Arroyo Toad Study Design for San Diego County, California

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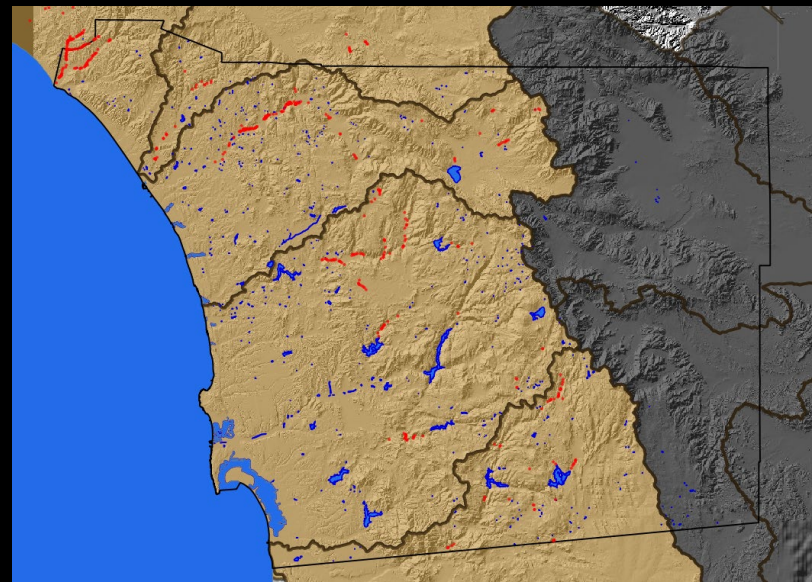

Basic Process

- Layers for watersheds, HUC12 units, and streams.
- Generate 125 m segments on stream layer.
- Hierarchically process watersheds, HUC12s, and stream segments to classify stream segments as:
  - Identifying HUCs with potential arroyo toad habitat
  - Discovery segments (about which little is known by may be toad habitat).
  - Core segments that will receive more intensive sampling.
  - Probabilistic segments that will be selected using a spatially balanced algorithm.
    - RRQRR order (explained below)
    - Optional stratification and/or inclusion probability
    - The number of sites that can be sampled based on funding and other constraints.

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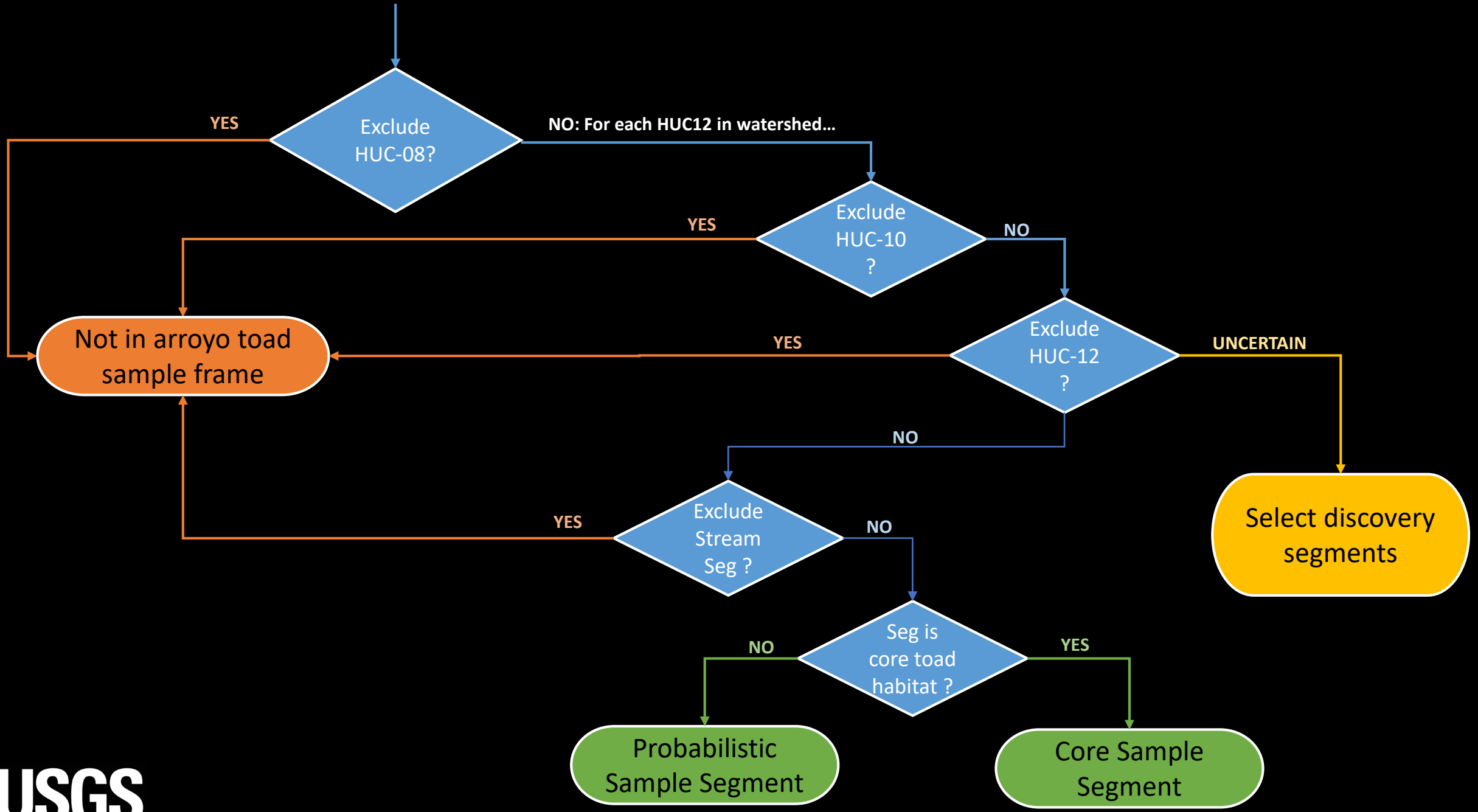

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Exclude HUCS

- HUC-08
  - Transmontane
- HUC-10
  - Not within selected HUC-08
  - Coastal with too much urbanization and no apparent toad habitat
- HUC-12
  - If observed toad locations: INCLUDE
  - If no observed toad locations but potential toad habitat: DISCOVERY
  - EXCLUDE if:
    - Not within selected HUC-10, or
    - No observed toad locations and no potential toad habitat

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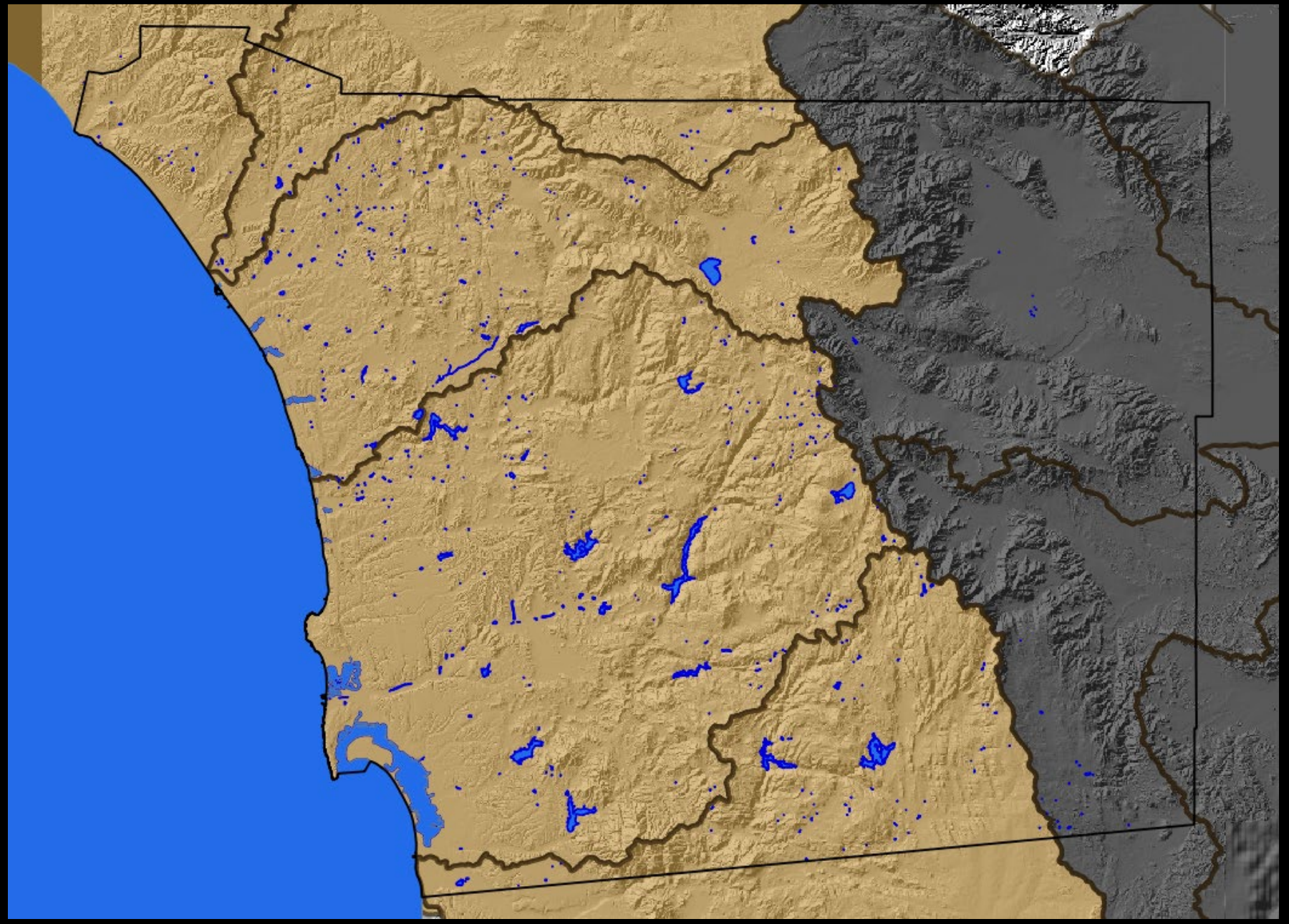
HUC-8 Level Selection

The gray HUC-08s are excluded because they drain into the desert. The HUC-08s in tan are passed through to the next level of selection.



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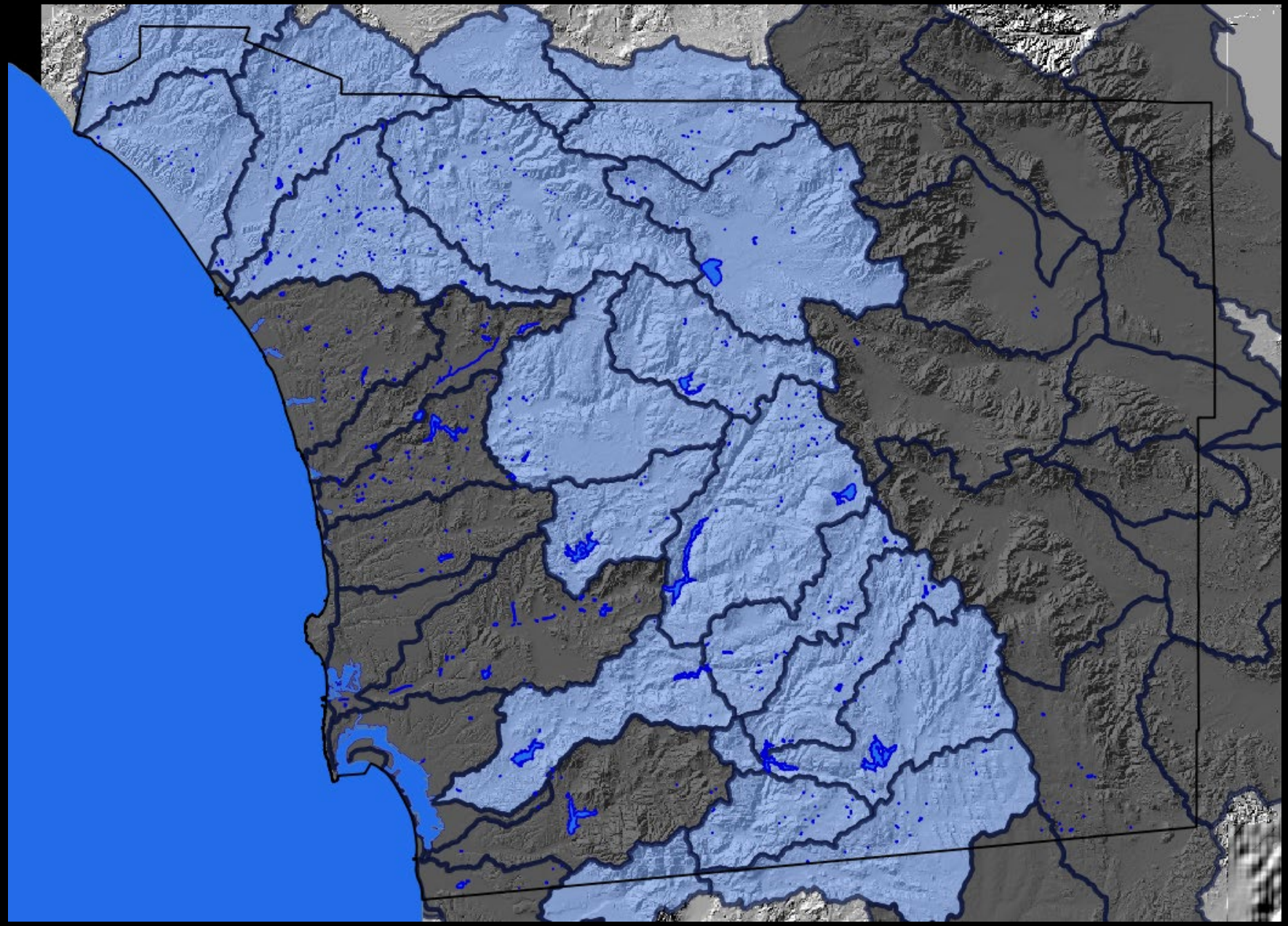
HUC-10 Level Selection

The gray HUC-08s are excluded because they drain into the desert or are too urbanized with little or no toad habitat. The HUC-10s in blue are passed through to the next level of selection.



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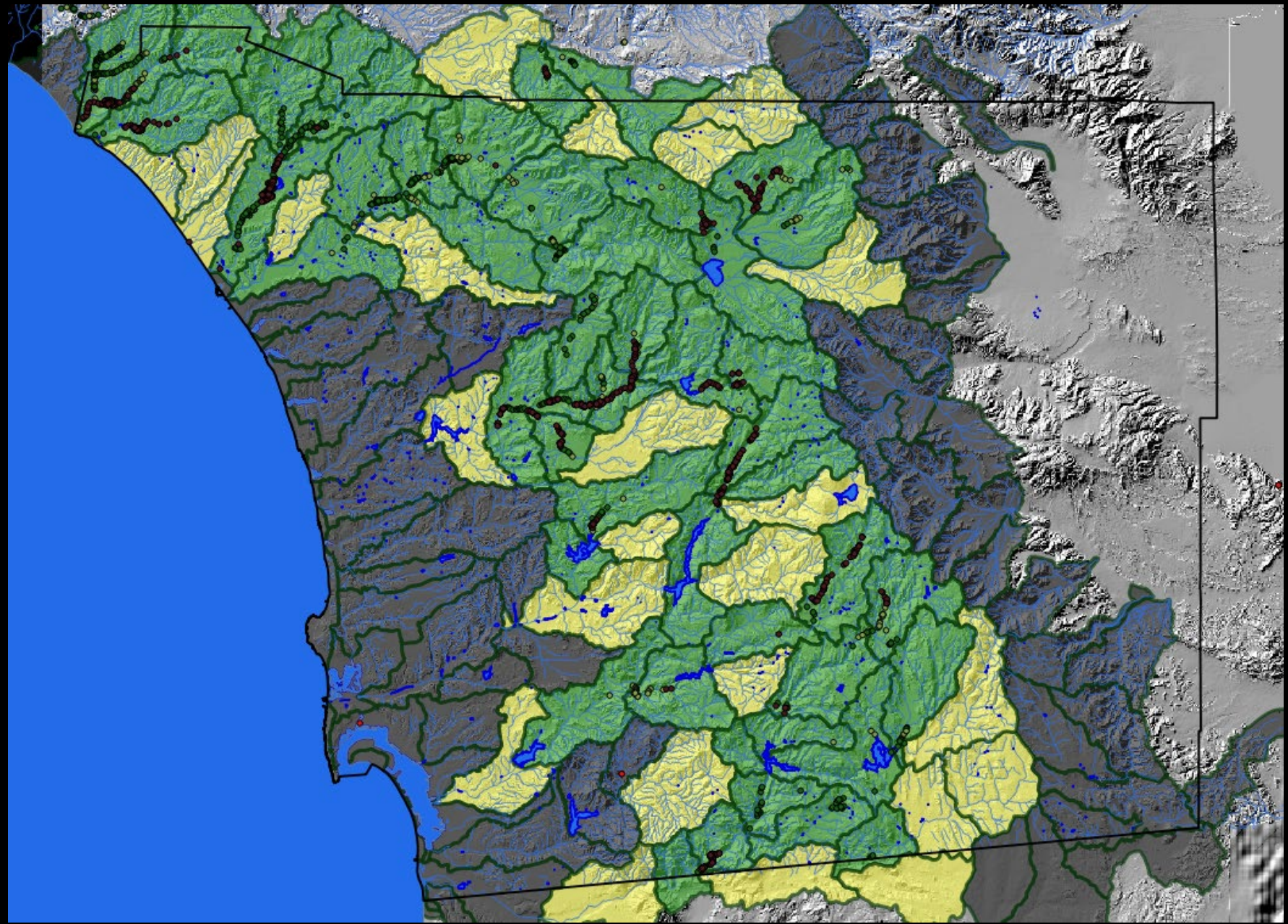
HUC-12 Level Selection

The HUC-12s in green are INCLUDED because they include observed toad locations (red points). The HUC-12s in yellow based on whether or not they might contain potential habitat and will be subject to “discovery surveys.”



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125-meter Stream Sample Segments

- Create segments from stream layer
- Apply RRQRR algorithm to assign spatially-balanced order of sampling
- Exclude segments:
  - Within bodies of water
  - Outside of conserved lands
- Classify remaining segments as:
  - Discovery segments
  - Core habitat segments
  - Spatially-balanced sample segments

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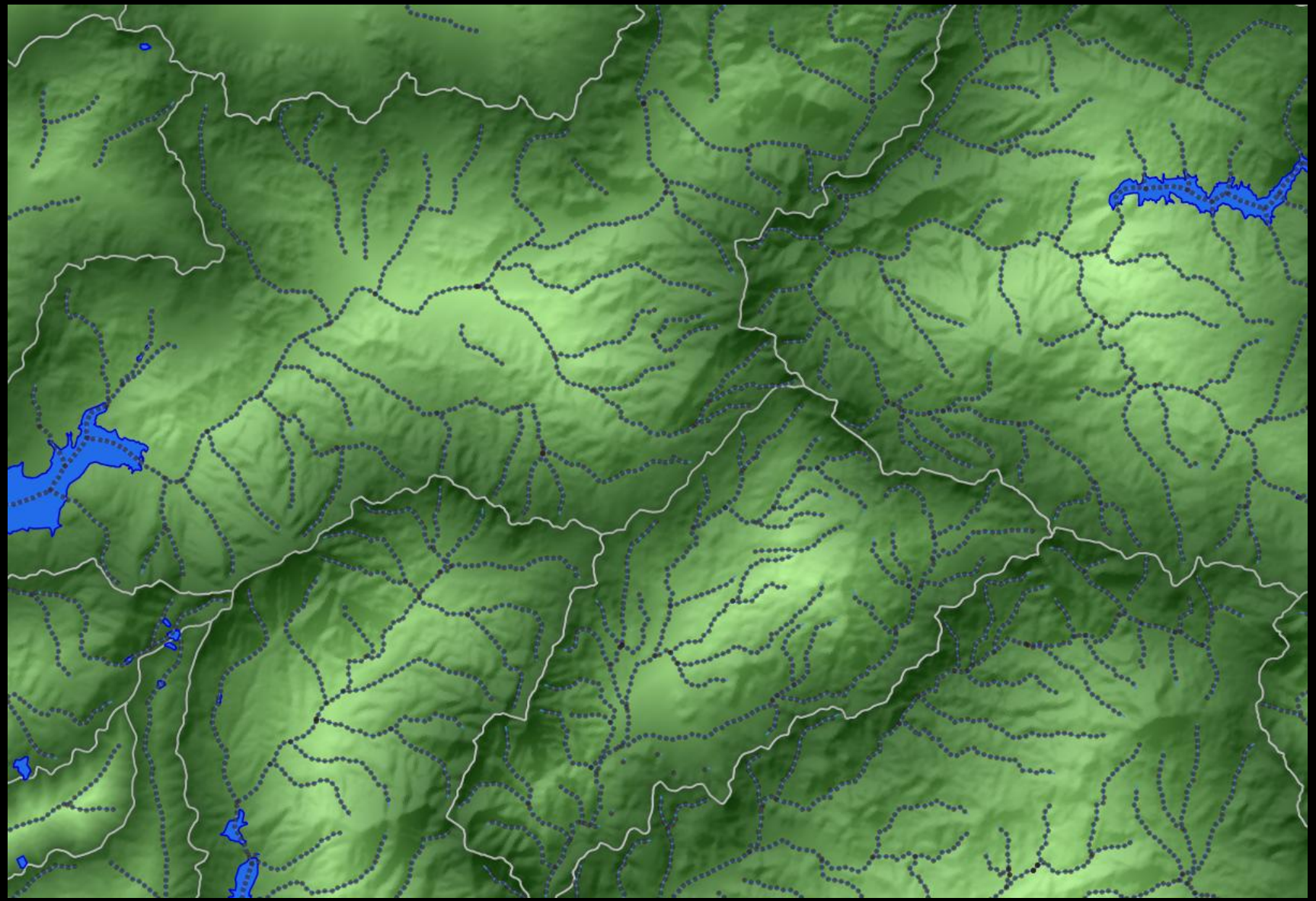
Stream Segments (125-m sample units)



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Stream Segments (125-m sample units)

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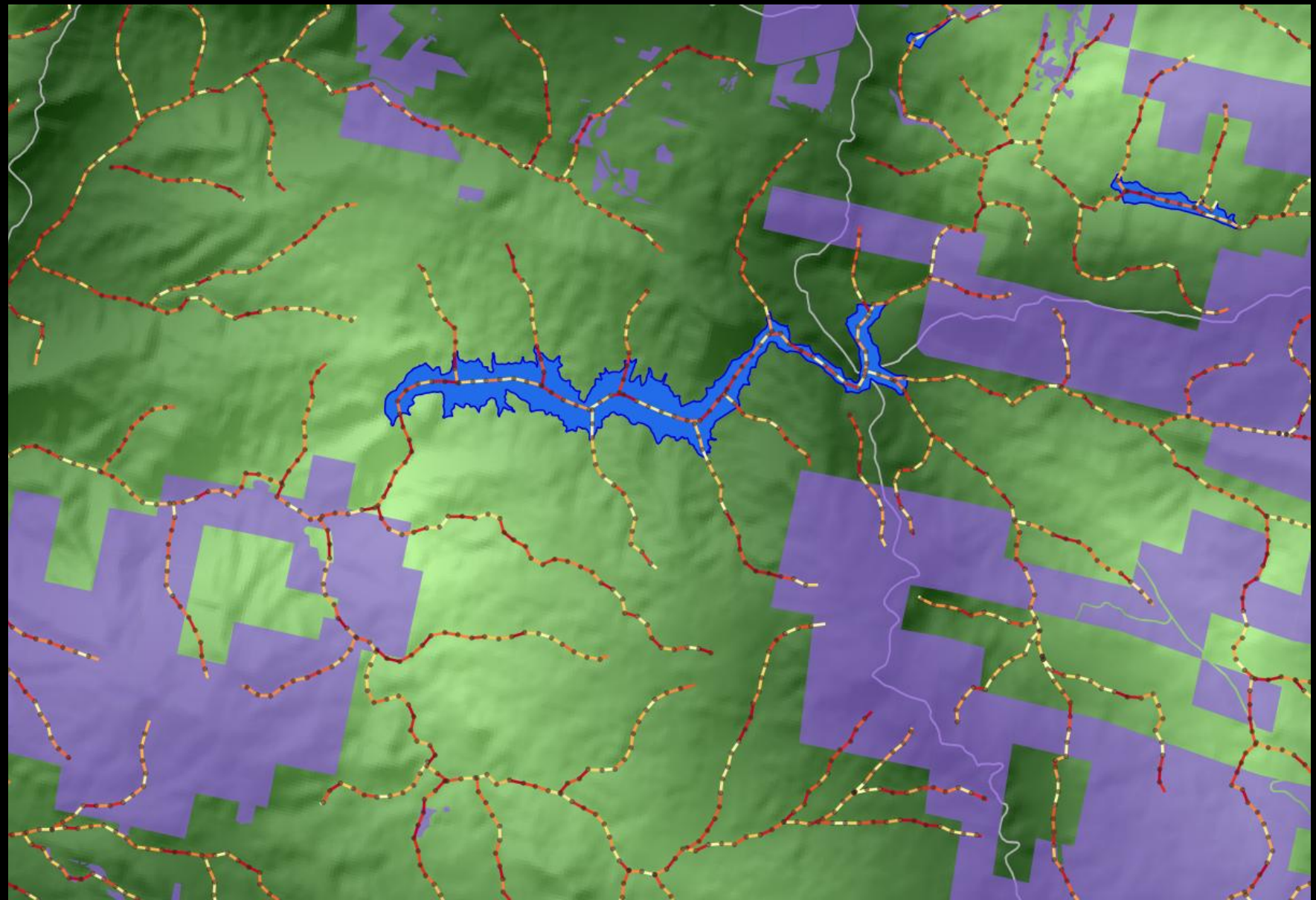
RRQRR Ordered Stream Segments

Segments within conserved lands (in purple) and not continuously inundated in selected HUC-12s will be part of our final sample frame.

As new lands are acquired, the RRQRR ordering provides a mechanism for incorporating them.



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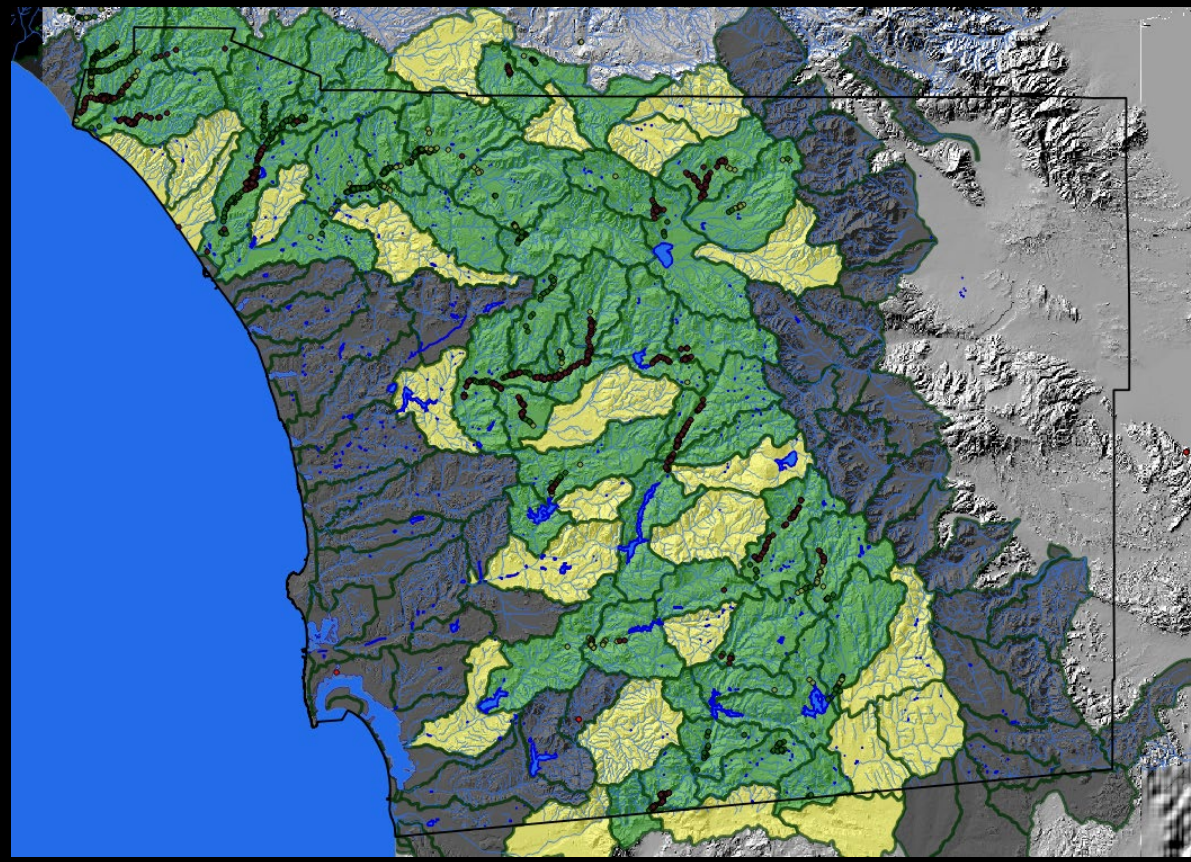
Discovery Stream Segments

- Stream segments:
  - Within a HUC-12 polygon identified as having potential toad habitat and lacking adequate surveys (yellow, 25 HUC-12s total) and
  - Within high-quality habitat on conserved lands
- will be surveyed for toads in the spring during good rain years.



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Core Stream Segment

- …(describe selection criteria)

The selection criteria for these stream segments is an important topic for discussion…
Possibilities include:

- Surveyed multiple years over some minimum range of years.
- Occupancy during all or most surveys.
- Possible source population.
- …and so on…

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Probabilistic Stream Segment

- Sample Frame:
  - Within San Diego County, (2) in a HUC-12 with known toad observations, (3) within conserved lands, and (4) not continually inundated with water.
- Sampled in order determined by RRQRR algorithm
  - Spatially balanced with randomness
- Optional stratification or sample inclusion probability
  - Based on?
    - Can be applied in post-processing after sorting according to sampling priority with RRQRR algorithm.

Stratification and/or sample inclusion probability are an important topics for discussion…

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RRQRR Algorithm

- Reverse Randomized Quadrat-Recursive Raster
- Places sample units in order for sampling based on a spatially balanced algorithm that includes randomization.
- See Theobald et al. (2007) Environ Manage 40: 134-146

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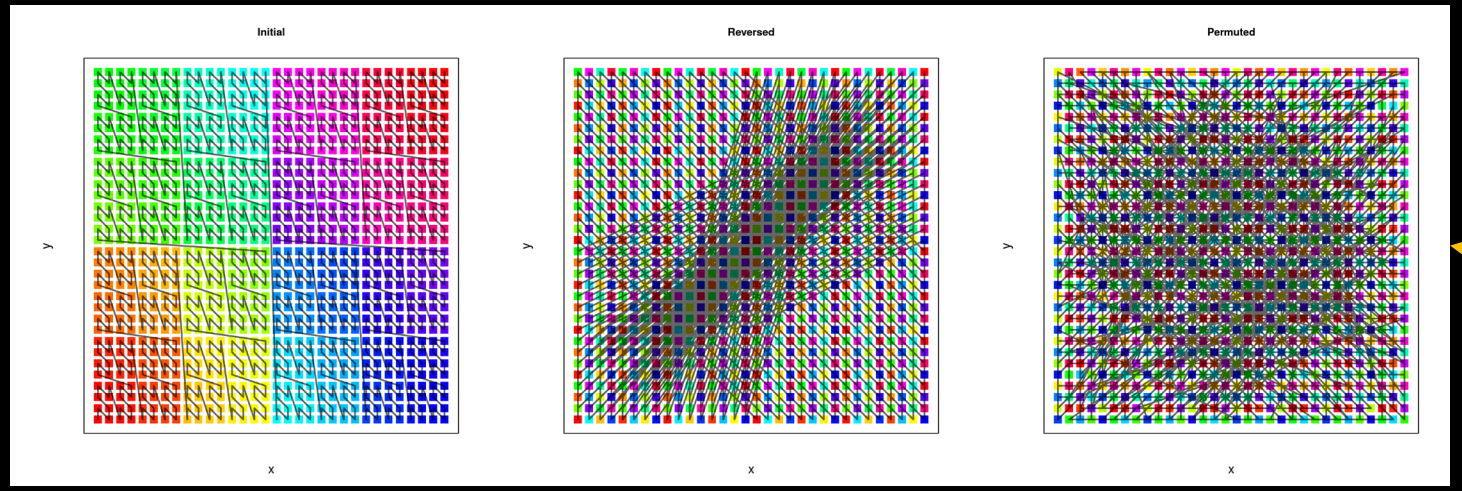
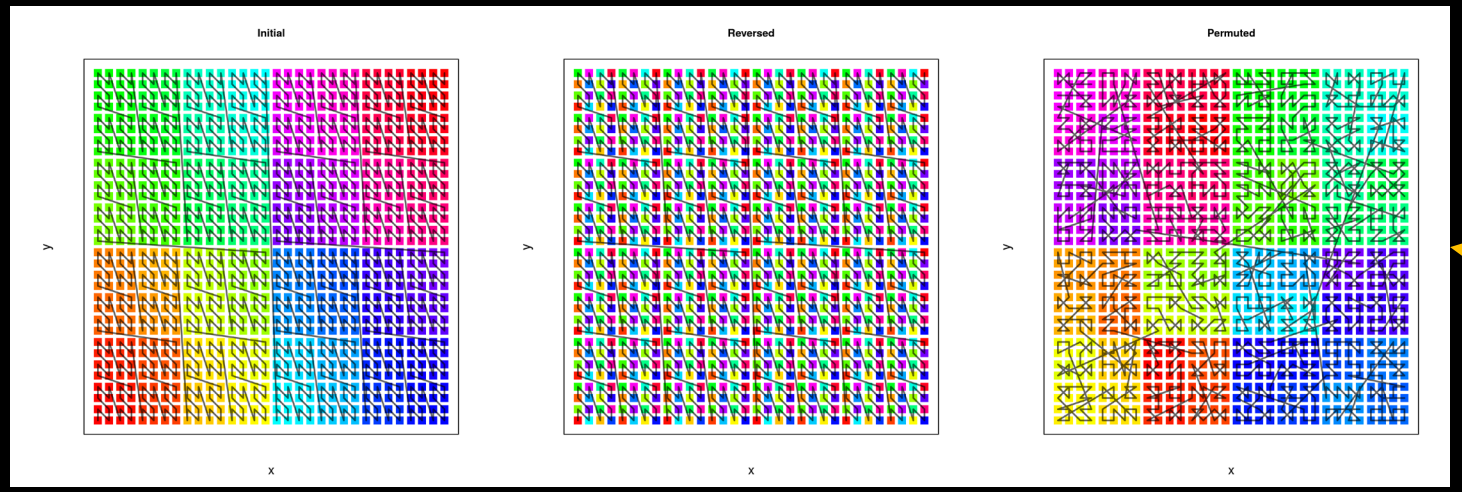


Hierarchical randomization with reversal step

Full RRQRR with 5 Levels



Hierarchical randomization without reversal step

RRQRR without the reversal step

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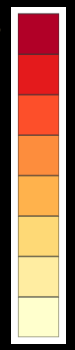
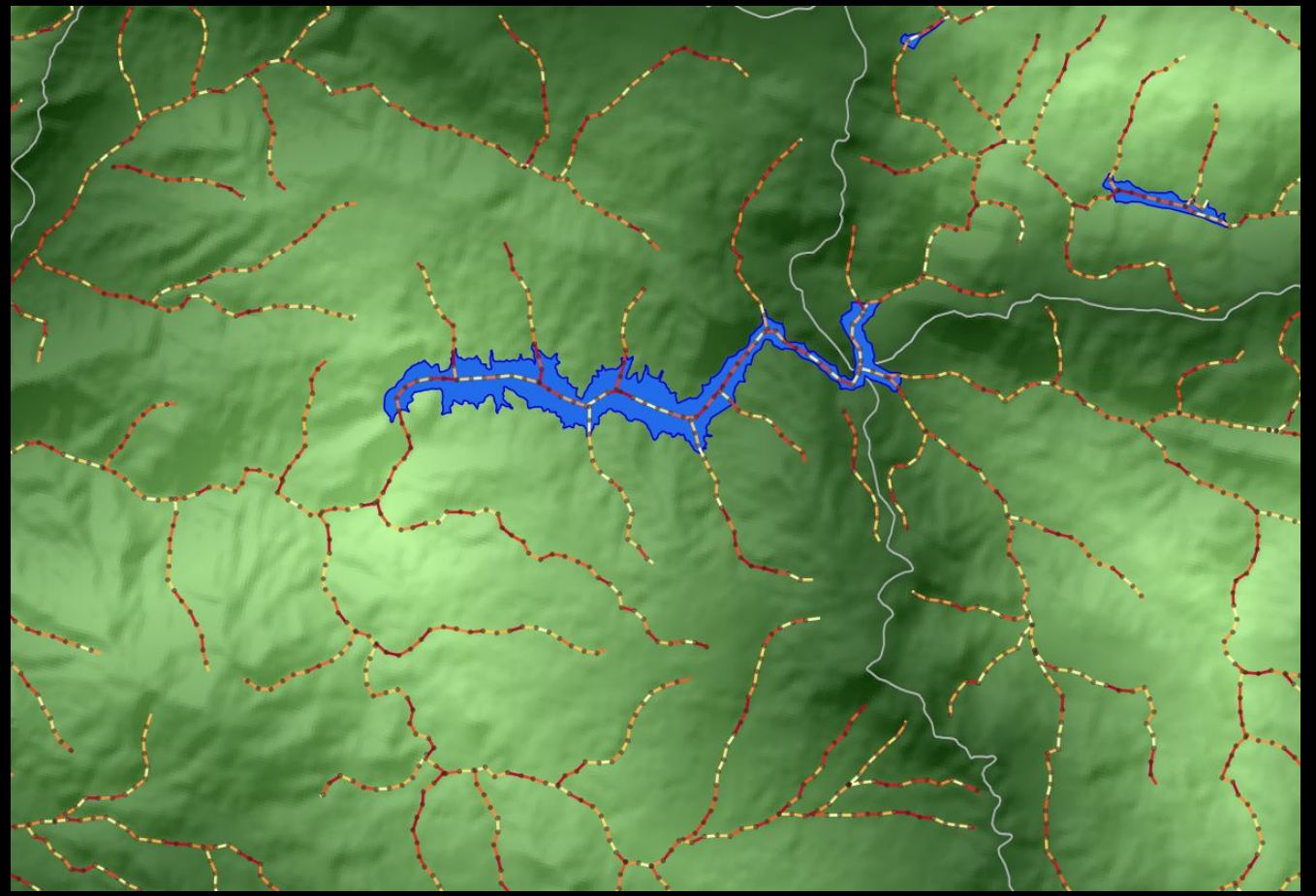
RRQRR Ordered Stream Segments

sampling priority

higher



lower



- Spatially match stream sample segments to RRQRR cells.
- Assign RRQRR order to stream segments.
- Handle duplicate matches.
- In post-processing step(s) apply:
  - Inclusion probability?
  - Stratification?

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Other considerations

These should be discussed…

- Pilot study in 2020 with further refinements of study design.
- Temporal considerations in study designs:
  - Based on type of site:
    - Core stream segments
    - Probabilistic stream segments
    - Discovery sites
  - Event driven sampling (rainfall, non-native invasions, fires, water management)?
- What if, during sampling, a stream segment is…
  - completely dry?
  - Completely inundated/flooded (e.g. upstream of reservoir with high water level)?
- Integration with aquatic IBI work.