A Thought Exercise

Building Hydrologic Resilience to Climate Change is Analogous to and Synonymous with Salmonid Ecosystem Restoration

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SRF 2015

Definitions and Context

Hydrologic Resilience -

:ability to sustain water dependent economic systems and ecological services in the face of changing climactic conditions

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“Hydrologic resilience of the system can be affected by both human and natural elements.”

Linked Hydrologic And Social Systems That Support Resilience Of Traditional Irrigation Communities

A. Fernald et. al., Hydrology and Earth Systems Science. 19, 293–307, 2015
www.hydrol-earth-syst-sci.net/19/293/2015/
doi:10.5194/hess-19-293-2015

Definitions

Analogous –

:comparable in certain respects

:showing a likeness that permits one to draw an analogy

:similar to another situation, process, etc. so that the same things are true of, or relevant to both

Definitions

Synonymous -

:having the same meaning

:closely associated with

:very strongly associated with something

Definitions

Climate Change –

:Rising global temperatures accompanied by changes in weather and climate; changes in rainfall, resulting in more floods, droughts, or intense rain, as well as more frequent and severe heat waves…

"As these and other changes become more pronounced in the coming decades, they will likely present challenges to our society and our environment."

http://www.epa.gov/climatechange/basics/

Definitions

Salmonid Ecosystem Restoration –

:Long term freshwater salmonid habitat protection and restoration to conserve fish abundance and productivity

Two Scales of Restoration

- **Finer scale**: actions designed to improve in-stream habitat, *e.g.*, reconnection of side channels, removal of dikes and culverts, restoration of natural bank conditions…
- **Coarse scale**: protect and restore watershed hydrologic function, *e.g.*, reforestation, reduction of impervious surfaces…

From **Projected Impacts of Climate Change on Salmon Habitat Restoration**

Battin *et.al.*, NOAA NWFSC, University of Washington, Pacific Institute for Studies in Development, Environment and Security. February 2007

Climate Change Projections

"The rate of climate change over multi-decadal scales is also important, with faster rates of change resulting in less time for human and natural systems to adapt."

From **Near-term Acceleration In The Rate Of Temperature Change**

Steven J. Smith,
James Edmonds,
Corinne A. Hartin,
Anupriya Mundra
& Katherine Calvin

Nature Climate Change
(2015)
doi:10.1038/nclimate2552

Figure 3: Past and future regional rates of change from CMIP5.

From

Near-term acceleration in the rate of temperature change

Steven J. Smith, James Edmonds, Corinne A. Hartin, Anupriya Mundra & Katherine Calvin

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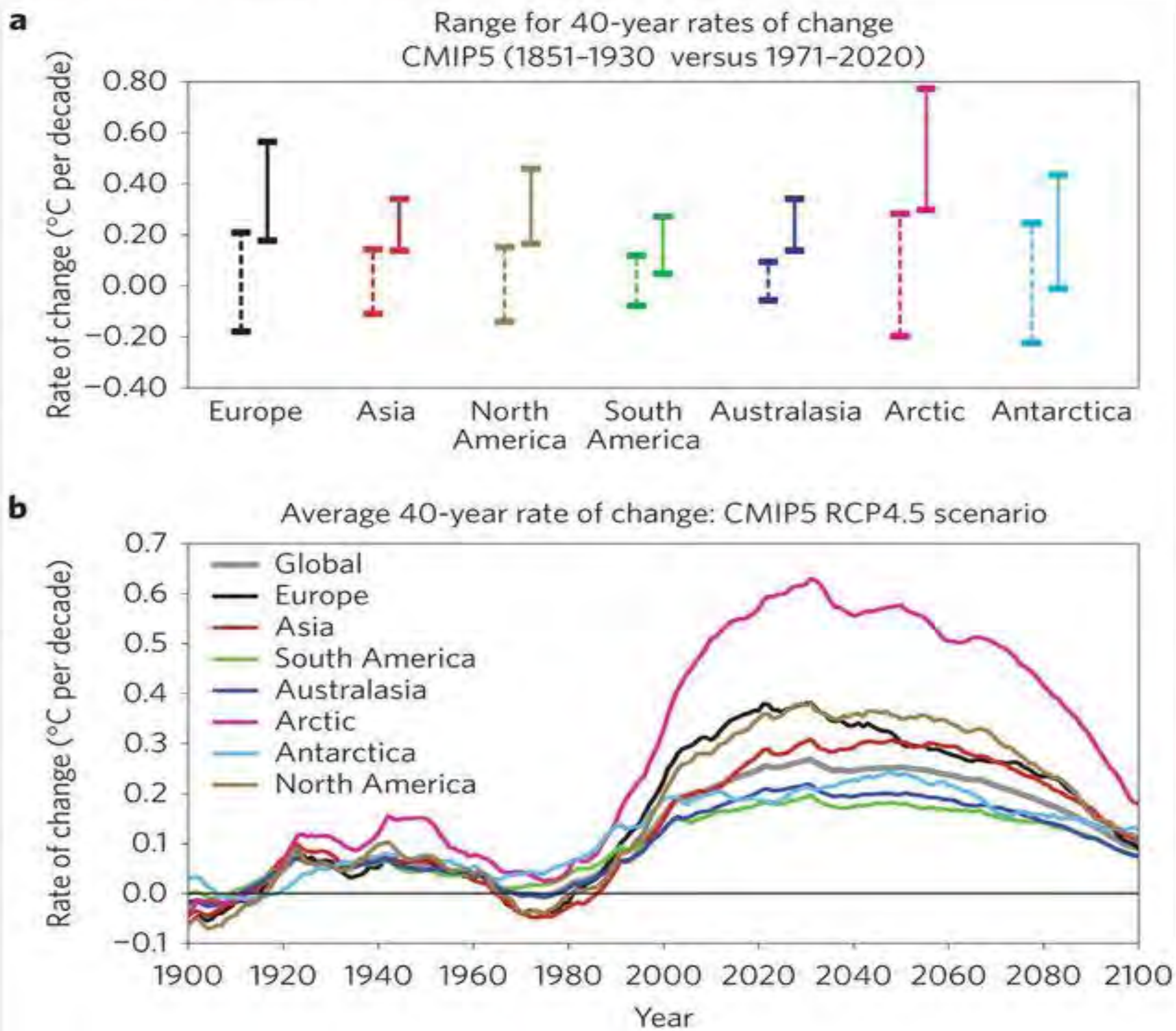
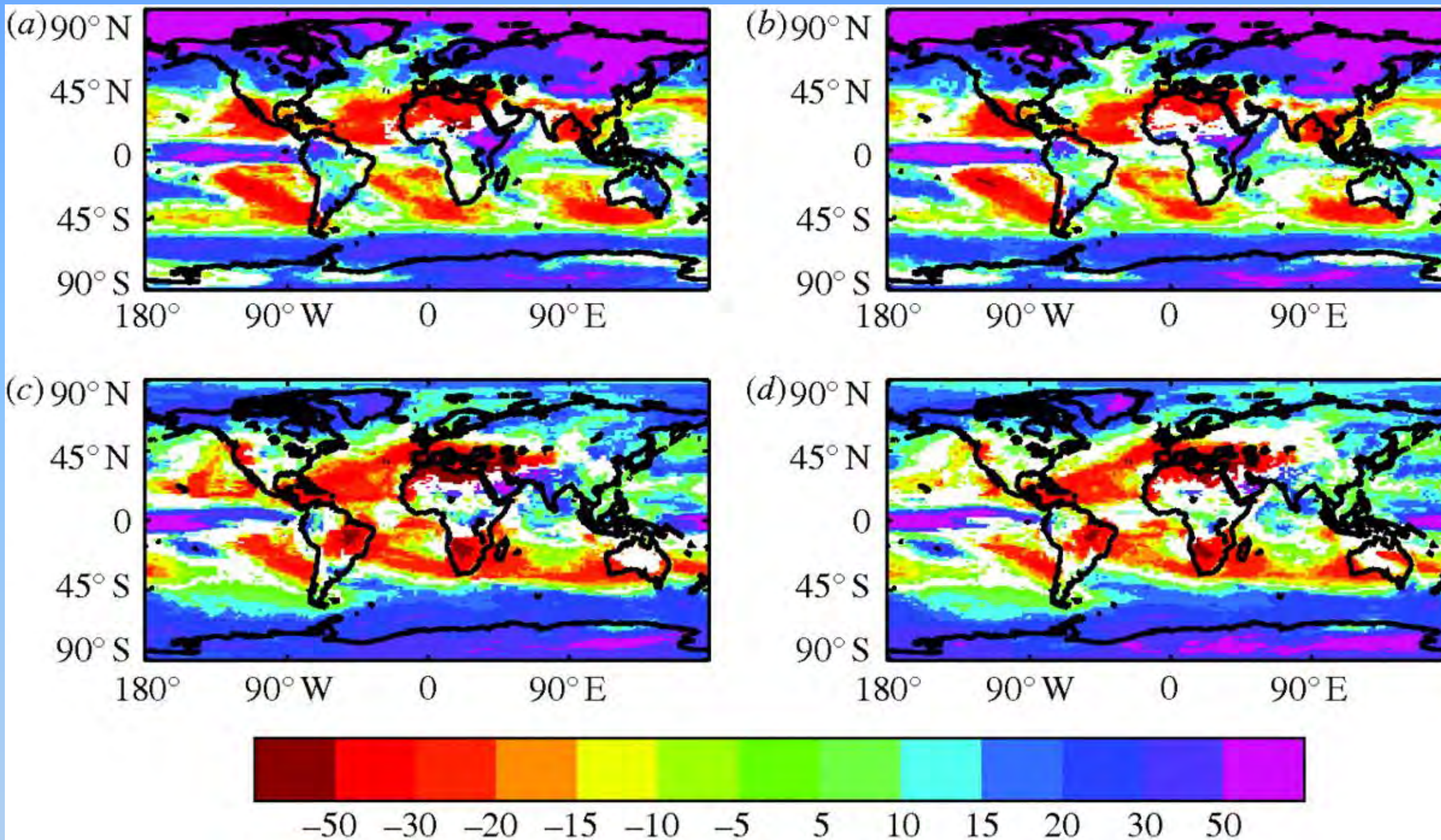


a, 5–95% occurrence range of the decadal rate of change over 40-year periods from the CMIP5 archive over a time with small anthropogenic influences (1851–1930, dotted lines) and a period centred on the present (40-year periods ending in 2011–2020, solid lines) from the RCP4.5 scenario. Because the CMIP5 archive is a 'sample of convenience', these percentages should not be interpreted as probabilities. **b**, Average over CMIP5 models for the regional rate of change. Rates of change in this figure are annual averages over land + ocean areas in each region.

Precipitation changes (%) in (a,b) DJF and (c,d) JJA from the median of the A2 ensemble, after scaling to 4°C global mean warming in all cases.



M. G. Sanderson et al. Phil. Trans. R. Soc. A 2011;369:85-98

Basin Characterization Model* (BCM) coupled with a General Circulation Model** (GCM) for California Ecoregions

"This broader scope provides insight into multi-watershed or landscape-scale ecosystem dynamics, as well as being able to calculate hydrologic response with the spatial resolution to capture habitat-relevant processes."

From **The magnitude and spatial patterns of historical and future hydrologic change in California's watersheds**. Thorne, J. H., R. M. Boynton, L. E. Flint, and A. L. Flint. 2015. Ecosphere 6(2):24. http://dx.doi.org/10.1890/ES14-00300.1

*Flint and Flint 2007; Flint 2013 **General Fluid Dynamics Laboratory (GFDL)

Coupled Models Basin Projections of Drying

"Focusing on four BCM outputs—
snowpack,
climatic water deficit (CWD),
recharge, and
runoff—we asked:"

Thorne, J. H., R. M. Boynton, L. E. Flint, and A. L. Flint. 2015. **The magnitude and spatial patterns of historical and future hydrologic change in California's watersheds.** Ecosphere 6(2):24. http://dx.doi.org/10.1890/ES14-00300.1

“1. What is the magnitude of historical and projected future change in the hydrologic cycle?

2. Are watersheds that show the greatest historical change the same as those predicted to have the greatest change under future conditions?

3. To what degree are the same watersheds most sensitive to hydrologic stresses under both wetter and drier futures?”

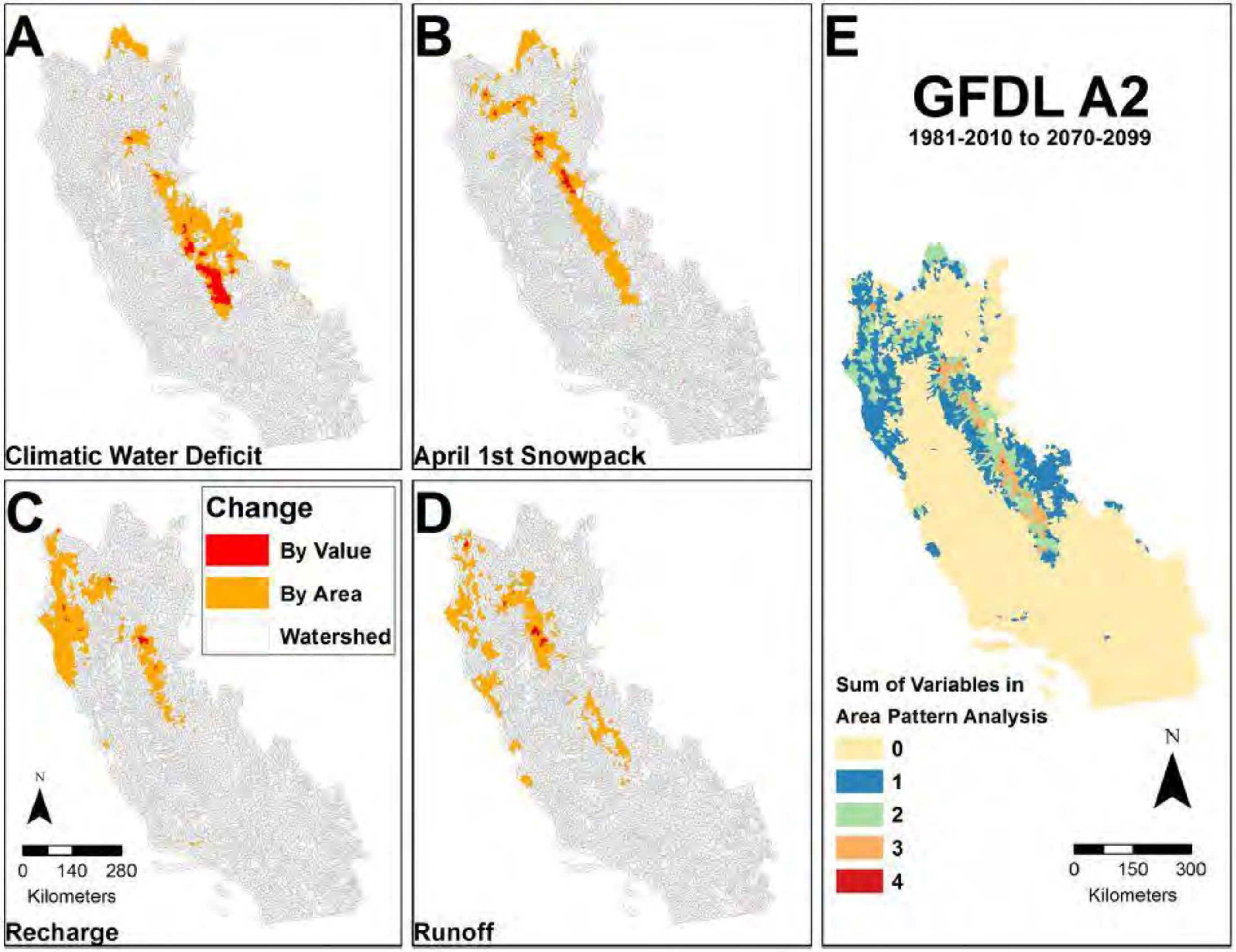
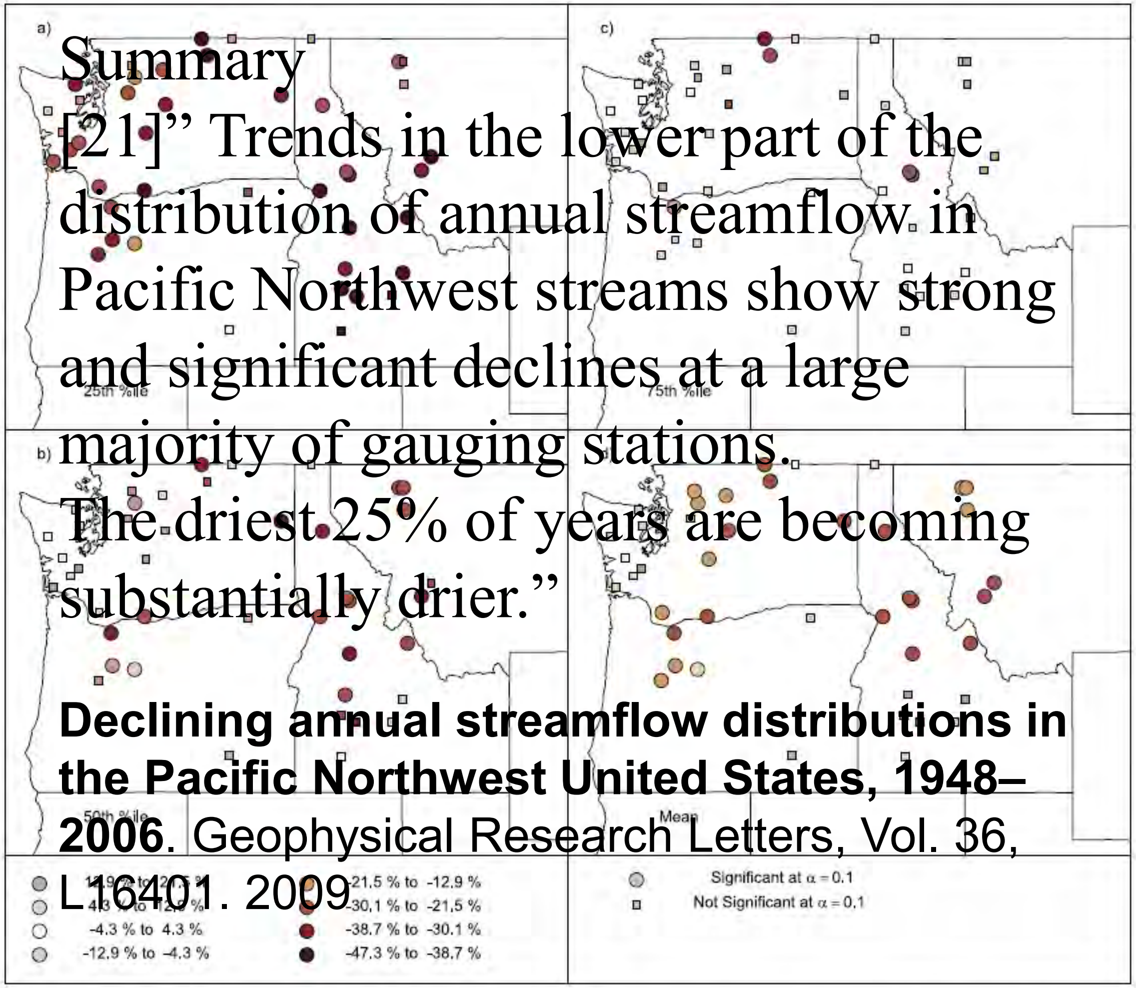


Fig. 7. Future change in BCM outputs from 1981–2010 and 2071–2100. The watersheds in orange are the 514 (10%) of 5135 watersheds with the highest amount of change towards drier conditions (decreasing snowpack, recharge and runoff, and increasing CWD) projected under GFDL A2 (A–D). Watersheds shown in red represent the watersheds whose changes were in the top 20% of change for each variable. The sum of the 514 watersheds projected to have the most change from each of the four categories (E) is shown, to identify basins that are in the highest category (most exposed) for two or more hydrologic parameters.

Hydromodification is a reality.
Desertification is already underway, before considering climate change

- Massive land drainage programs
- Channelization
- Incision
- Urbanization
- All reducing water storage

Decreased stream flows have already occurred:



Summary
[21]" Trends in the lower part of the distribution of annual streamflow in Pacific Northwest streams show strong and significant declines at a large majority of gauging stations.
The driest 25% of years are becoming substantially drier."

Declining annual streamflow distributions in the Pacific Northwest United States, 1948–2006. Geophysical Research Letters, Vol. 36, L16401. 2009

Figure 2. Maps of changes to (a) 25th percentile annual flow, (b) 50th percentile annual flow, (c) 75th percentile annual flow, and (d) mean annual flow across HCDN stations in the Pacific Northwest 1948–2006.

Evolutionarily Stable Strategy(ESS)

- Set of strategies allowing persistence through time.
- Game theory, - strategy sets used depending on actions of other players.
- Species strategy sets: genotypic variants, and phenotypic expression.
- Individuals express traits differentially in strategic interactions with the environment.

Salmonid Life Cycle Models

Based on the success of transition, or the survival rate to each successive life history stage, these models can provide insight on ESS of salmonids.

TRANSITION SURVIVAL RATES

AVERAGE

Two spawning adults, transition to *Eggs* in the gravel ------------------ = 5000 Eggs

Eggs in the gravel to emergent *Alevin* transition-----70 to 90 % --- = 4000 (0.80)

Alevin to free swimming *Parr* transition -------------- 1 to 7 % ------- = 140 (0.035)

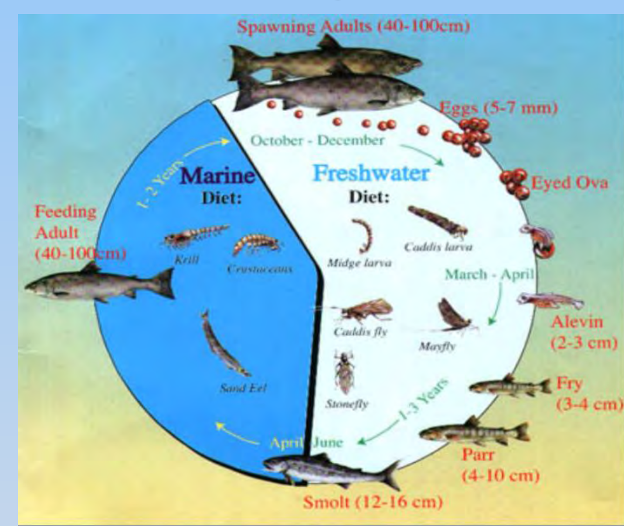
Parr to Ocean entry *Smolt* transition ------------------1 to 20 % ----- = 14 (0.10)

Smolt to Ocean feeding *Adult* transition -------------1 to 18 % ----- =1.26 (0.09)

Ocean Adult to Freshwater *Spawner* -----------------90 % --------- =1.1 Spawners

Unimpaired Watershed Conditions

*Bradford, M.J. 1995. *Comparative review of Pacific salmon survival rates*



Upper Yuba River Life Cycle Model:

~25% of fry rear in natal streams prior to outmigration, yet account for **94 percent** of returning adults.

75 % of emergent fry migrate downstream to rear in the estuary and main river wetlands, but account for only 6 percent of returning adults!

Modeling Habitat Capacity and Population Productivity for Spring-run Chinook Salmon and Steelhead in the Upper Yuba River Watershed

Technical Report, Stillwater Sciences 2012.

Prepared for National Marine Fisheries Service

Ecological Applications, 17(1), 2007, pp. 66–80

DISTRIBUTION OF SALMON-HABITAT POTENTIAL RELATIVE TO LANDSCAPE CHARACTERISTICS AND IMPLICATIONS FOR CONSERVATION

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“widespread recovery of coho salmon is unlikely unless habitat can be improved in high-intrinsic-potential reaches on private lands.”

<u>These are floodplains; alluvial valleys.</u>

What is a hydrologically resilient hydrologic system?

Lost Water Storage Potential

- Incised channels lower the water table in their valley, reducing water held in aquifer storage.
- How big is this issue ?
- Every alluvial valley is incised and channelized or leveed, thus floodplains are disconnected.
- But how much water is that really?
- Is it “desertification” prior to climate change?

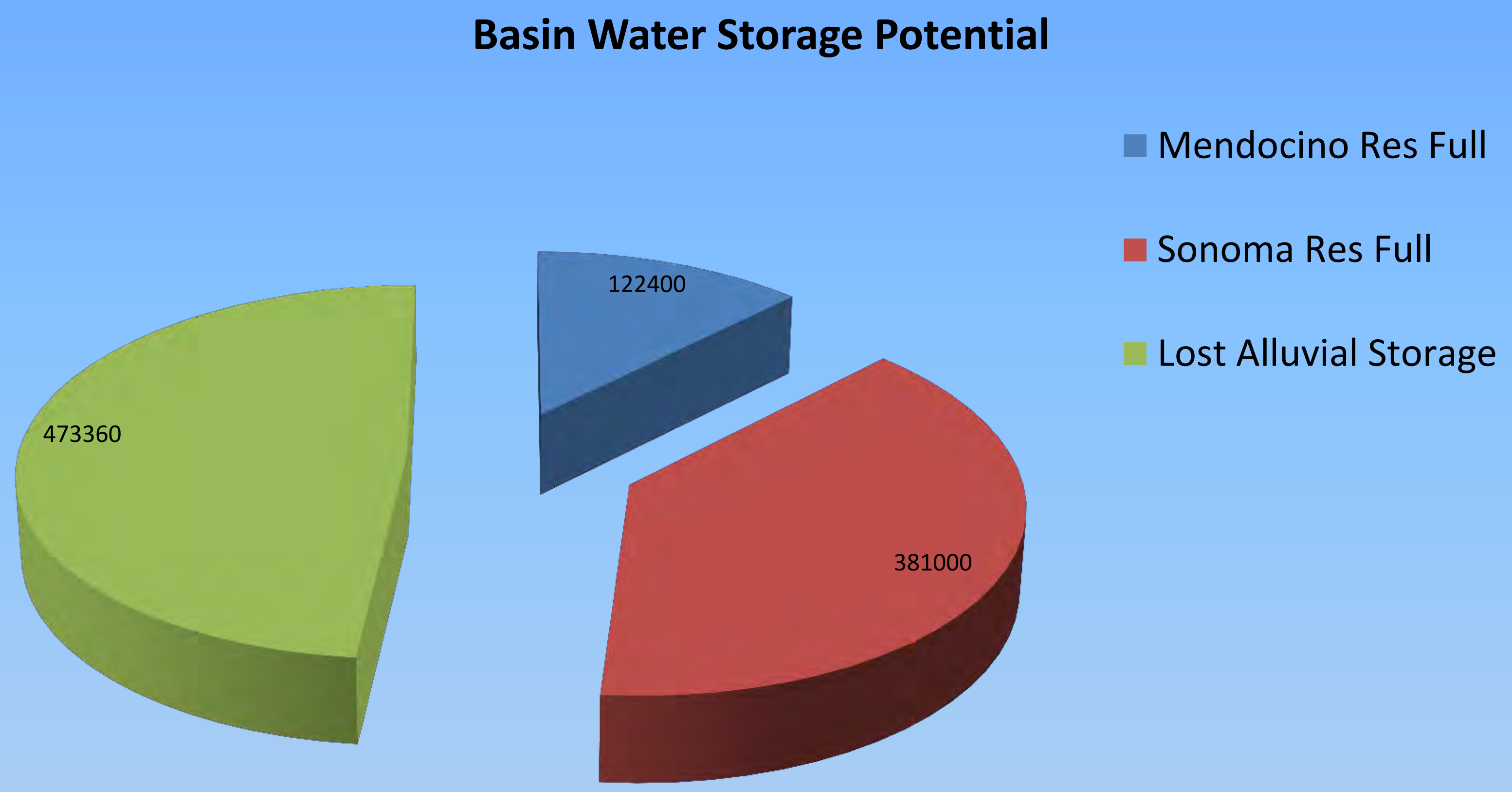
Aquifer Water Storage Potential

- A Russian River example:
- Willow Creek between 2nd and 3rd bridges has aggraded.
- Water table is up ~ 6 feet in the 64 acre Valley. (State Parks land)
- At a low porosity of 20%, that is 77 acre feet of additional water now stored in the aquifer.
- That stored water has head, and feeds the habitat downstream.
- Averaged over the 6 month dry season, that is cold water flow of 0.22 cfs!

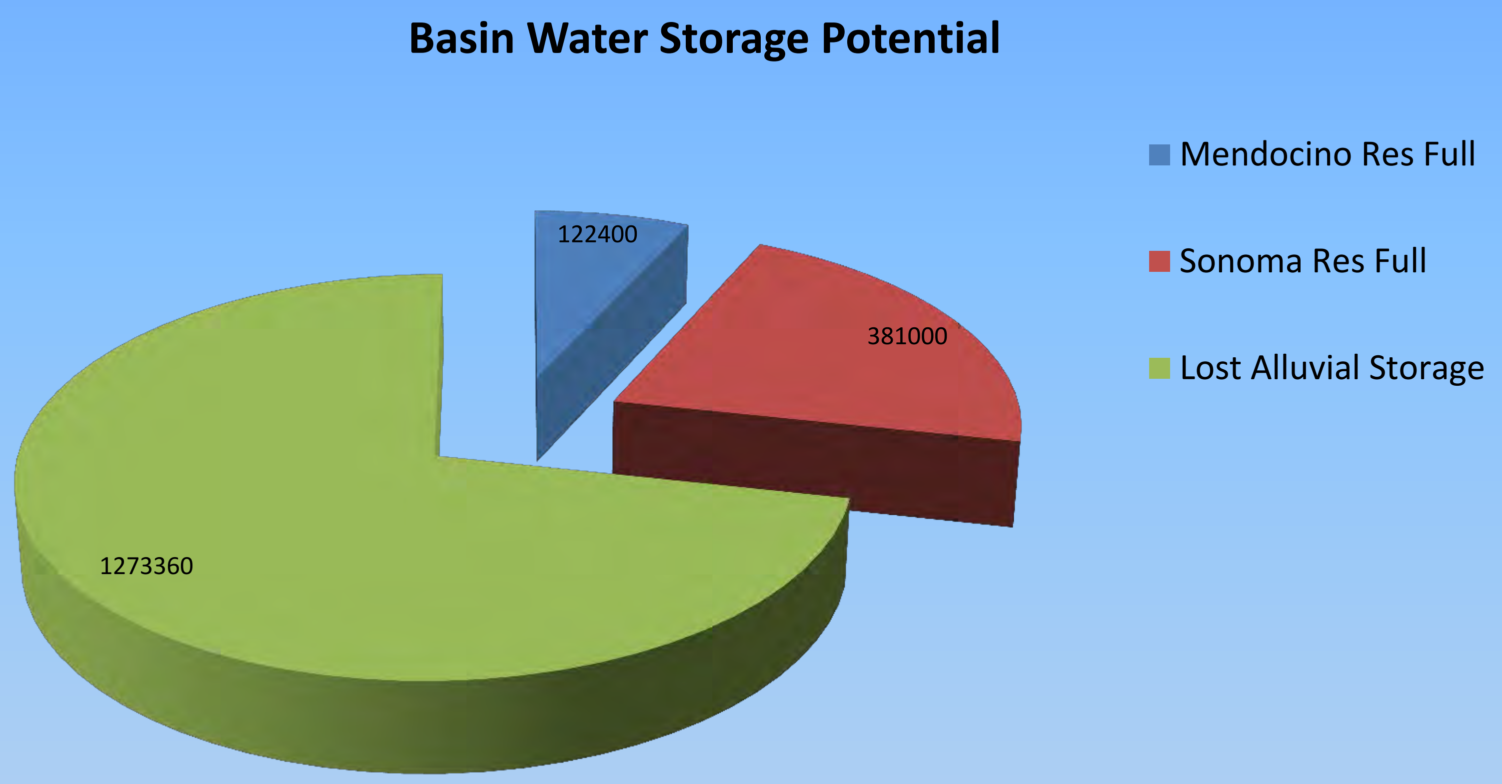
RR valleys water storage potential:

Valley	Unused thickness (ft)	Porosity estimate (%)	Acre Feet
Ukiah	20	30	31,800
Hopland	10	30	6,000
Alexander	10	30	50,500
Middle	20	30	48,300
Dry Creek	20	30	16,600
SR Plain	20	20	320,000
SR Plain with current pumping drawdown	*70*	20	*1,000,000*

Compared to surface reservoirs



Compared to surface reservoirs



Pumping drawdown included for SR Plain only.

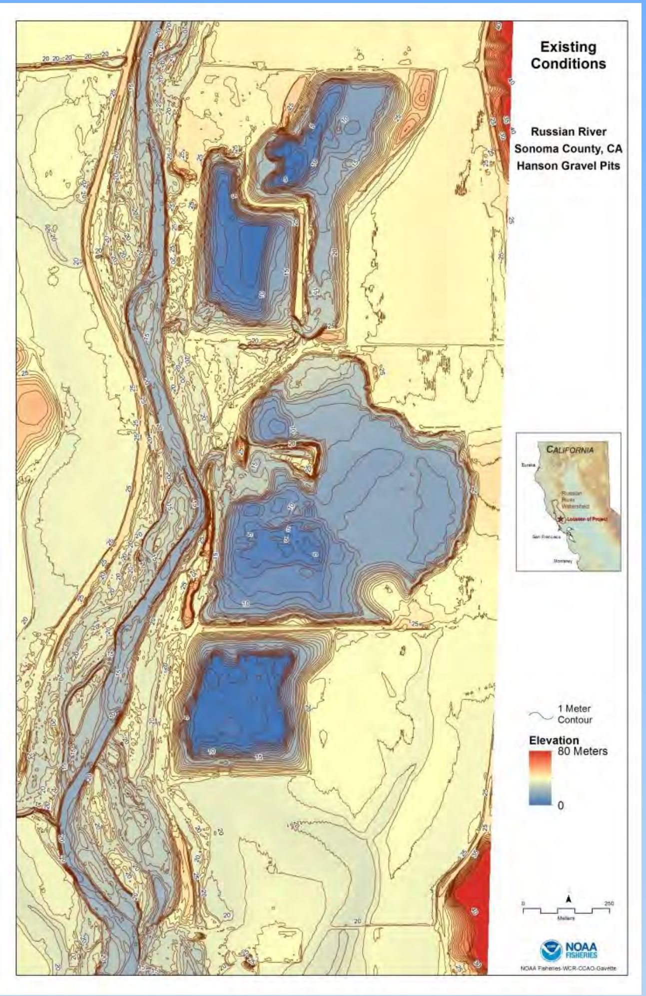
MUTUAL BENEFITS OF RECONNECTING CHANNELS TO FLOODPLAINS

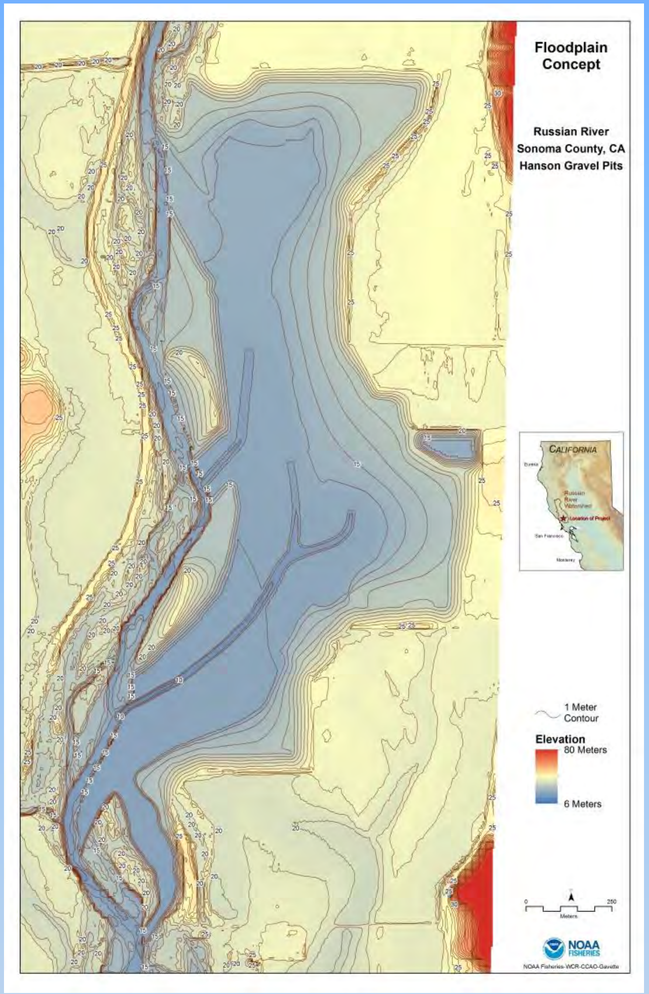
Hydrologic Resilience	**Ecosystem Restoration**
Floodwater attenuation: Reduce flood impacts on infrastructure, agriculture	Reduce redd scour frequency Increase channel meander and spawning/rearing quantity & quality
Water availability: Increase aquifer recharge.	Increase hyporheic flows Increase dry season flow resilience Decrease dry season temperatures
Reversing channel incision: Decrease bank failure Increase channel elevations Increase of aquifer storage	Increase shallow winter/spring rearing habitat, recruitment Increase off-channel habitat
Ecological Services: Sediment/nutrient/pollutant deposition and processing	Increase water quality and quantity, Increase invertebrate prey production.

To Re-build Resilient Systems:

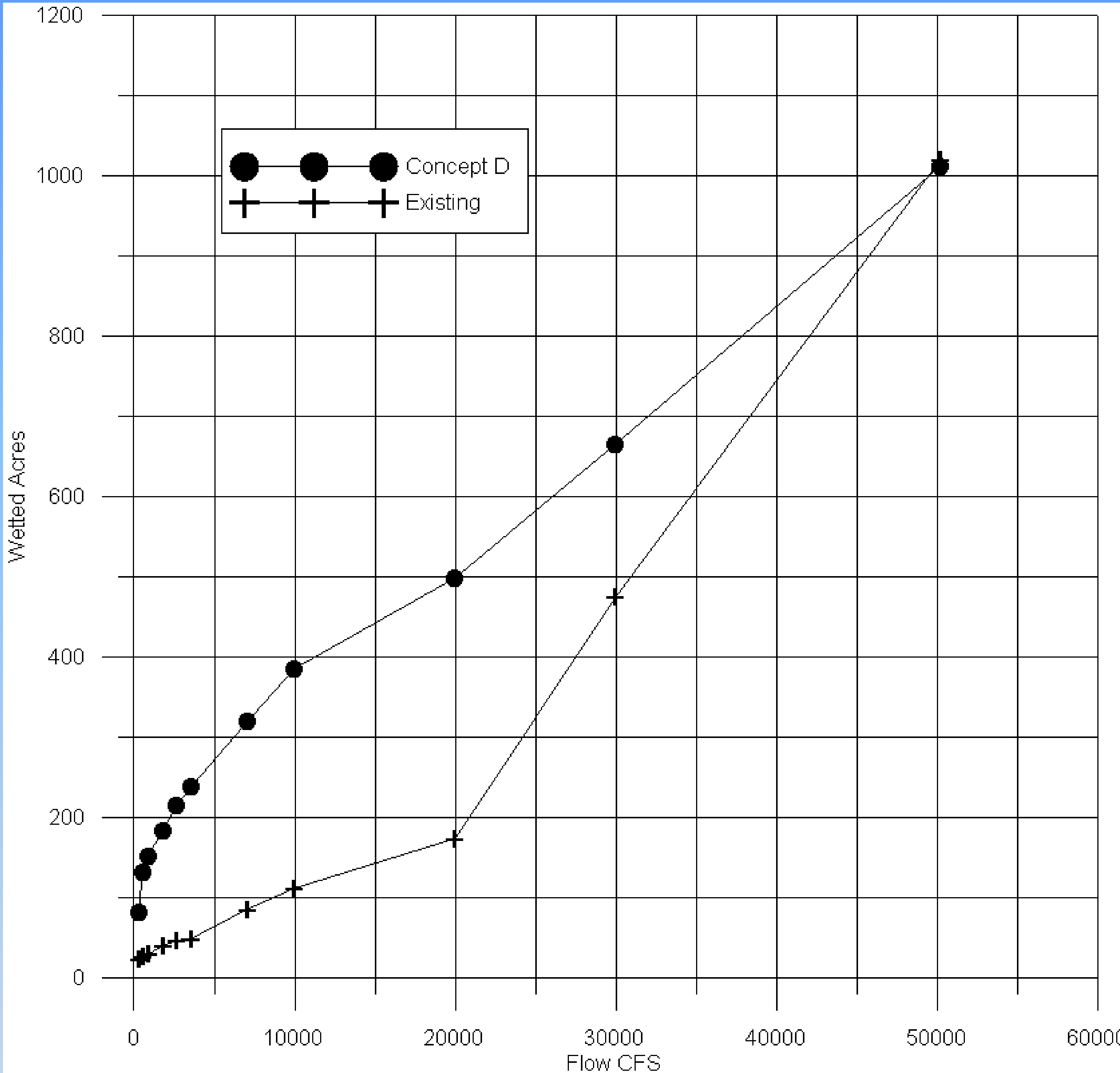
- Slow it, Spread it, Sink it, Store it, Share it!
- Need to judiciously and objectively evaluate opportunities to recharge aquifers via floodplain reconnections.
- Humans, commerce, and fish and wildlife will be beneficiaries.

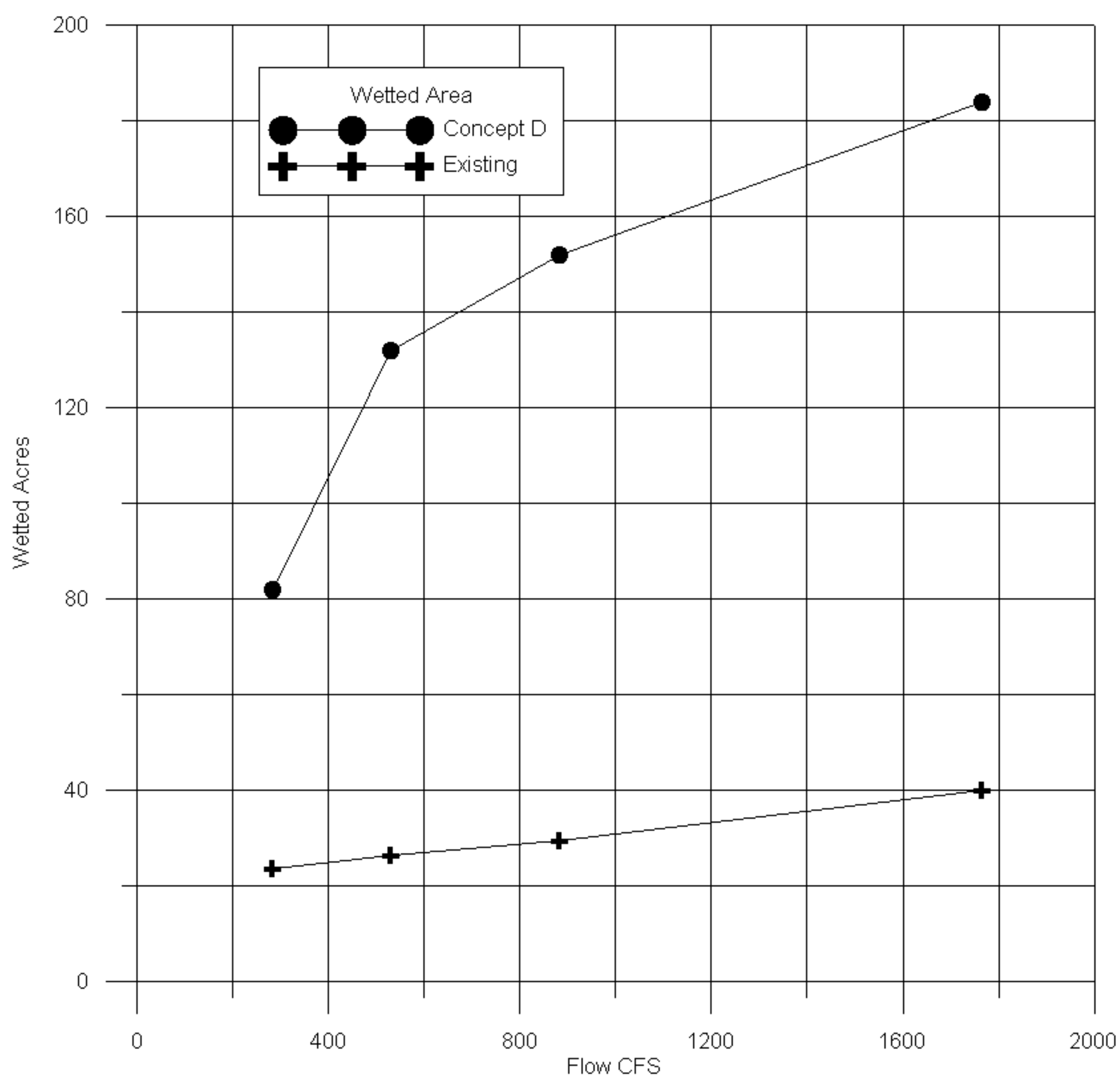
Summary


Existing Conditions
Russian River
Sonoma County, CA
Hanson Gravel Pits
1 Meter Contour
Elevation
80 Meters
0
NOAA FISHERIES


Floodplain Concept
Russian River
Sonoma County, CA
Hanson Gravel Pits
1 Meter Contour
Elevation
80 Meters
6 Meters
NOAA FISHERIES

Hanson gravel pits – floodplain project





Wetted Area
Concept D
Existing
Wetted Acres
Flow CFS
0
40
80
120
160
200
0
400
800
1200
1600
2000