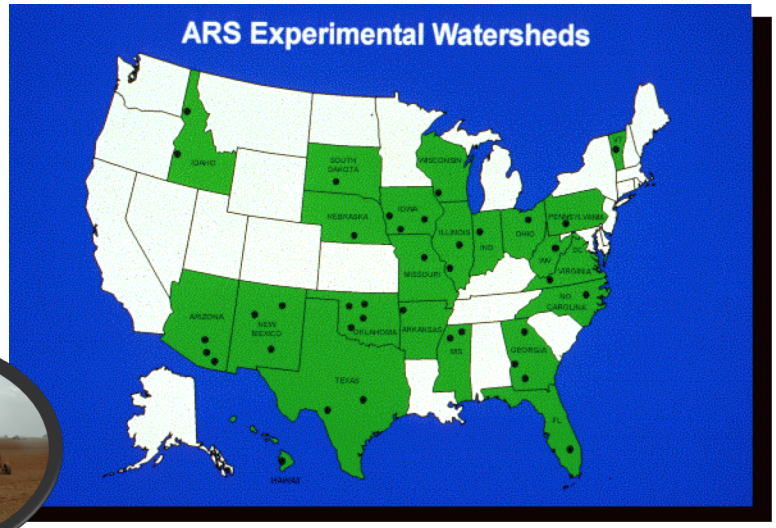
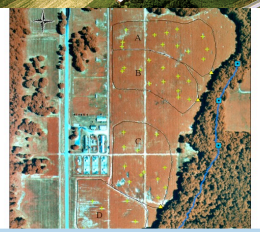
The USDA-ARS Experimental Watershed Network – Evolution, Lessons Learned, and Moving Forward





D. Goodrich, P. Heilman, S. Moran, J. Garbrecht, D. Marks, D. Bosch, J. Steiner, J. Sadler, M. Locke, D. Smith, P. Kleinman, S. Gunter, T. Tsegaye

Various USDA-ARS Locations

Presentation to the ACWI-SOH Streamflow Infor. Collaborative

Aug. 14, 2018

Overview

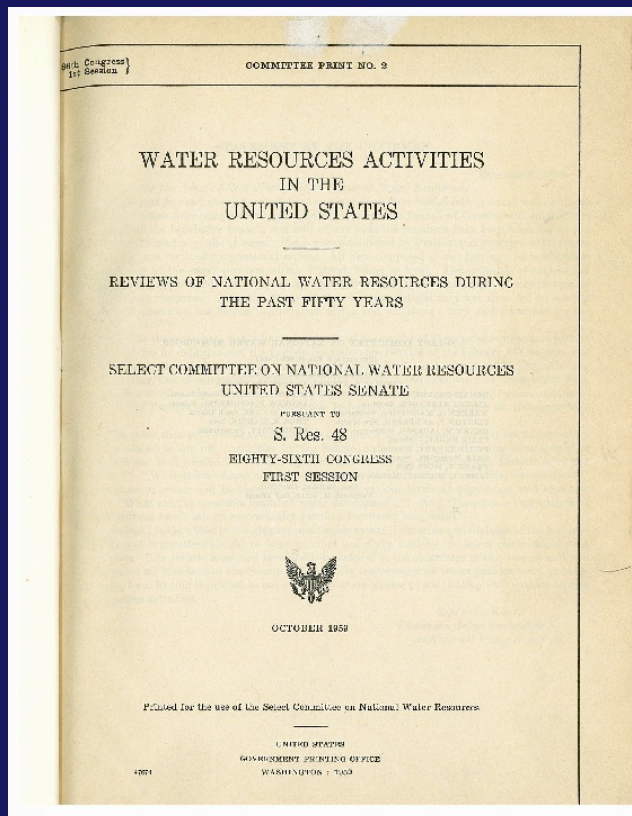
- Early History & Establishment
- Evolution
- Examples
  - Reynolds Creek Experimental Watershed – Idaho
  - Walnut Gulch Experimental Watershed - Arizona
- Challenges
- Future – LTAR (Long Term Agroecosystems Research) Network
- Lessons Learned

Early History

- Established 1935 – Research Div. of the Soil Conservation Service
- Purpose – Quantify the effects of soil and water conservation practices on a watershed scale
- 3 small experimental watersheds were established: (OH, TX, NE)
- Became part of Agric. Research Service when it was created in 1953

- In 1958 the U.S. Senate conducted nationwide hearings and a review of US water resources & policy and requested USDA "to make a study of facility needs for research on soil and water problems…"

- USDA study resulted in Senate Document 59 which identified "Hydrology of Agricultural Watersheds" as a high priority



86th Congress, 1st Session

COMMITTEE PRINT NO. 2

WATER RESOURCES ACTIVITIES
IN THE
UNITED STATES

REVIEWS OF NATIONAL WATER RESOURCES DURING
THE PAST FIFTY YEARS

SELECT COMMITTEE ON NATIONAL WATER RESOURCES
UNITED STATES SENATE

PURSUANT TO

S. Res. 48

EIGHTY-SIXTH CONGRESS
FIRST SESSION

OCTOBER 1959

Printed for the use of the Select Committee on National Water Resources

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1959

Quotes from Senate Doc. 59

"Hydrologic studies are urgently needed on Precip.-Runoff relationships and the effect of all types of conservation treatments on runoff … from agricultural watersheds ranging in size from 1 to 400 sq. miles" (*National Research Objective*)

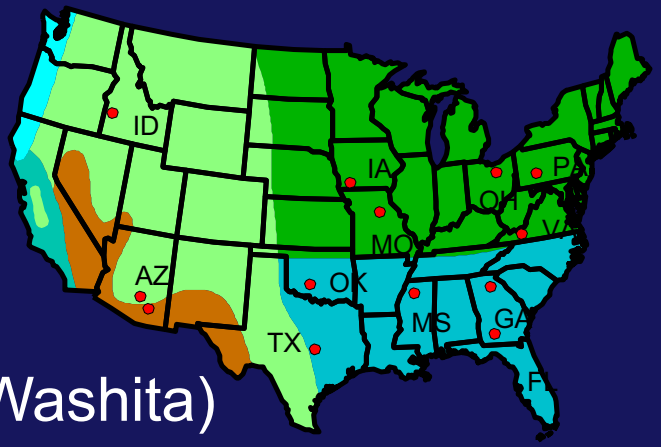
"Experimental watersheds are needed in all 15 major land resource regions; however establish only 6 at this time….To provide the max. opportunity for interpolating values between locations with markedly contrasting conditions each should include a number of satellite locations … " (*NEON Like Design*)

"..agricultural watershed behavior is a complex problem.. centers must be large enough to represent numerous disciplines" (*Multidisciplinary*)

Senate Doc. 59 Recommendations

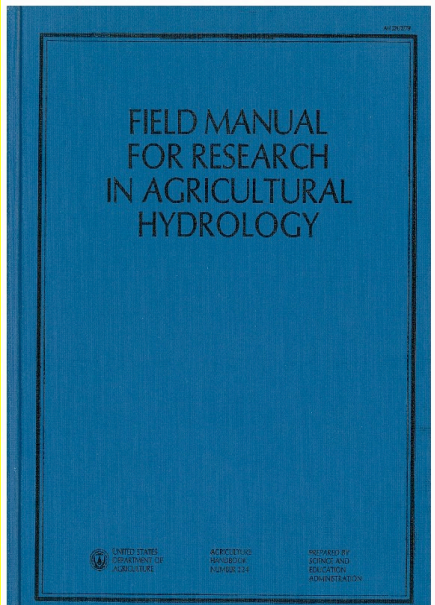
Est. Res. Centers & Experimental Watersheds (Primary & Satellites)

1. Northwest (Boise-Reynolds)
2. Southwest (Tucson-Walnut Gulch)
3. NE (Univ. Park-Mahantango)
4. SE (Tifton-Little River)
5. Southern Great Plains (Chickasha-L. Washita)
6. North Central Research Watershed (Columbia/Treynor)



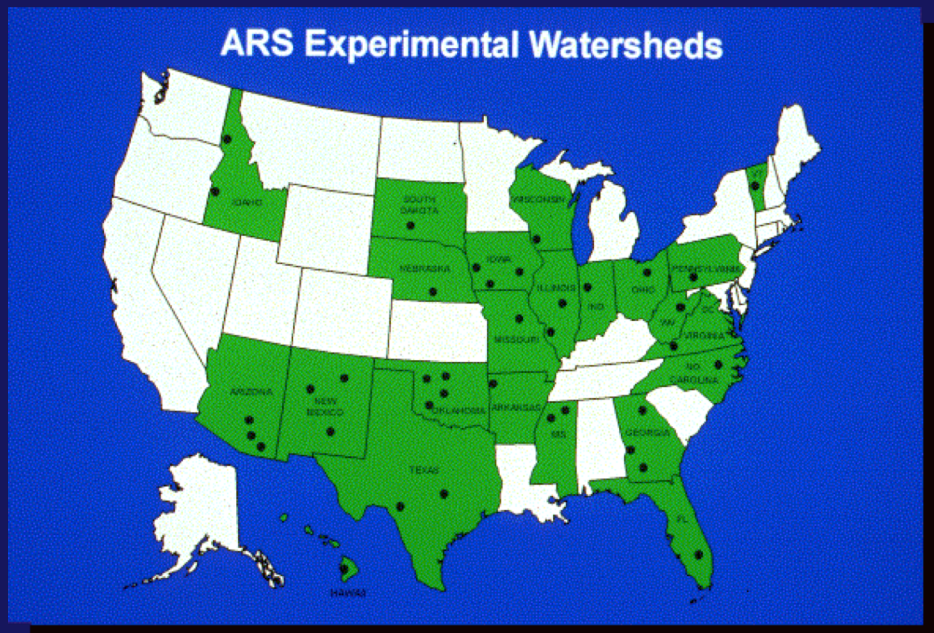
Measure a common set of variables with standard protocols, periodic review of network data, and a central data repository (Beltsville)

"…Evaluate the effect of, and the relationships between …runoff & water yield, precipitation, plant cover, conservation practices, soils, climate, slope, geology, ET, soil moisture"



Early ARS Water Database

- Precipitation / streamflow data from small agricultural watersheds in the United States
  - Collection of ~16,600 station years of record
  - Sufficient for reconstruction of hyetographs and hydrographs (ASCII files)
  - Almost entirely from analog instrumentation (digitized strip charts)

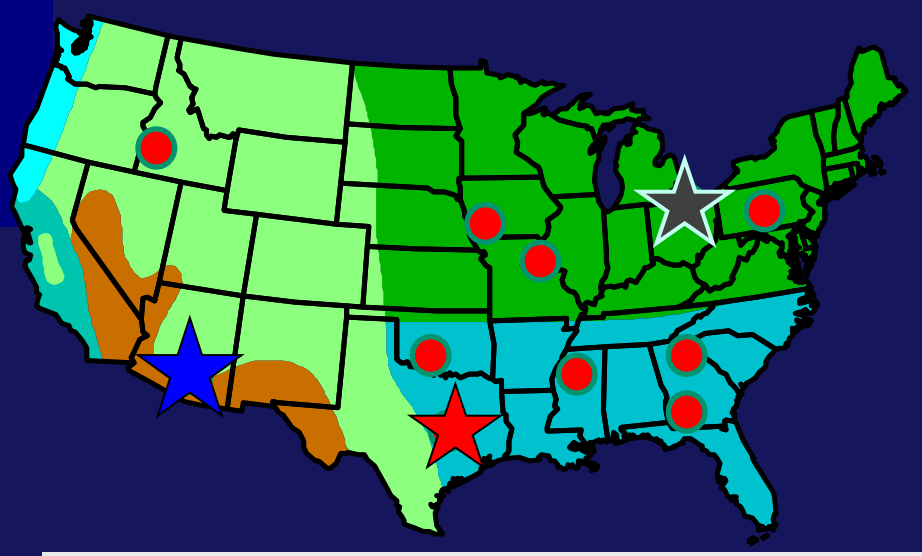


- Watersheds from 0.2 ha to 12,400 km^2
- No. rain gauges range from 1 to 200 per watershed
- Record submittal from locations to central location halted ~1990

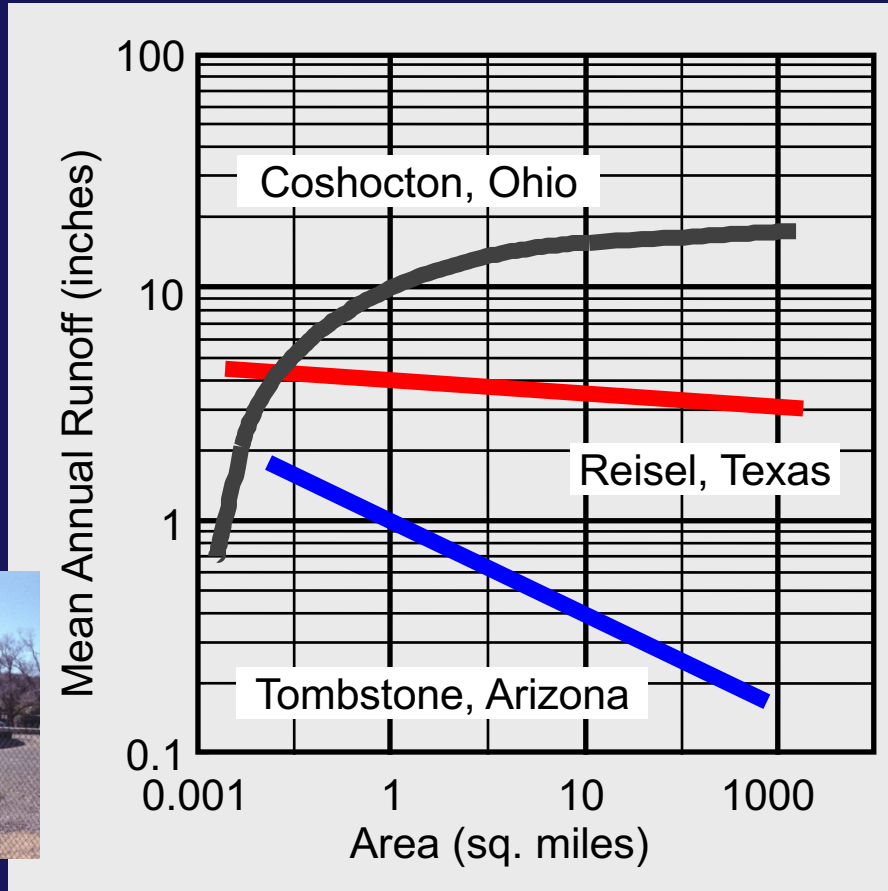
https://data.nal.usda.gov/dataset/ars-water-database

https://data.nal.usda.gov/dataset/ars-water-database/resource/60d4acb9-4cf8-476a-a2f9-a7b94f13cb4f

Recent ARS Exper. Watershed Network



- Network of stable, high-quality research platforms (40 to 85 years)
- Covers a range of hydro-climates
- Dense observations in time & space
- 11 long-term locations with nested watersheds (~100: 25 ha to 610 km^2)
- Long-term knowledge & data base
- Process-based understanding
- Magnets for collaboration leading to interdisciplinary field campaigns
- Special Journal Sections: WRR, Ecohydrology, JSWC
- Most privately owned



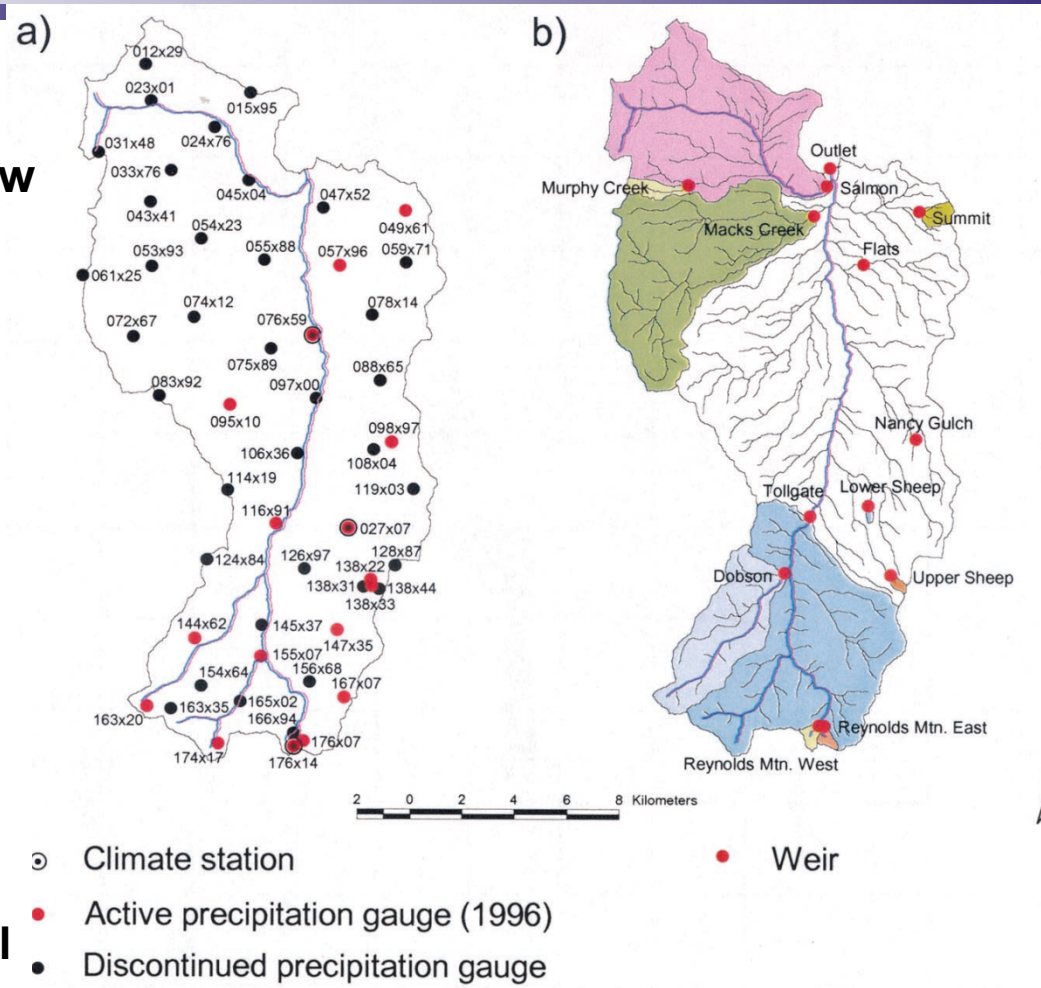
Reynolds Ck. (239 km^2): Snow Dominated

- SW Idaho – Trib to Snake
- Elev. - 1,101 m to 2,241 m AMSL
- 230 to 1100 mm Ann. ppt, 75% snow
- 32 climate - 36 ppt stations
- ~42 – 54 years of record
- 5 EC systems
- 14 weirs (nested)
- 6 soil microclimate stations
- 4 hill-slope hydrology sites
- 4 instrumented catchments
- 3 instrumented headwater basins:

<u>Upper Sheep Ck</u> (0.25 km^2, 186m relief) ephemeral, groundwater dominated, annual precipitation 300-500mm

<u>Johnston Draw</u> (1.8 km^2, 380m relief) ephemeral, rain-snow boundary, annual precipitation 500-600mm

<u>Reynolds Mtn East</u> (0.38 km^2, 116m relief) perennial, surface water dominated, annual precipitation 750-1000mm

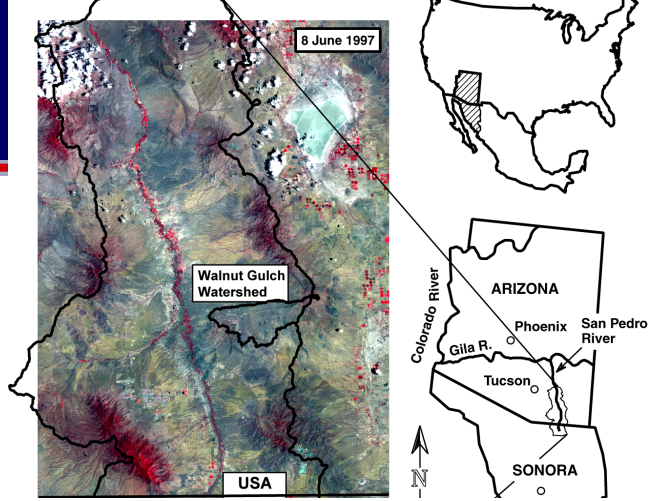


Special Section WRR: Nov. 2001

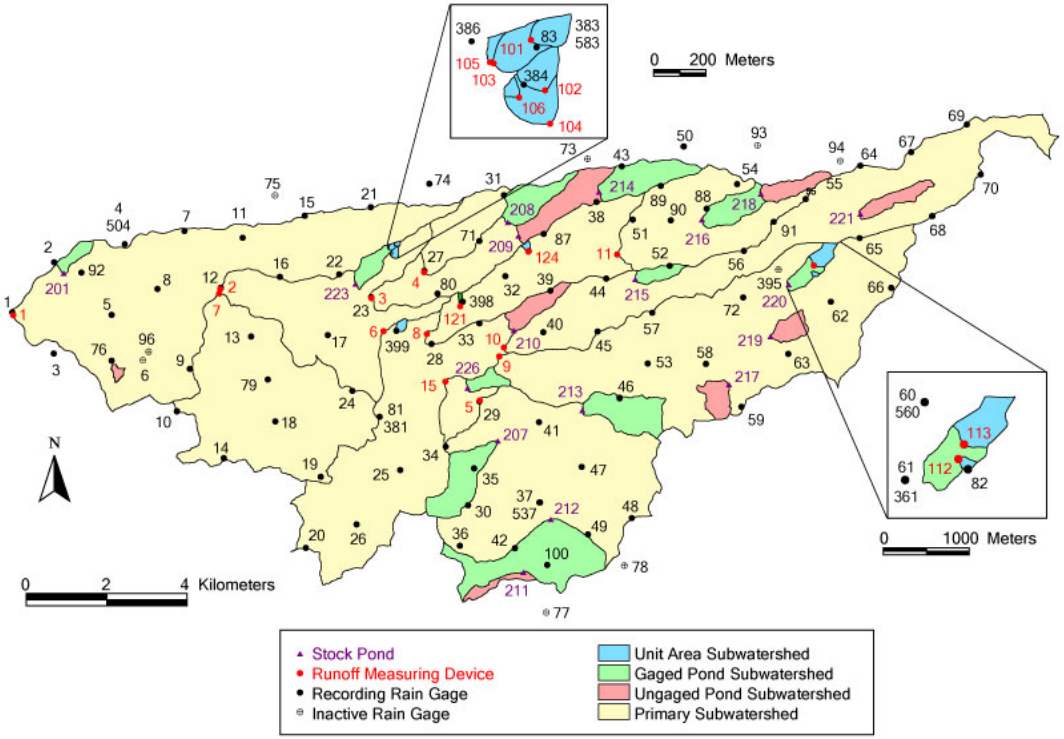
https://criticalzone.org/reynolds/infrastructure/field-area/reynolds-creek-experimental-watershed/

Walnut Gulch (149 km^2):

- SE Arizona – Trib. to Colorado
- SW Dominated – Depth to GW ~ 40 meter
- Elev. 1,220 to 1,950 m AMSL
- ~312 mm Ann. Ppt – 65% summer monsoon

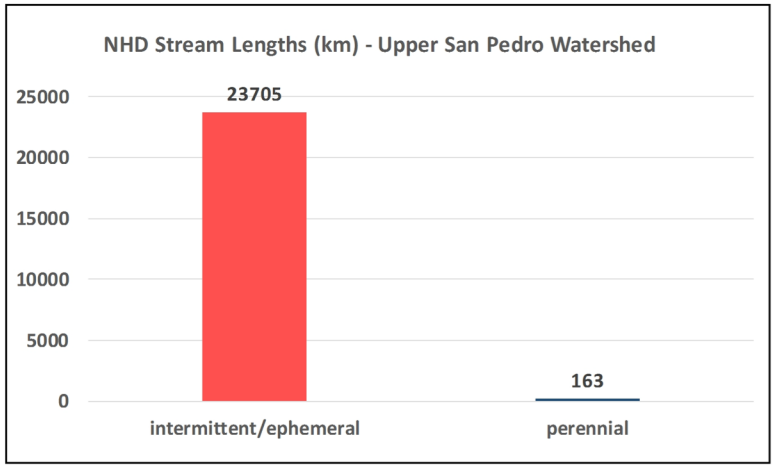


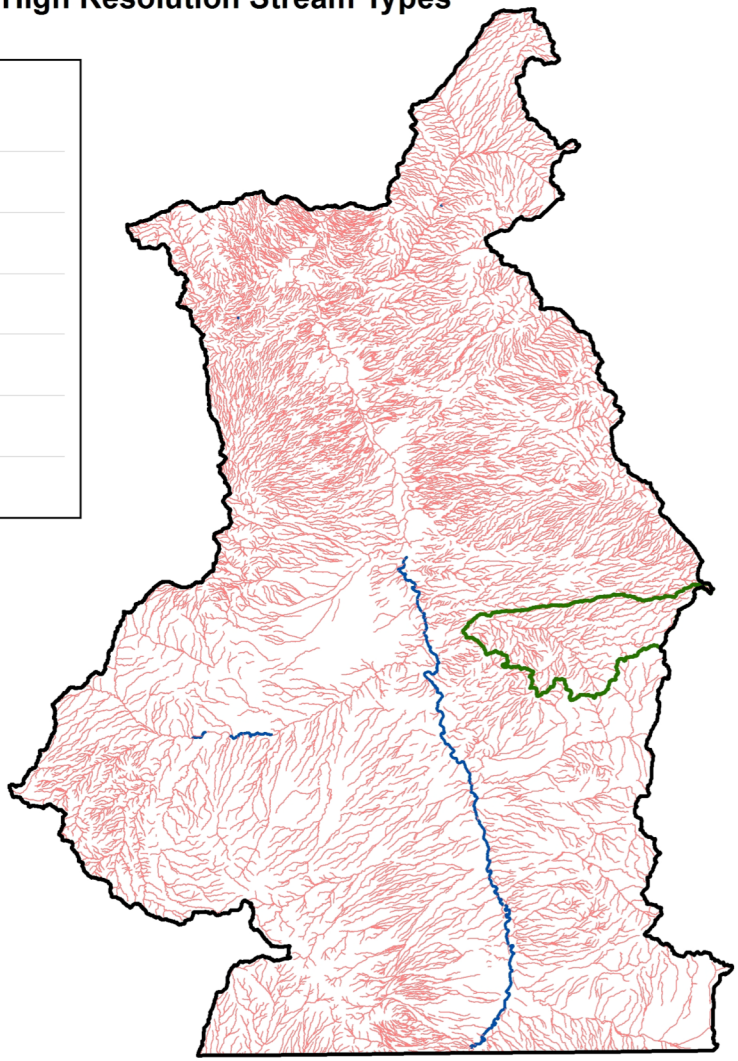
- 88 to 98 recording raingages
- 27 gauged subwatersheds
- 57 years of record
- 3 climate stations
- 2 Energy/carbon flux stations
- 24 Surface soil moisture locations (5 with multi-depth)
- 2 intensively instrumented headwater with sediment measurements
  - LH – desert brush
  - Kendall – desert grass



Special Section WRR: 2008

Upper San Pedro Watershed - NHD High Resolution Stream Types





Legend

- Upper San Pedro Watershed (US only)
- Walnut Gulch Experimental Watershed

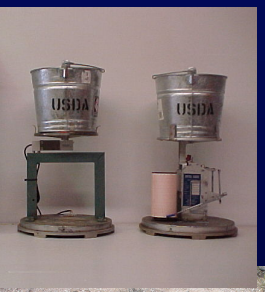
NHD High Resolution Streamlines

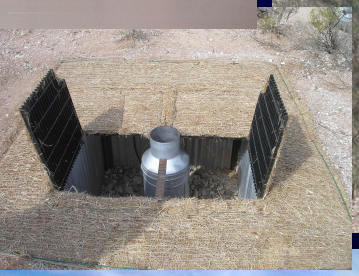
- Intermittent/Ephemeral
- Perennial

0 10 20 40 Kilometers

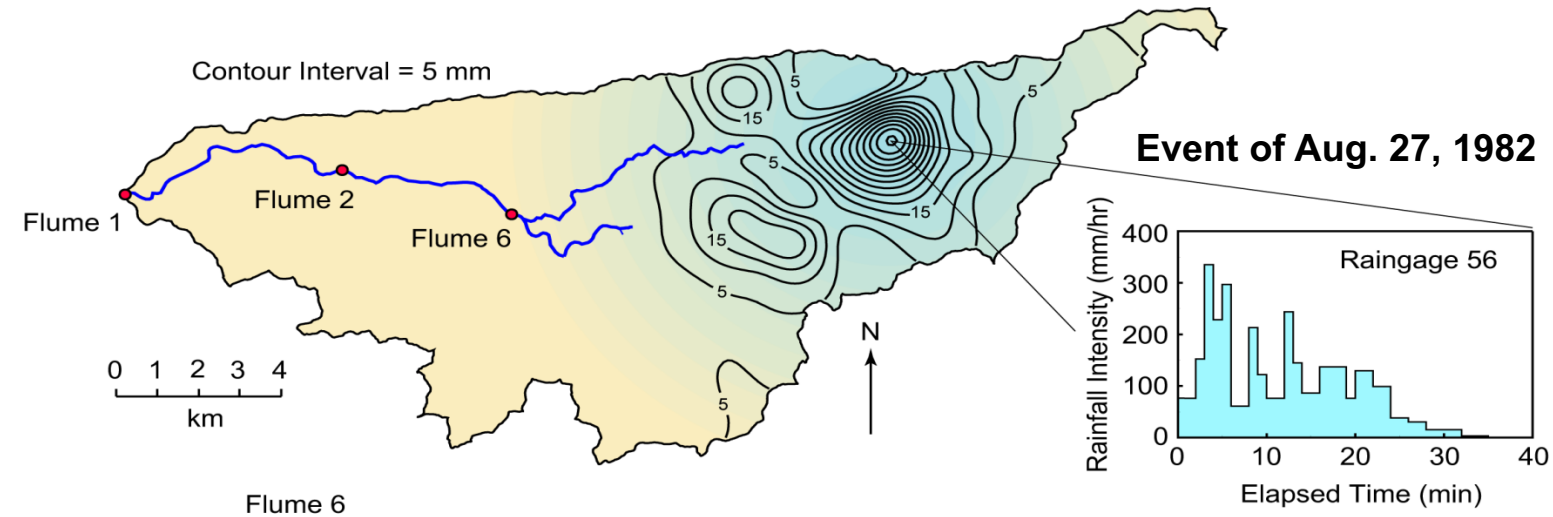
N

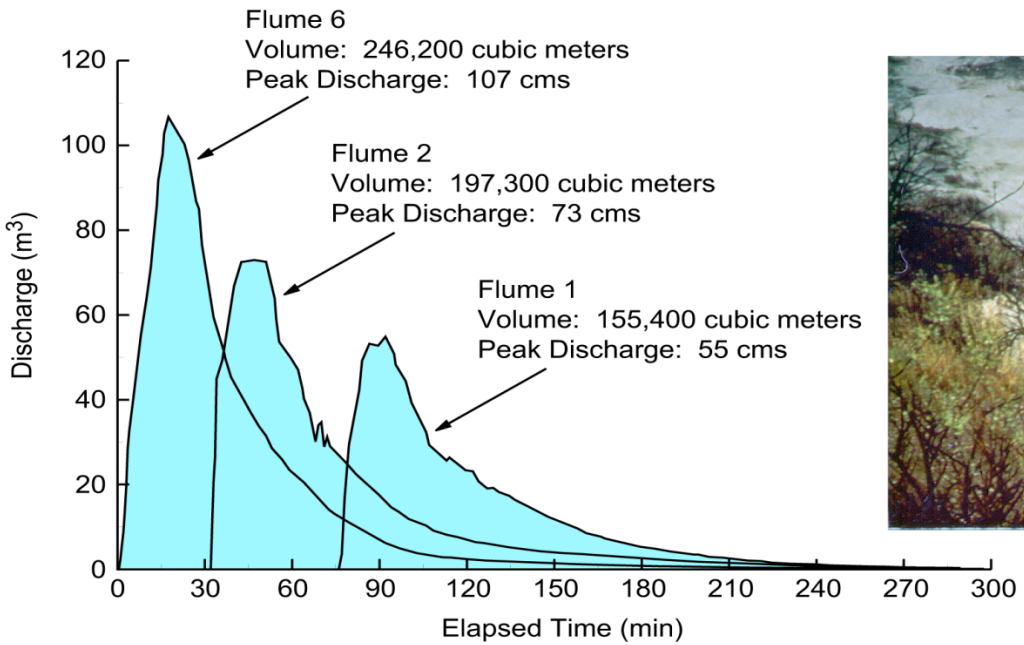
WGEW INSTRUMENTATION



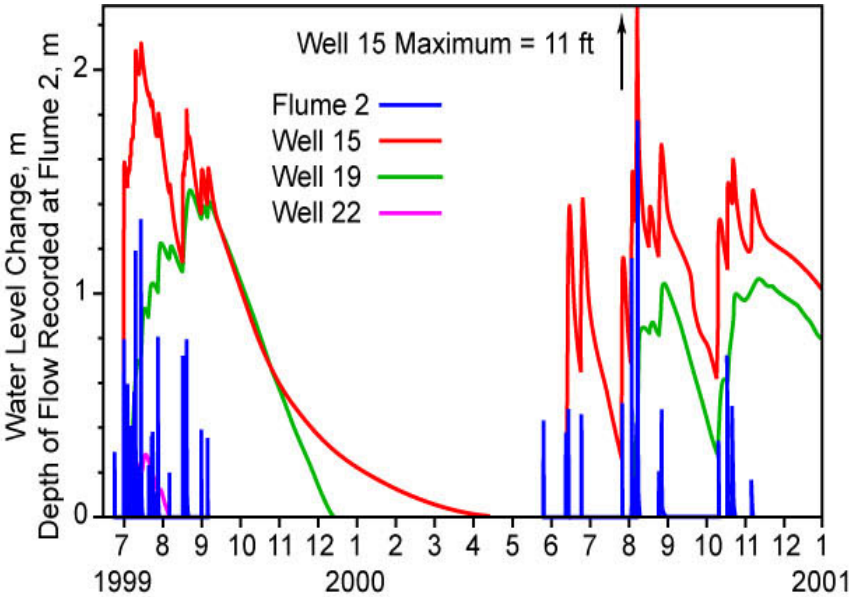


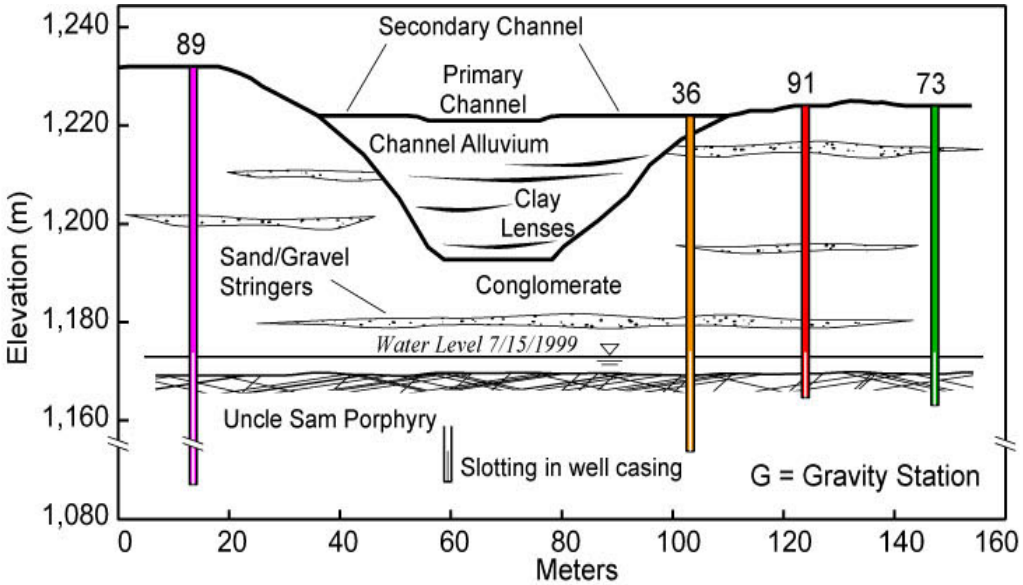
Nested Watersheds – Quantify Channel Trans. Losses

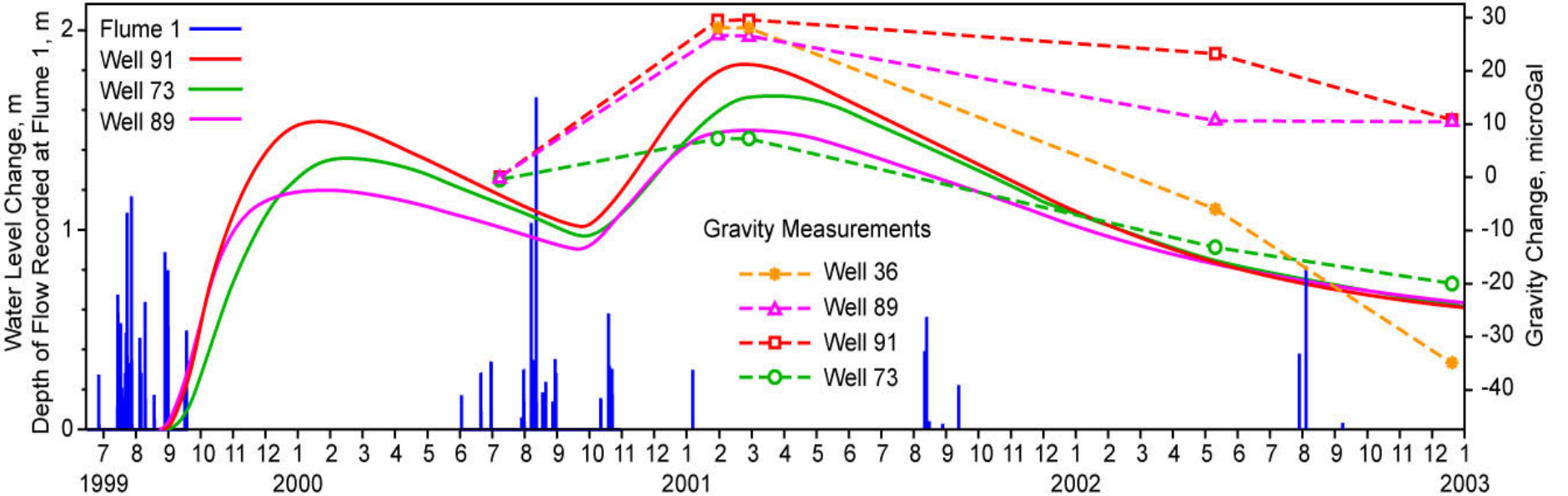




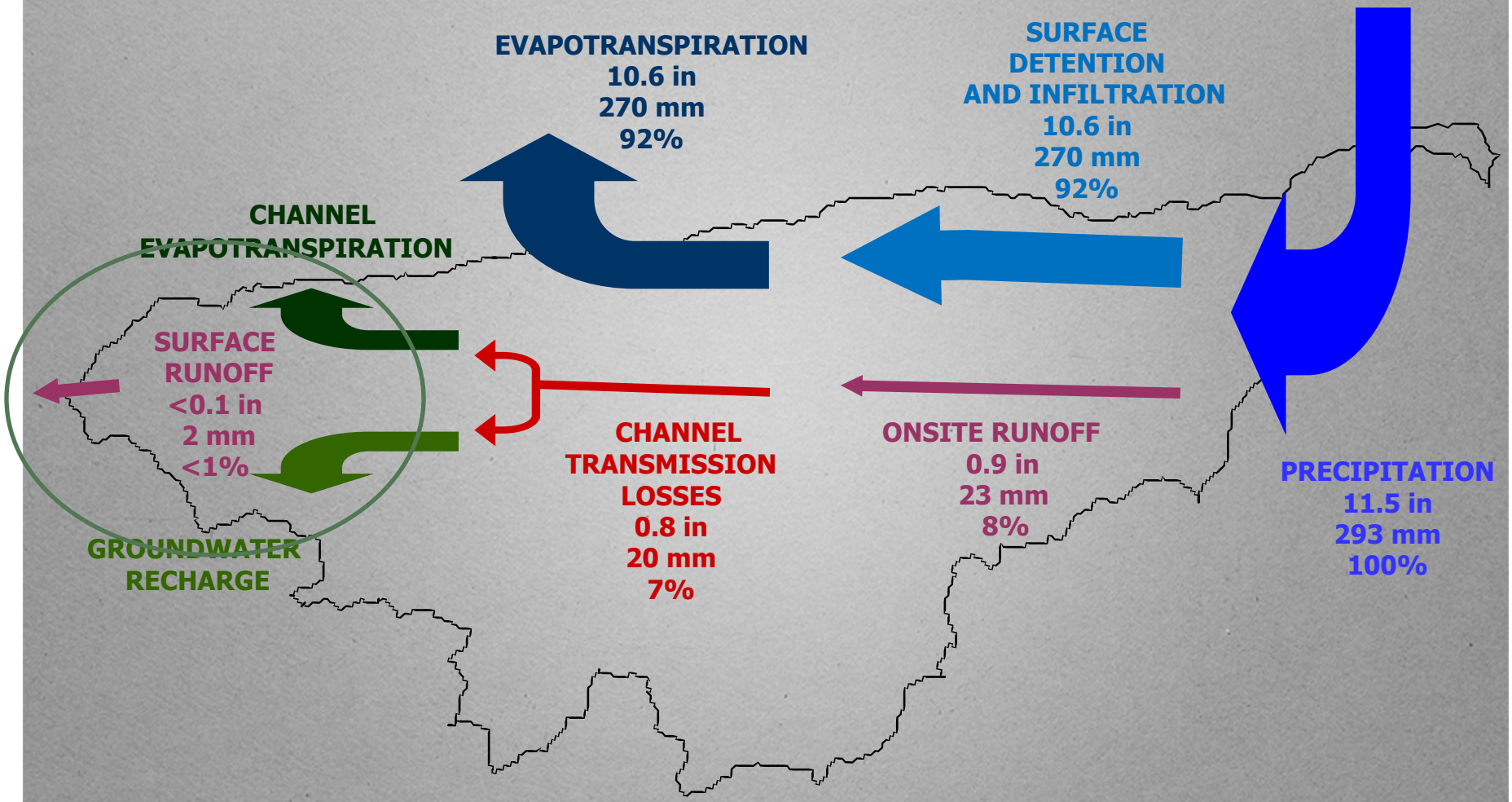
OBSERVATIONS – Ppt, Q, GW, Microgravity





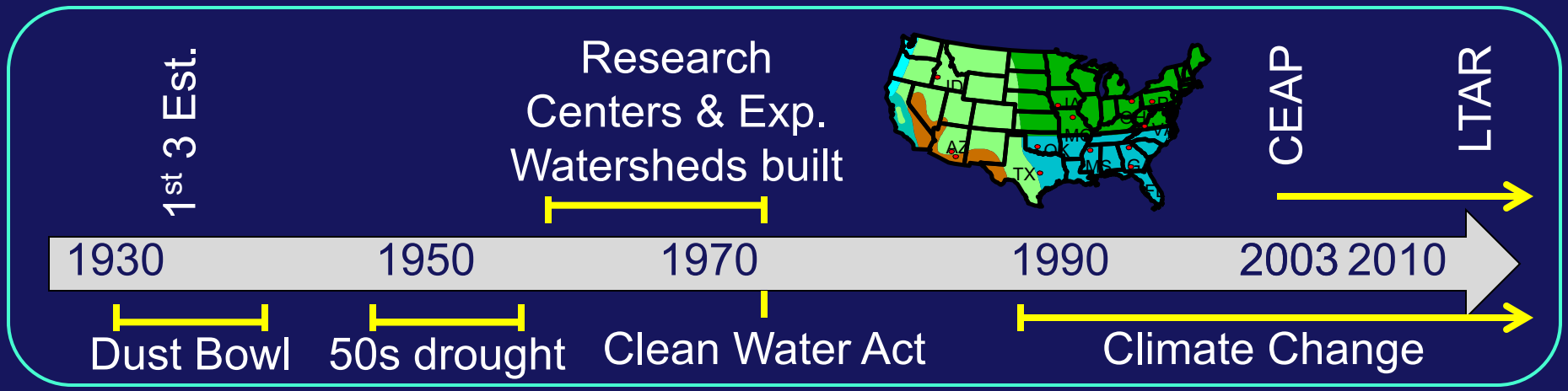


WALNUT GULCH EXPERIMENTAL WATERSHED
ANNUAL WATER BALANCE



ARS Watershed Network Evolution

ARS is a mission driven agency – research is not just for research sake but to address issues important to society, agriculture & the environment



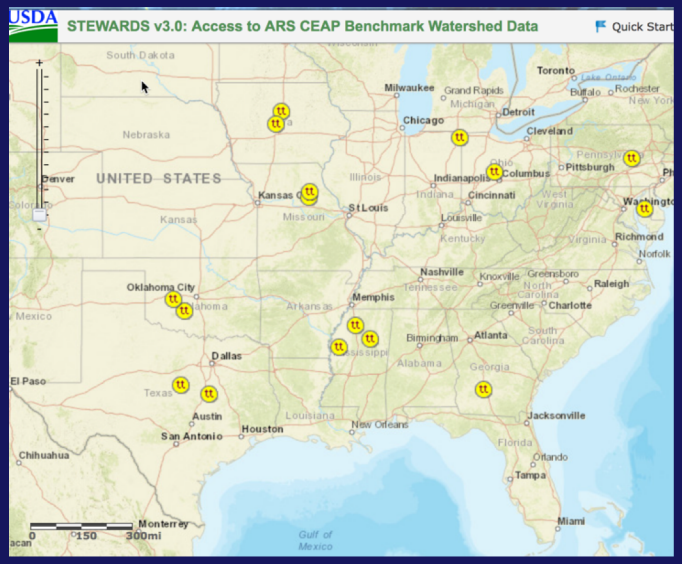
- ARS Exp. Watershed Network initially established in response to droughts and soil loss focusing on water and soil conservation
  - Instrumentation and data collection largely uniform – analog
- With the CWA, water quality data collection was expanded; regional differences in Ag. production lead to different WQ concerns
  - This and budget limits led to divergence in network data collection
- 2002 Farm Bill – OMB – what are we getting for conservation spending? Initiated CEAP (Conserv. Effects Assessment Project)
- As climate change awareness increased many locations added energy and carbon flux monitoring and recently soil BGC

CEAP

- Conservation Effects Assessment Project (CEAP) is a multi-agency effort to quantify the environmental effects of conservation practices and programs
- Develop the science base for managing the agricultural landscape for environmental quality and guiding USDA conservation policy
- CEAP was initiated in 2003 by NRCS, ARS, and the National Institute of Food and Agriculture (NIFA) in response to Congressional and OMB requests for greater accountability to taxpayers following a near doubling of USDA conservation program funding in the 2002 Farm Bill.

STEWARDS Database

- Sustaining the Earth's Watersheds-Agricultural Research Data System (currently cropland centric)
  - Web-based access to of soil, water, climate, land management, and geospatial data produced by Conservation Effects Assessment Project (CEAP) watershed research sites across the United States.
  - Data access via ArcGIS Server and MS SQL Server
  - Access to high-resolution imagery
  - Enhanced graphing options



https://www.nrrig.mwa.ars.usda.gov/stewards/stewards.html

Steiner, et al (2008). J. Soil Water Cons. 63(6):569-576.

NUMEROUS ACCOMPLISHMENTS

- Effectiveness of conservation and BMPs in reducing runoff, erosion, and water quality impacts of Ag. production
- Environmental impacts of Ag. chemicals at the watershed scale
- Guidelines for reclamation of disturbed lands
- EPA guidelines based on watershed response
- Value of riparian ecosystems in improving water quality
- Instrumentation development and hydraulic structure design
- Effects of floodwater retarding structure
- Development & validation of numerous remote sensing products
- Water supply forecasting
- Numerous, widely used, watershed, WQ & natural resource management process based models

… while maintaining continuity the ARS watersheds have adapted to meet changing research needs and *regional issues*

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Challenges with Changing Technology

- Mechanical clocks – analog charts
  - ~ 7000 charts/yr to digitize at Walnut Gulch alone
  - When converting to digital had to run both gauge types in parallel for 5 yr to understand differences
  - Phase I internet data accessibility estimated to cost ~$700,000

- Measurement instruments suitable for one part of the country may not be appropriate for other regions
  - Runoff estimates from the east/midwest too low for SW

- Measurement technology may not be available "off the self" but developed by trial and error
  - Pump samples of sediment are not representative of total transport in the SW

ARS Watershed Network Evolution

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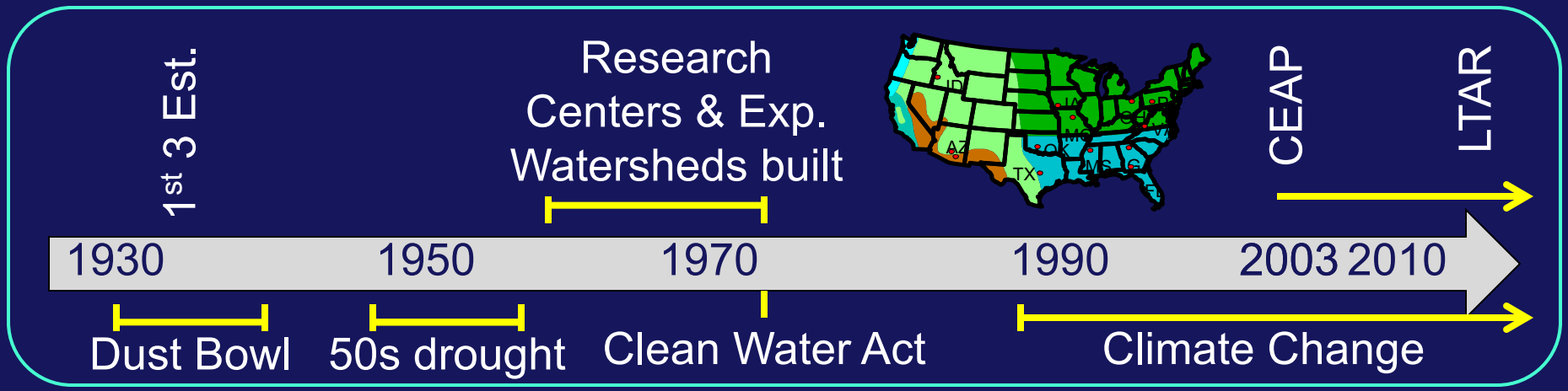

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Future – Long Term Agro-Ecosystems Network

Subset of ARS Exp. Watersheds & Ranges selected to be part of LTAR + several Non-ARS locations

Vision: Multi-decadal trans-disciplinary science in different regions to enhance the sustainability of agro-ecosystems goods and services.

Goal: To sustain a land-based infrastructure for research, environmental management testing, and education that enables understanding and forecasting of the Nation's capacity to provide agricultural commodities, ecosystem services, and rural prosperity under changing conditions.

- Intensify Ag. Production while maintaining Ecosystem Services
- To help understand how agricultural system interact at watershed & landscape scales
- To help anticipate the Environ. effects of shifting agricultural practices
- To help improve the effectiveness of conservation programs
- To help identify societal benefits of agriculture (bio-energy production; carbon sequestration; improved WQ & water-use efficiency; habitat)

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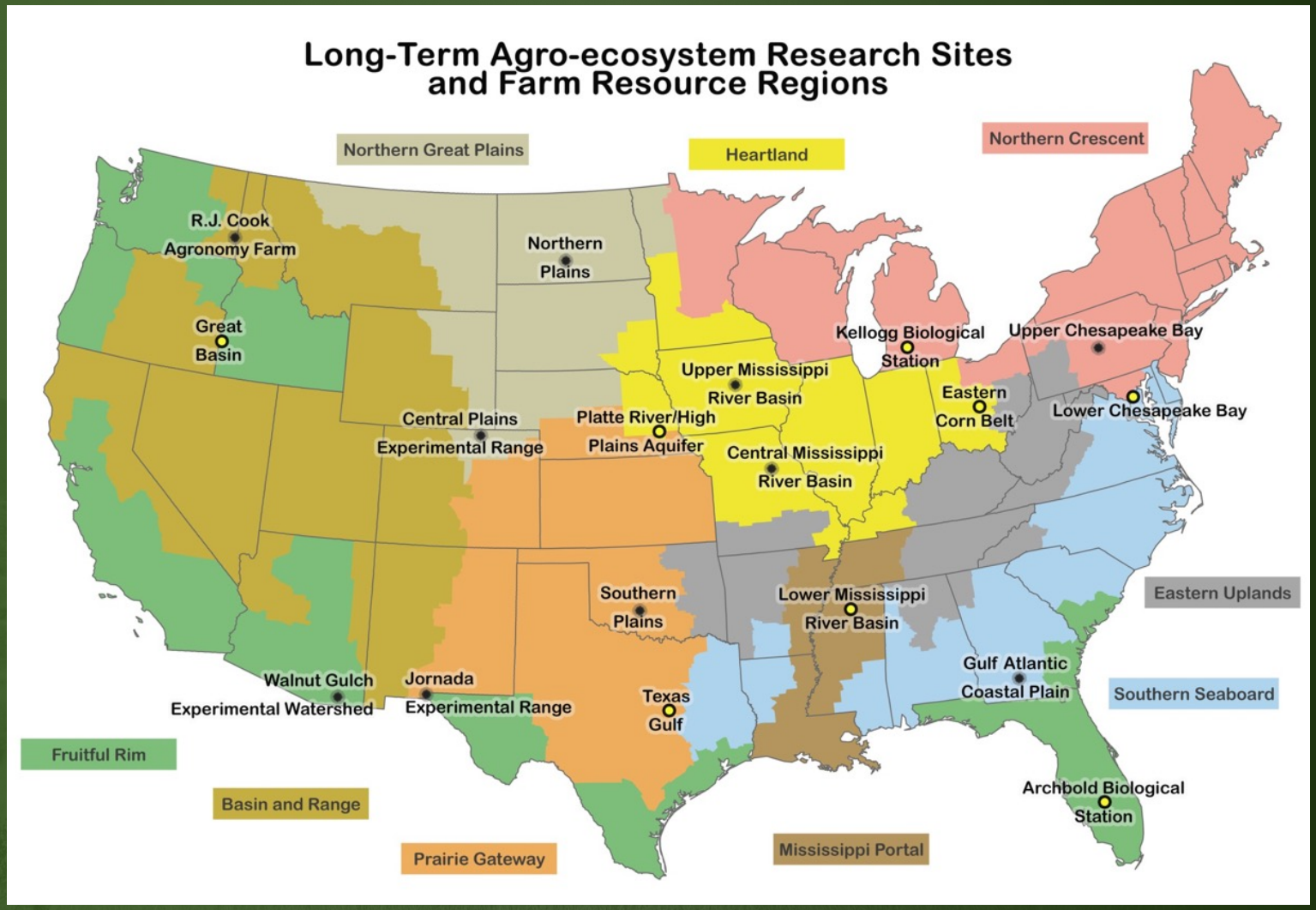
The LTAR Network



18 Sites - includes ARS Experimental Watersheds, Ranges, two Biological Stations and two Research Farms

USDA ARS Southwest Watershed Research Center Tucson, Arizona

LTAR – Integration of Crop, Animal, and Economic Sciences with Watershed & Ecosystem Sciences

P/A/E: New cultivars or animal breeds

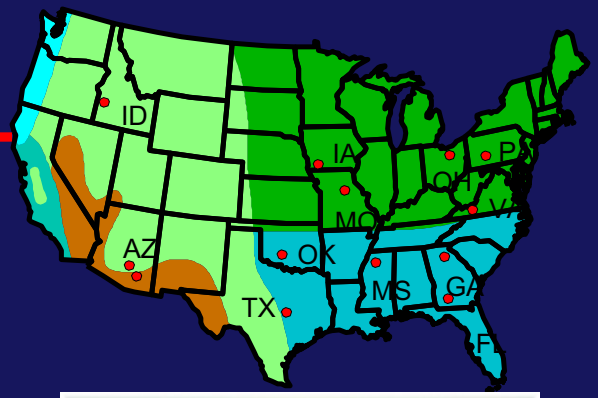
- Evaluate at plot/field scale
- Common Obs. (yield, plant stress, fertilizer inputs, erosion, costs, etc.)
- Limited trial periods

Agro-Ecosystems

- Monitor at watershed or landscape scale
- Common Obs. (runoff, sediment yield, WQ/BGC, etc.)
- Over longer periods

- Many common Obs. (Ppt, Temp, RH, soil moisture, ET and carbon fluxes)
  - Different time and spatial scales
  - Used for different predictive purposes
- Attempt effectively combine these approaches to assess integrated effects of new crops, animals, pests, and management/conservation practices on:
  - Production and economics
  - ESS (soil quality, downstream WQ, GW quality, etc.) over the long-term, with a changing climate?

Lessons Learned - Challenges



- Instrumentation may not be universally suitable over diverse environments
- Trial and error will be inevitable
- Time and expense for permitting and access permission is considerable
- Personnel with good technical, field, and fabrication skills are in short supply
- Centralized funding model will help ensure network uniformity
- Science and societal challenges will emerge that the network designers did not anticipate
- How does a interoperable network evolve to not only incorporate new technology and address new regional issues but also collect measurements that may be regionally important for a subset of the network and not for other portions of the network?

Moving Forward

- Nat. Ag. Library house LTAR and Exp. Watershed data
- What new core observations should be added to the entire network? (Trace gases, water and wind erosion, ET and CO2 fluxes, and imaging, among others ?)
- How will the network evolve to incorporate new technology and address new national and regional issues?
- As a research network, its evolution should not be solely driven by standardized instrumentation, uniform data collection for all variables, and centralized database management.
- The network should address national issues that require region-specific data collection to address region-specific problems, and develop high-impact region-specific solutions.
- The network should be defined by its capability to address national issues across physiographic and environmentally diverse regions, not as an assemblage of region-specific data of the various watersheds and rangelands dispersed across the continent.