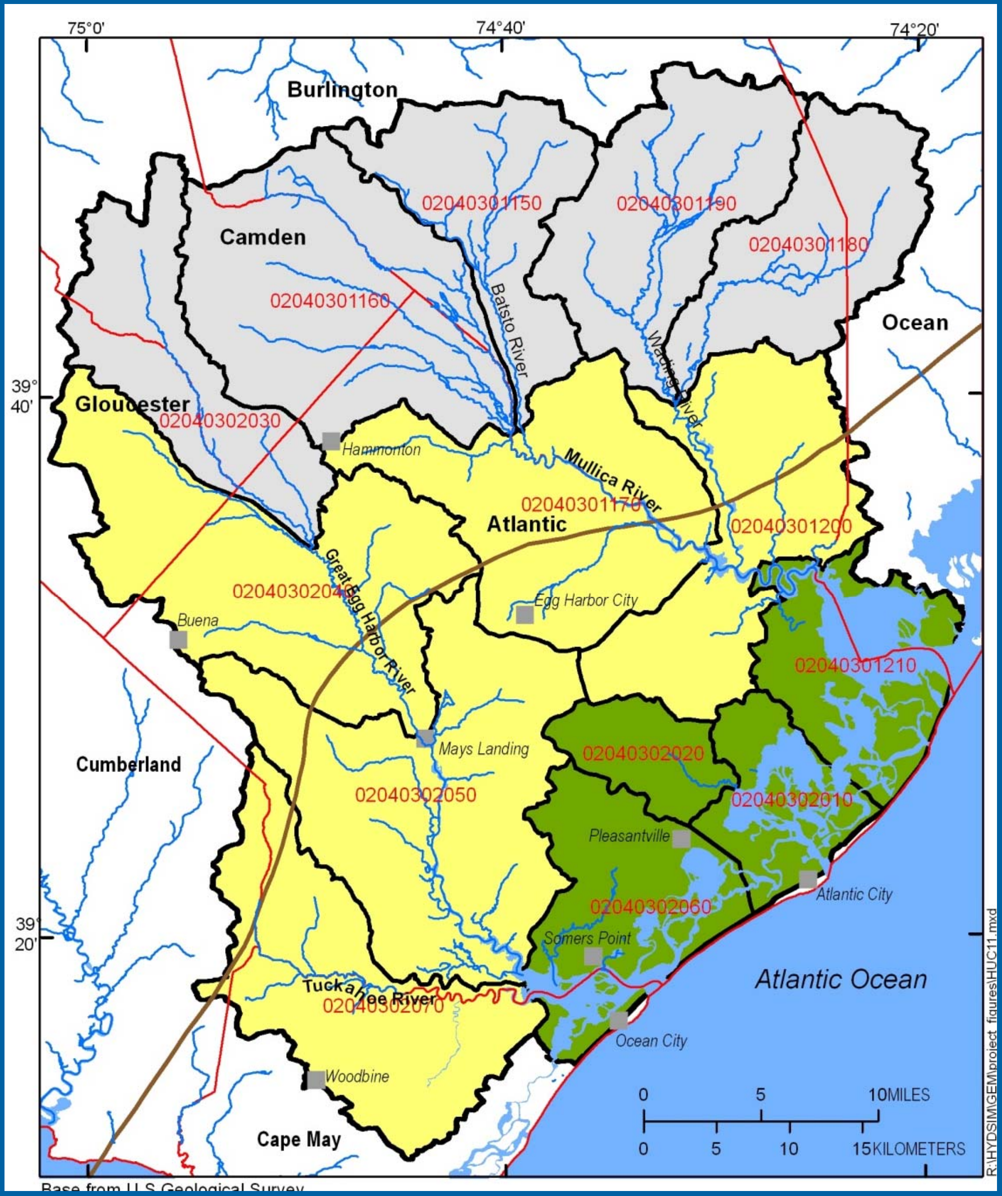
HUC 11 Basins

- Updip
- Mixed
- Downdip



11 digit HUC codes all start with '0204030' in the study area. So often refer to them by last 4-digits, ie, basin '02040302030' would be '2030'

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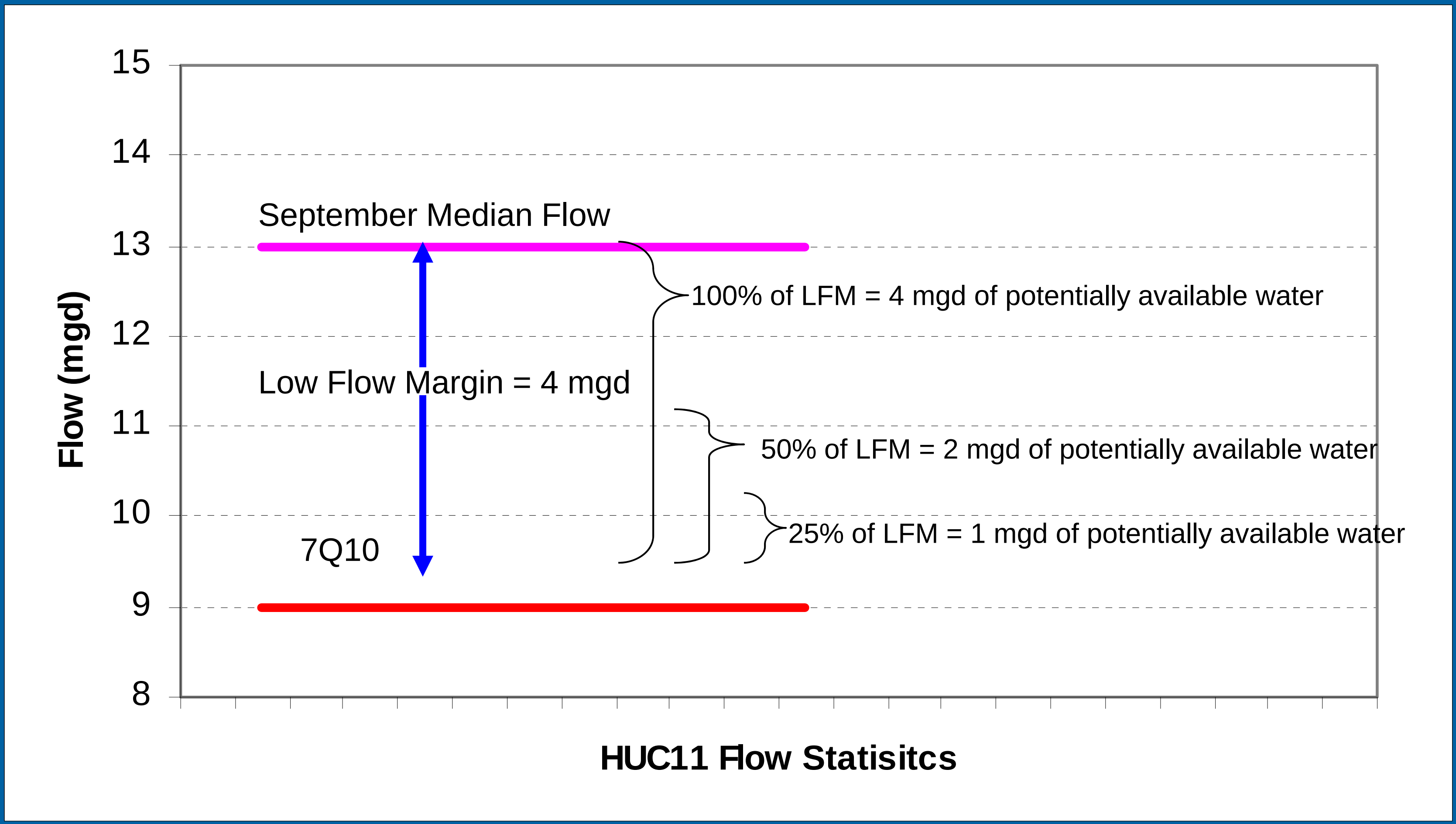
NJDEP Low Flow Margin Method (LFM)

- Assumes that some percentage of streamflow can be removed without affecting stream ecology
- Identifies September as an ecologically critical stream flow period
- Identifies 7Q10 as a typical drought flow. The 7Q10 is the lowest 7-day flow expected to occur over a 10-year period
- Quantifies the volume of water available as a percentage of the difference between the September median flow and drought flow (7Q10)
- Water Available for Depletive and Consumptive Loss is proposed to be 25% of the Low Flow Margin
- The 25% criteria came from an ecological flow goals analysis of 10 watersheds. Hoffman and Rancan, 2009

Available Water



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Base-flow depletion Criteria

- Modified LFM for use in the GEM study
- Applied at a monthly level rather than annually in order to simulate Seasonal Conjuctive use
- Estimated monthly 7Q10 and monthly medians. Calculated the monthly Low-Flow Margin for each HUC11
- Used 25% of monthly Low-flow margin as available water
- Subtracted any consumptive surface-water diversions in the HUC

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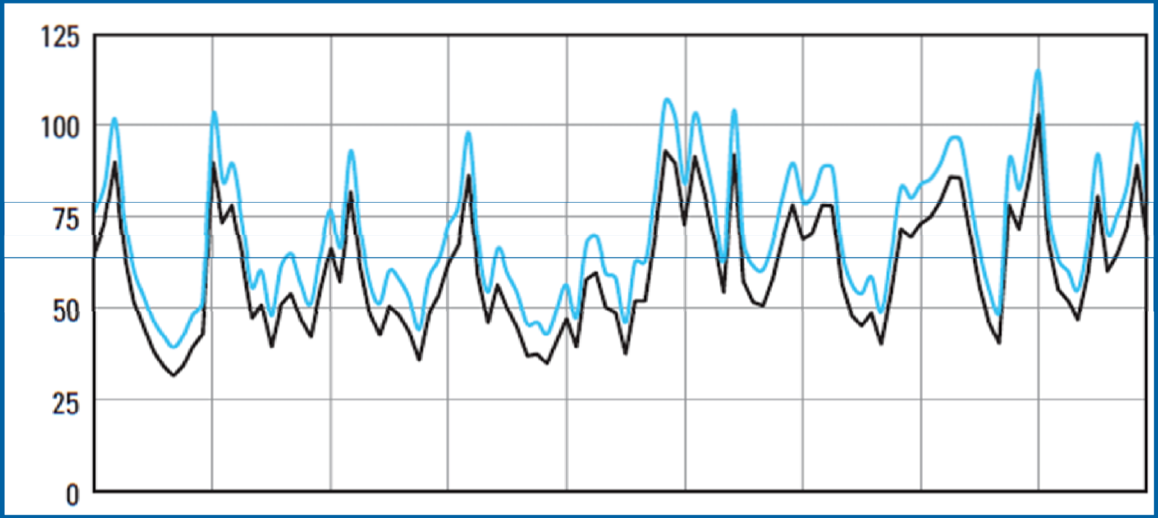
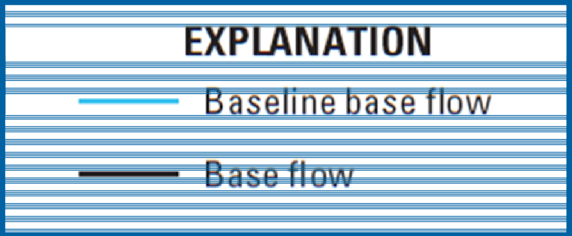
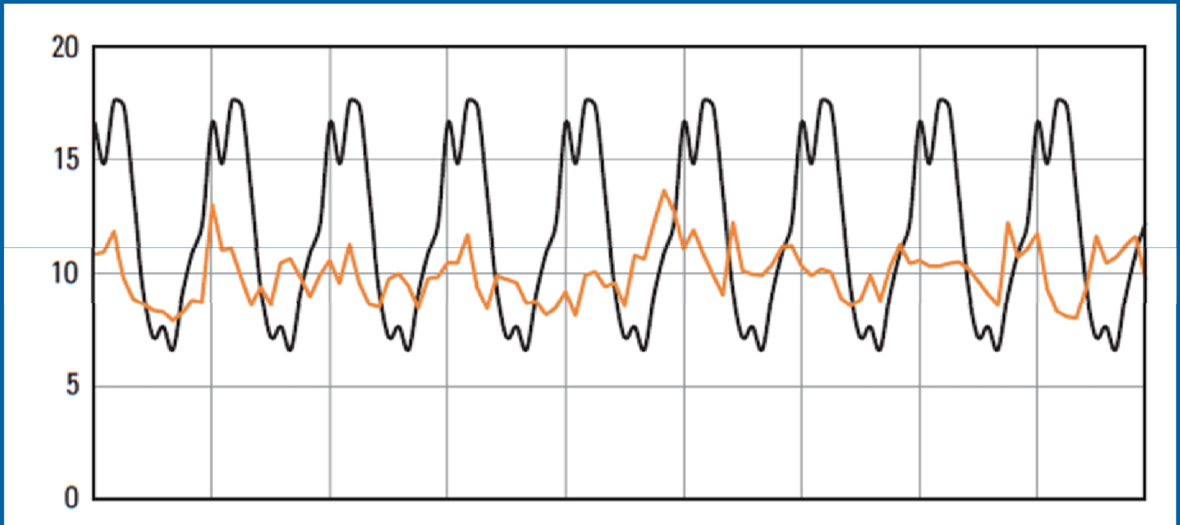
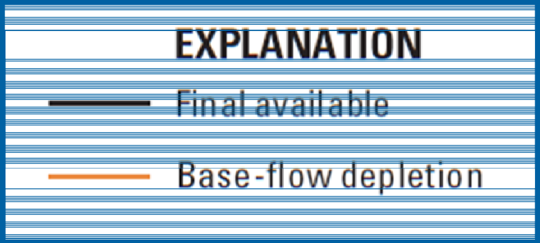
Simulated base-flow depletion

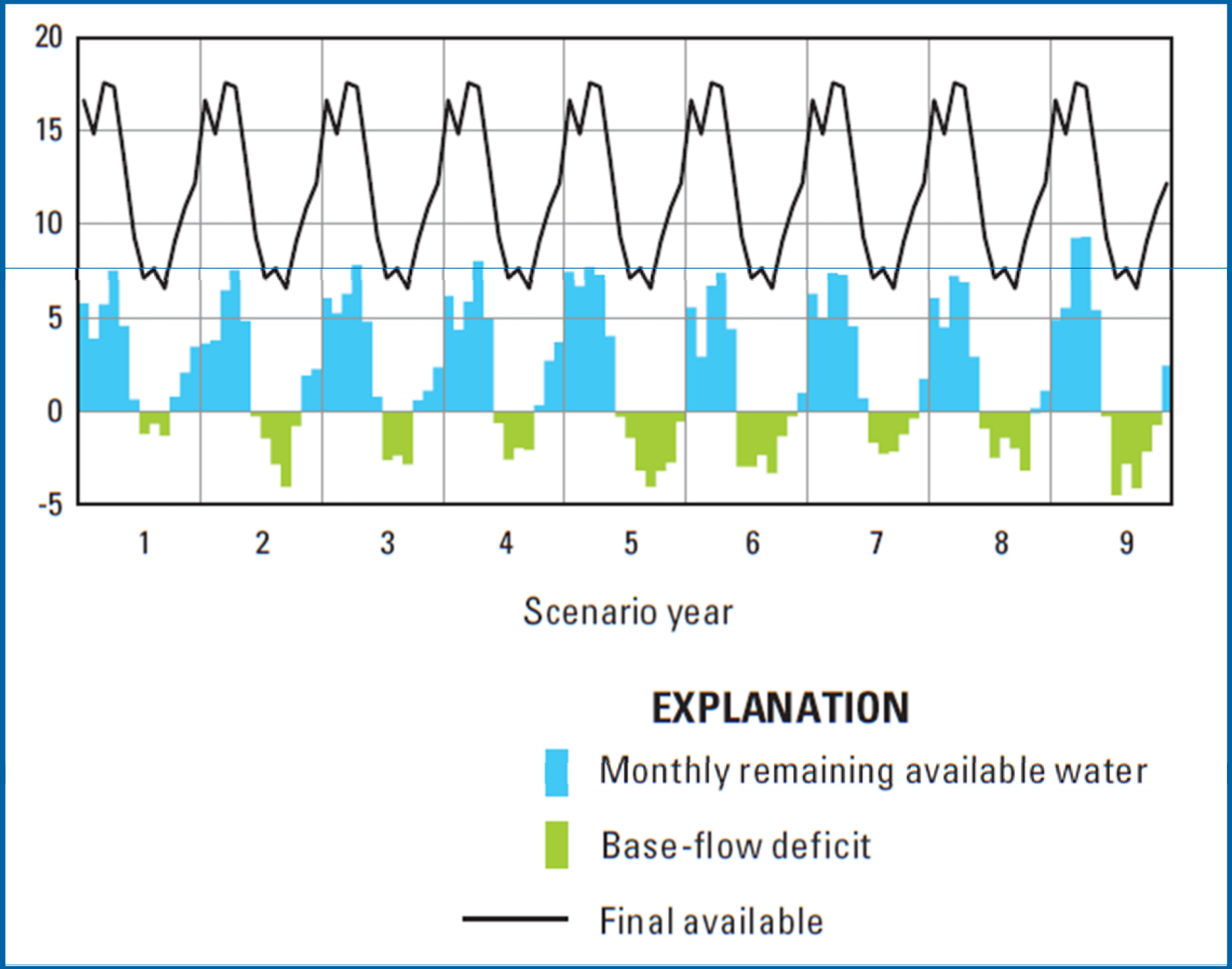








Base-flow thresholds, available water, and deficits



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Basic Scenarios

- Basins in deficits in AVG, FA, 2050 Demand
  - AG allocations affect Full Allocation
  - 800-ft sand withdrawals and 2050 Demand
  - Deficit in Basin 2020 because base-flow threshold in summer is 0.0 due to surface water diversions
- Effects on 800-ft sand heads of FA and 2050 Demand
  - Fall heads in 800-Foot sand drop up to 55 ft in FA
  - Fall heads in 800-Foot sand drop up to 63 ft in 2050 Demand
  - Declines are larger in 2050 demand scenario because of 800-Foot demand projections

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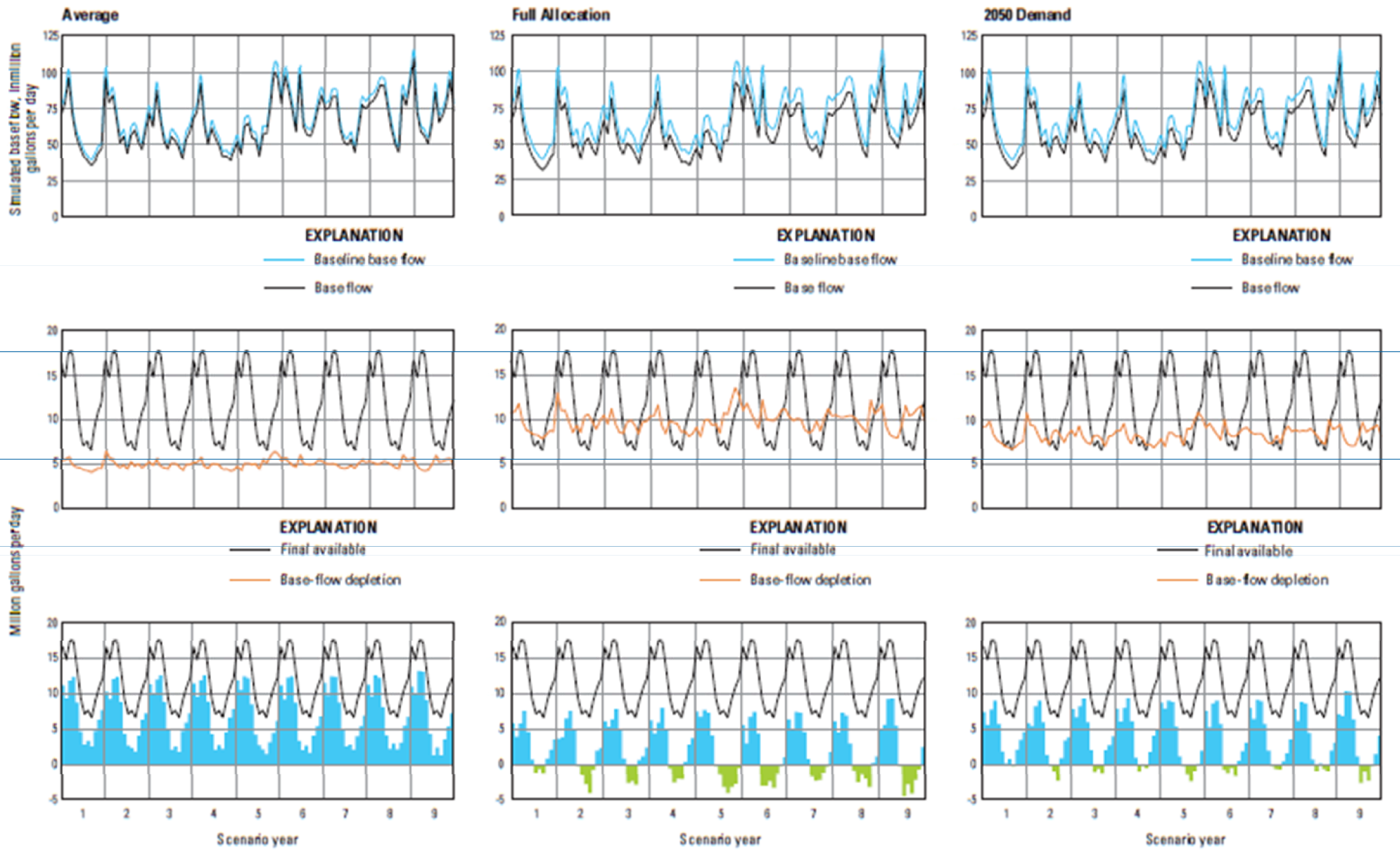
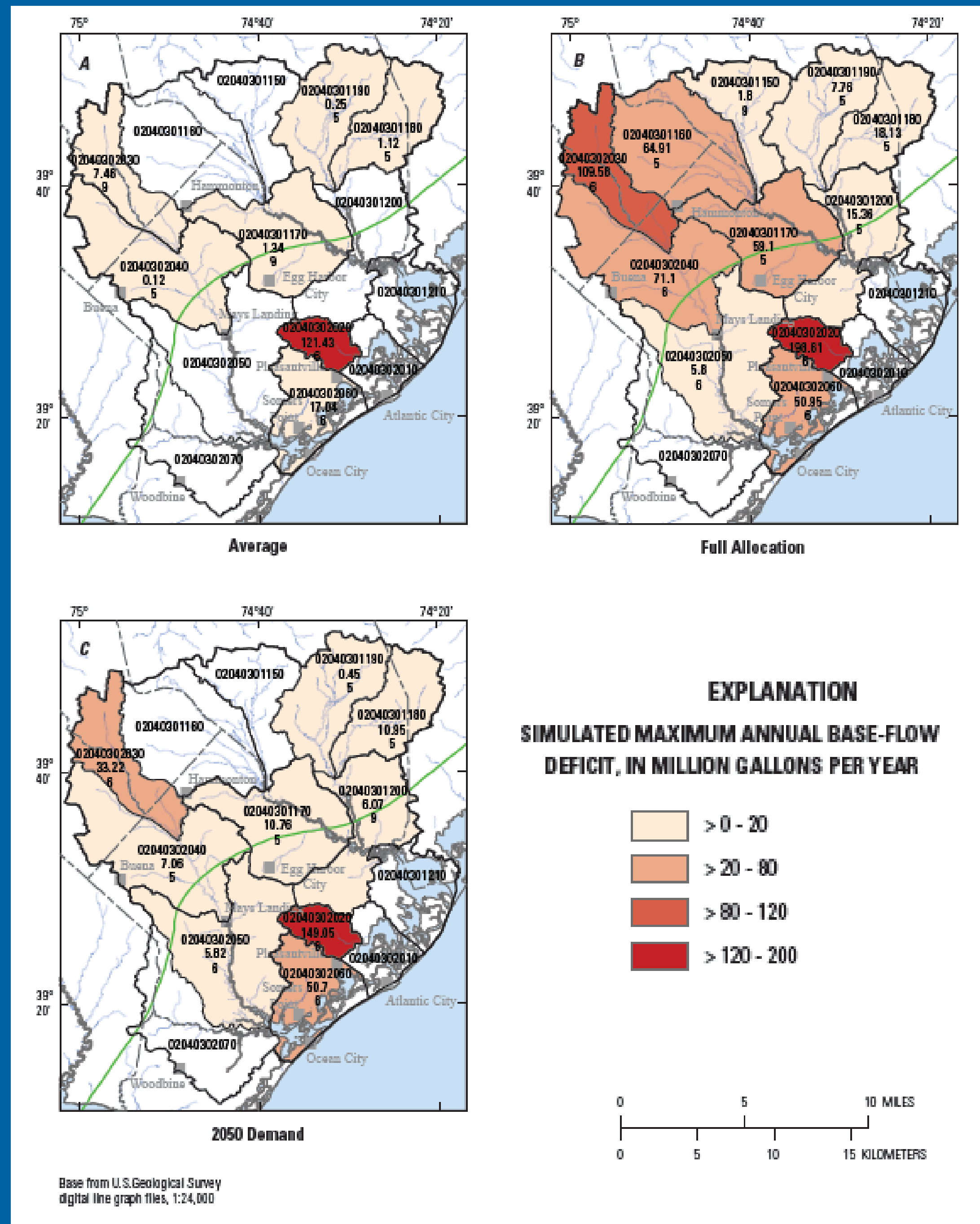
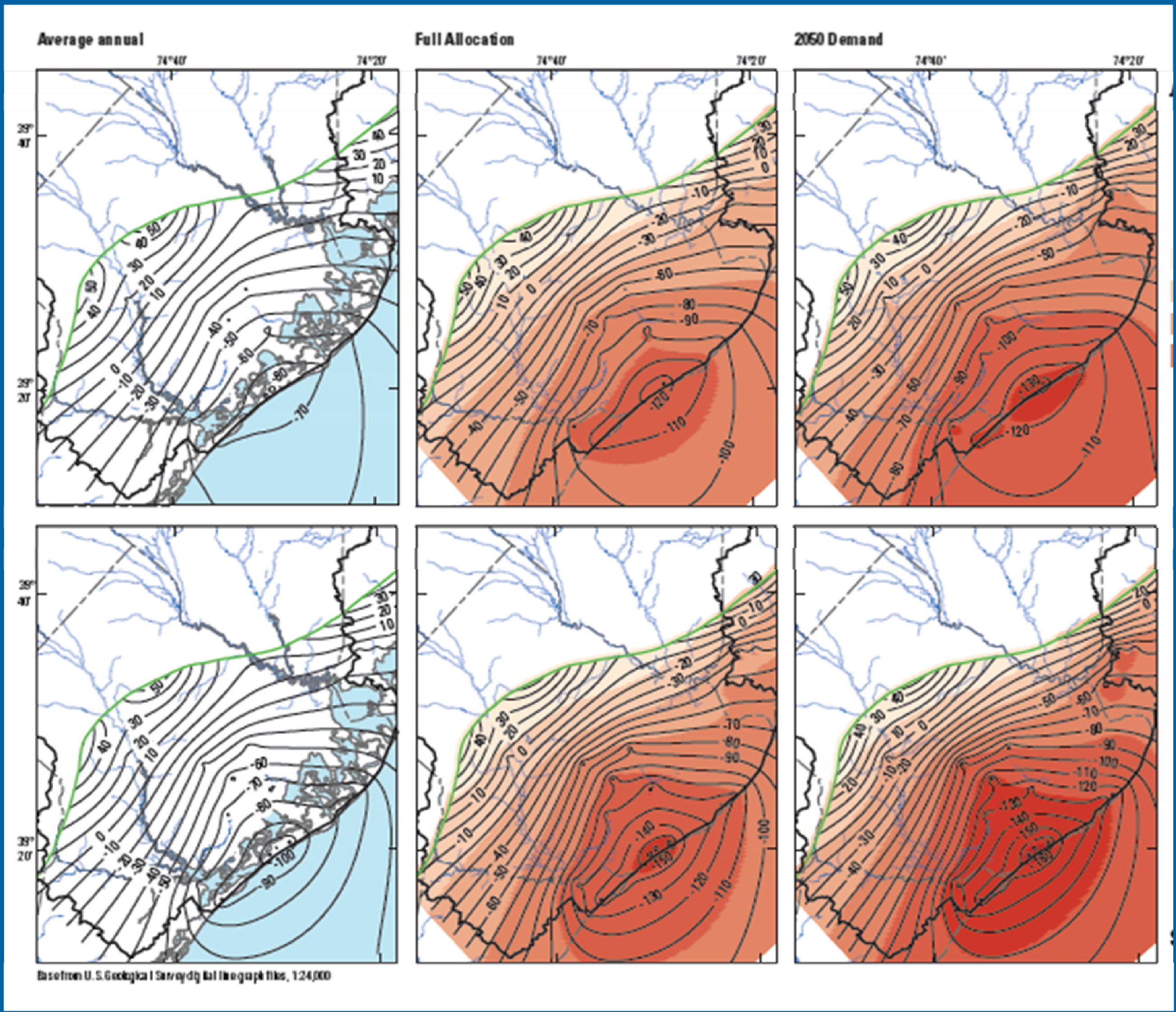
Basic scenarios



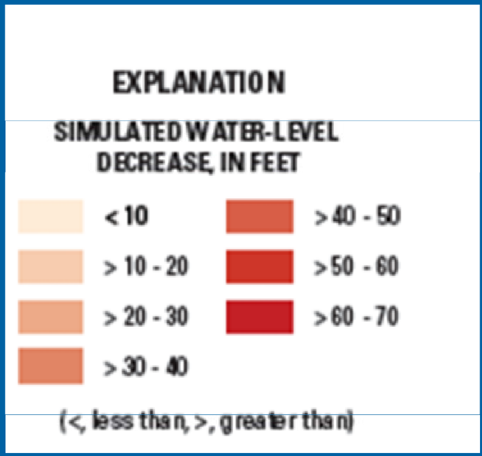
Basic conditions, Maximum annual deficit



Basic: Water levels in April and September of Scenario year 9



April



September

Adjusted Scenarios

- Simulated three hypothetical alternative adjustments in withdrawals to illustrate the relative effects of the methods. No plan is in place to implement these strategies.
- Started with deficits from Basic Scenarios
- Used a three ‘Tier’ approach
- Tiers 2 and 3 start with the changes made in the previous tier

Adjusted Scenarios

- **Tier 1: Move withdrawals in Kirkwood-Cohansey**
  - **Shifted withdrawals from shallow to deep units within the Kirkwood-Cohansey in downdip areas**
- **Tier 2: Seasonal Conjunctive use**
  - **All 800-ft sand withdrawals that are available (downdip areas) to be moved up to the CKKD in the winter are moved down into the 800-ft sand in the summer.**
  - **Net annual withdrawals from both the CKKD and the 800-ft sand are unchanged**
- **Tier 3: Reduce withdrawals**
  - **Cut back withdrawals from the Kirkwood-Cohansey aquifer system for all basins that are in deficit**
  - **Made changes in 10 percent increments**
  - **Made changes within the basin in deficit only**

Tier 1: Move withdrawals in Kirkwood-Cohansey

- Deficits
  - No deficits eliminated
  - Worked best in Basin 2060 downdip
    - 3 to 6 % of deficit removed
  - Deficits in some basins updip were increased slightly
- Heads in Atlantic City 800-Foot sand are unchanged

Tier 2: Seasonal Conjunctive Use

- Deficits
  - Deficits improved in three downdip basins (Basins 2020, 2050, and 2060)
  - Worked best in Basin 2060 downdip
    - Average: deficit reduced by 80 %
    - Full Allocation: deficit reduced by 40 %
    - 2050 conditions: deficit reduced by 35 %
  - Updip and mixed generally stay same or get worse
- Water levels in 800-Foot sand
  - Spring
    - Higher in center of cone, declines around edges
  - Fall
    - > 50 foot declines

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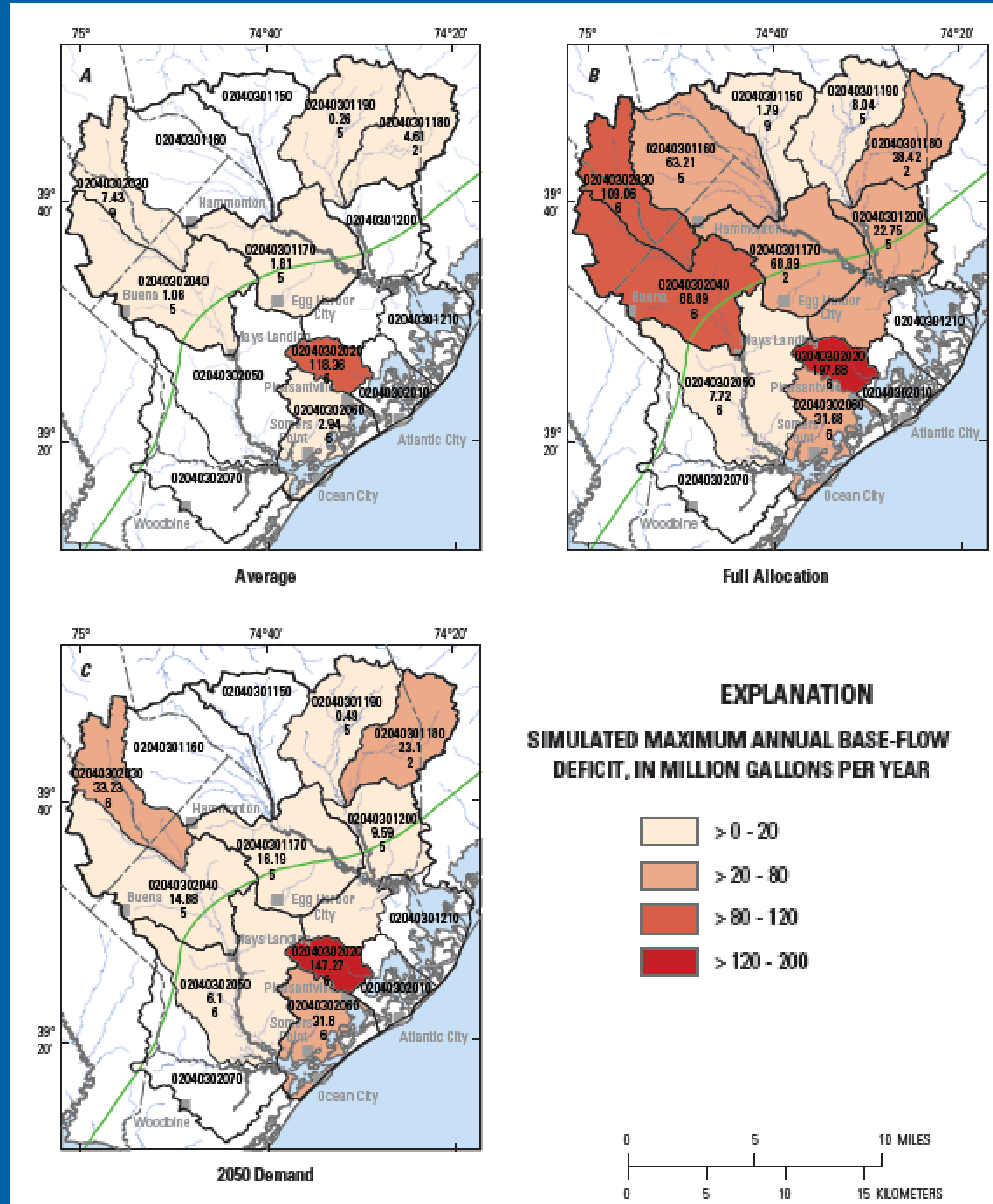
Conjunctive use, Maximum annual deficit



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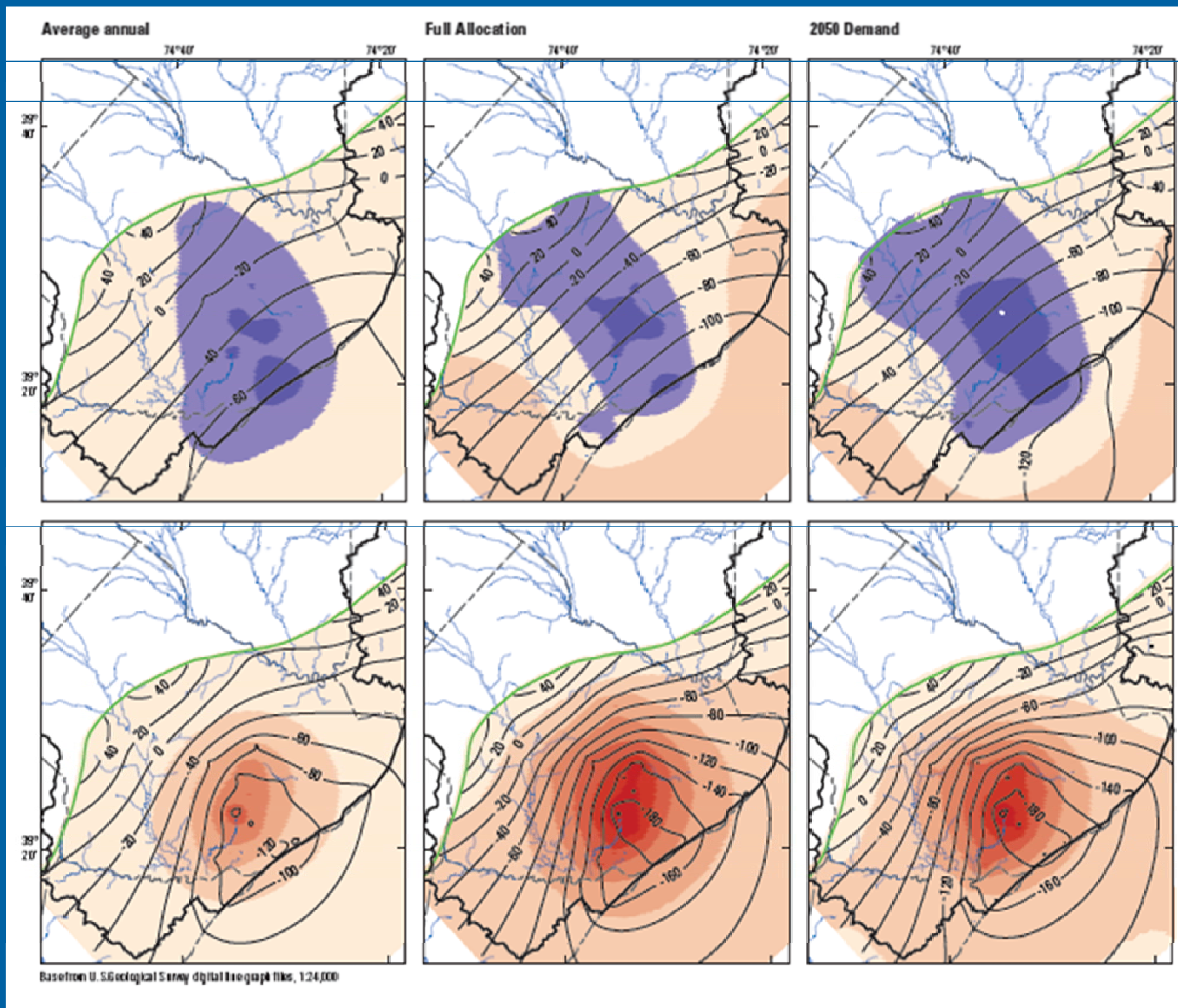
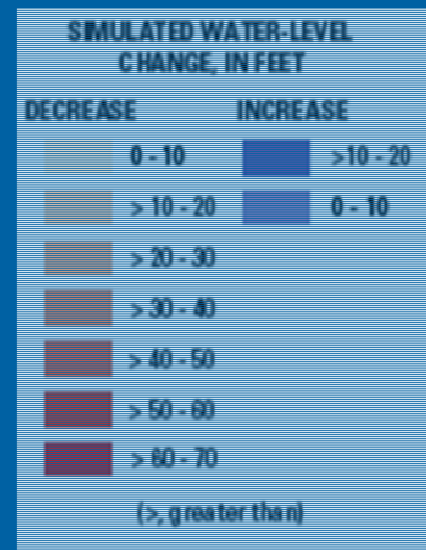
Conjunctive Use: Water levels in April & September of Scenario year 9



April

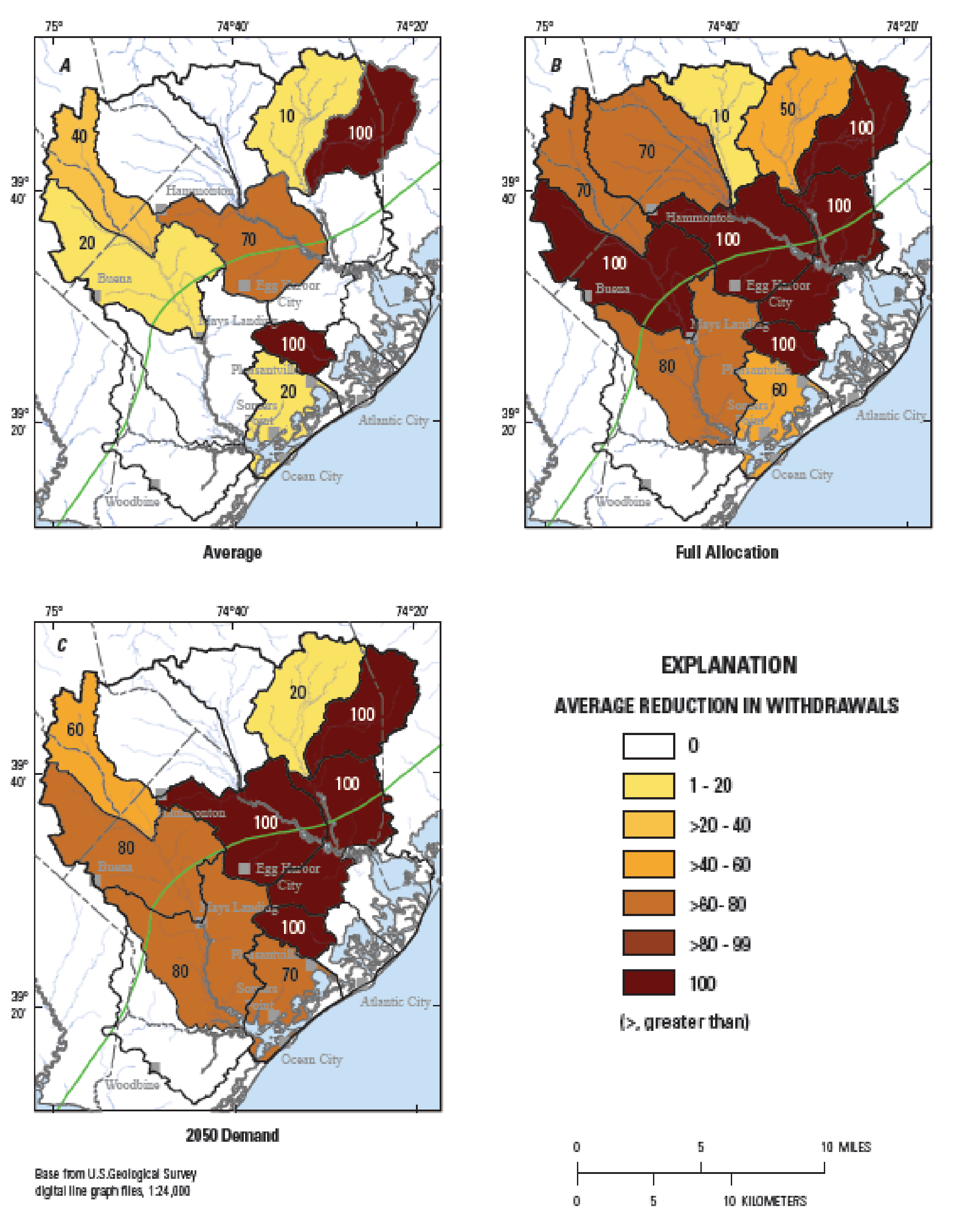


September

Cutbacks

- Deficits
  - Deficits were eliminated in all but 4 basins
  - Some deficits may only be eliminated by cuts in 800-ft sand withdrawals in downdip basins.
  - Some reductions in withdrawals may be larger because of the way the scenarios were simulated (Seasonal Conjuctive Use increases deficits in some updip and mixed basins)
- Heads
  - Heads in the 800-Foot sand are unchanged

Reductions required to eliminate deficits



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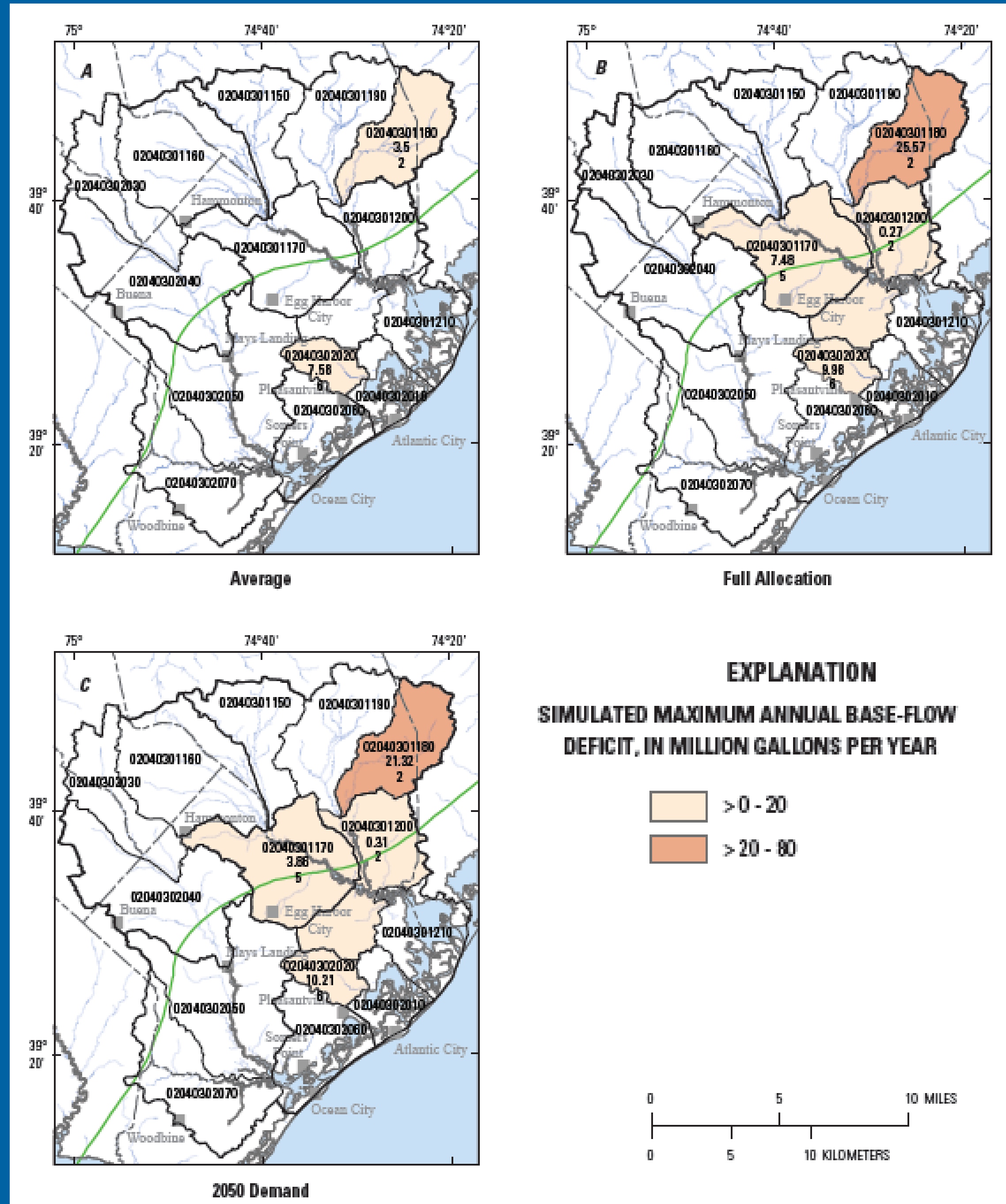
Adjusted scenario, Maximum annual deficits

After Tier 3



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Adjusted scenario summary

- Most deficits were ultimately reduced or eliminated using cutbacks
- Conjunctive use made deficits greater in updip and mixed basins in Full Allocation and 2050 Demand conditions
- Deficits
  - Deficits were eliminated in all basins except Basin 2020 (downdip), Basins 1170 and 1200 (mixed), and Basin 1180 (updip).
  - Deficits in Basins 1170, 1200, and 1180 would only be able to be eliminated by cuts in the 800-Foot sand in downdip basins

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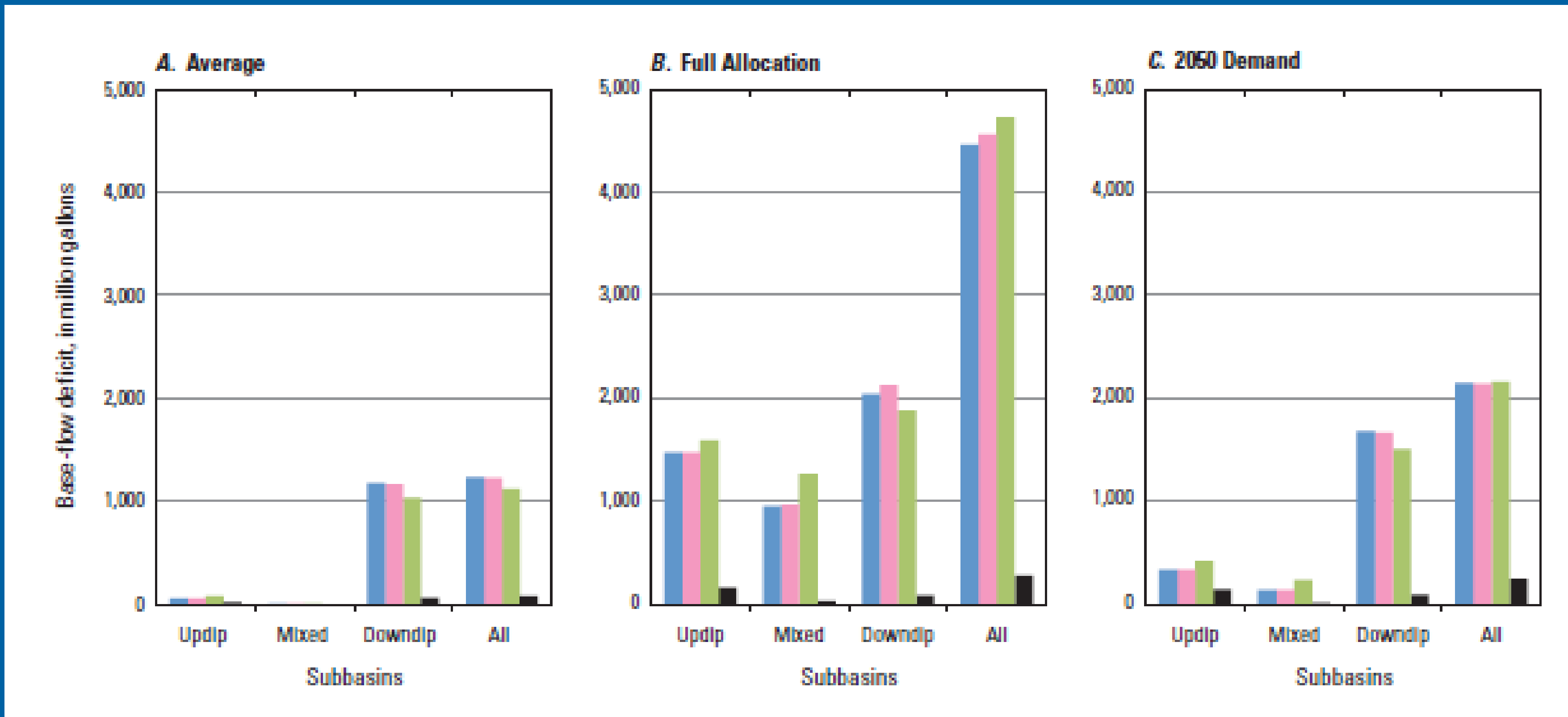
Deficits in Adjusted approaches



EXPLANATION

Basic

ADJUSTMENT

Tier 1

Tier 2

Tier 3

Summary

- Agricultural allocation limits are important during Full Allocation
- Water levels drop up to 60 feet in the Atlantic City 800-foot sand as a result of projected Public Supply withdrawal increases in the 2050 Demand scenario
- Interaction between basins was significant
- There was not a 1:1 correlation between withdrawals in a basin and base-flow depletion

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Summary

- The Kirkwood-Cohansey aquifer system and the Atlantic City 800-Foot sand are interconnected
- Withdrawals from the Atlantic City 800-Foot sand may affect updip basins
- Semi-Confining unit in Kirkwood-Cohansey aquifer does not isolate deeper withdrawals from base-flow effects on a regional scale

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Summary

- Seasonal Conjunctive use may be beneficial in some downdip basins (Basin 2060)
- Deficits in Basin 2020 cannot be eliminated because of the base-flow depletion threshold of 0.0 in the summer
- Seasonal Conjuctive Use may have been less successful than anticpated, in part, because of the way it was implemented. Our attempt to resolve the deficits in all basins at once (including Basin 2020) impacted the effectiveness of the approach on nearby basins

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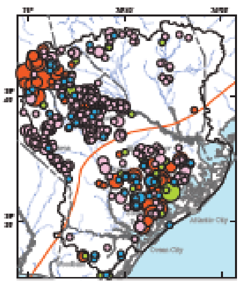
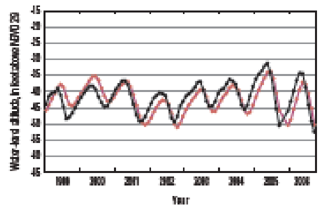
science for a changing world

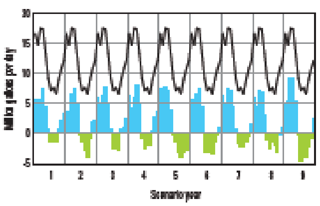
Prepared in Cooperation with the
New Jersey Department of Environmental Protection

Simulated Effects of Alternative Withdrawal Strategies on Groundwater Flow in the Unconfined Kirkwood-Cohansey Aquifer System, the Rio Grande Water-Bearing Zone, and the Atlantic City 800-Foot Sand in the Great Egg Harbor and Mullica River Basins, New Jersey


Well at Mullica River campsite


Annual 2005






Wading River

Scientific Investigations Report 2012–5187

U.S. Department of the Interior
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Model Report

http://pubs.er.usgs.gov/publication/sir20125187