Relating Pesticide Use and Well Construction to Trends in Pesticide Concentration in Domestic Wells Monitored in Vulnerable Areas of Fresno and Tulare Counties, California

John Troiano[1], Cindy Garretson, Terrell Barry.
Cal EPA, Department of Pesticide Regulation
1001 I Street, Sacramento, CA, United States
916-324-4115, jtroiano@cdpr.ca.gov

Outline

- Explain DPR's pesticide regulatory program for Ground Water Protection

- Measuring effectiveness of GW regulation
  - Domestic well network results

- Relating monitoring results to understanding subsurface processes

Initial Regulatory Approach: Pesticide Management Zones

- Initial method to delineate vulnerable areas based on sampling results of domestic wells
  Detection = Vulnerability

- Agricultural use of a detected pesticide (6800(a)) in section of land (PMZ) required as ***Advisory*** from Pest Control Advisor (PCA) who received training

- PMZ was specific to residue detected

- Vulnerable areas identified only after detection

Enacting PMZs in California

	Pesticide Management Zones (PMZs) for:						Total Sections	
Year Regulated	Atrazine	Bromacil	Diuron	Prometon	Simazine	Norflurazon	All	Distinct
	---------- # ----------							
All Sampled Sections								
1989	62	0	0	0	0	-	62	62
1990	1	11	20	7	66	-	105	41
1992	14	13	18	0	48	-	93	55
1999	100	114	201	18	269	-	702	330
2001	0	0	0	0	0	11	11	1
Total	177	138	239	25	383	11	973	489
Sections in DPR's Domestic Well Network								
1989	0	0	0	0	0	-	0	0
1990	0	0	0	0	0	-	0	0
1992	0	4	3	0	9	-	16	8
1999	17	25	42	3	50	-	137	50
2001	0	0	0	0	0	6	6	1
Total	17	29	45	3	59	6	159	59

dpr

Ground Water Regulation Revisions 2004

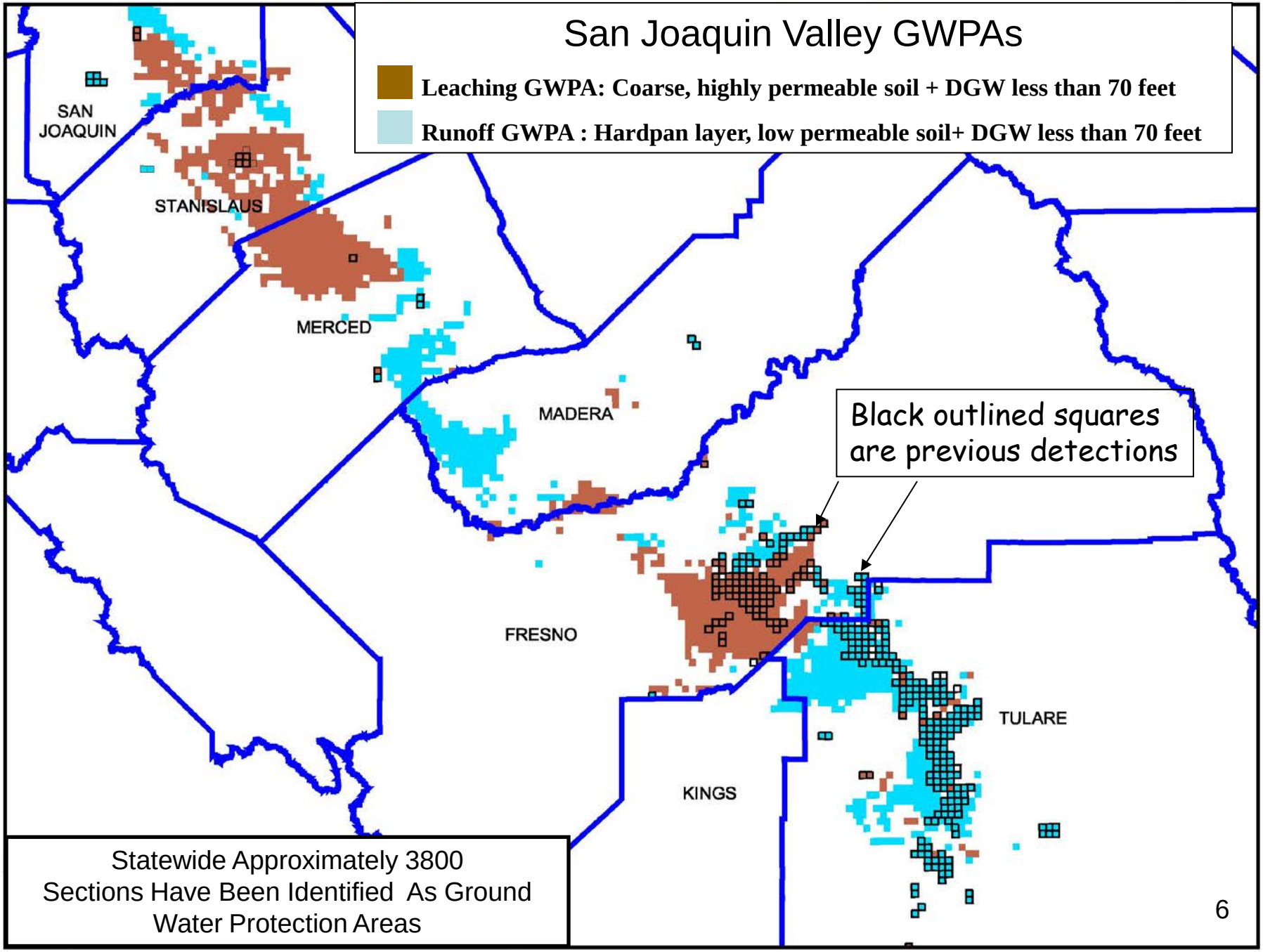
- In addition to well samples regulated areas based on prominent geographic features of vulnerable areas.
- Vulnerable areas renamed Ground Water Protection Areas (GWPA)
- Permits for use of any product of an active ingredient on the (6800(a)) list issued and conditioned by County Agricultural Commissioner

In GWPA

- Leaching GWPAs, coarse soils, high permeability – 5 options
- Runoff GWPAs, hardpan soils, low permeability – 9 options
- Engineered rights of way – 11 options

Statewide

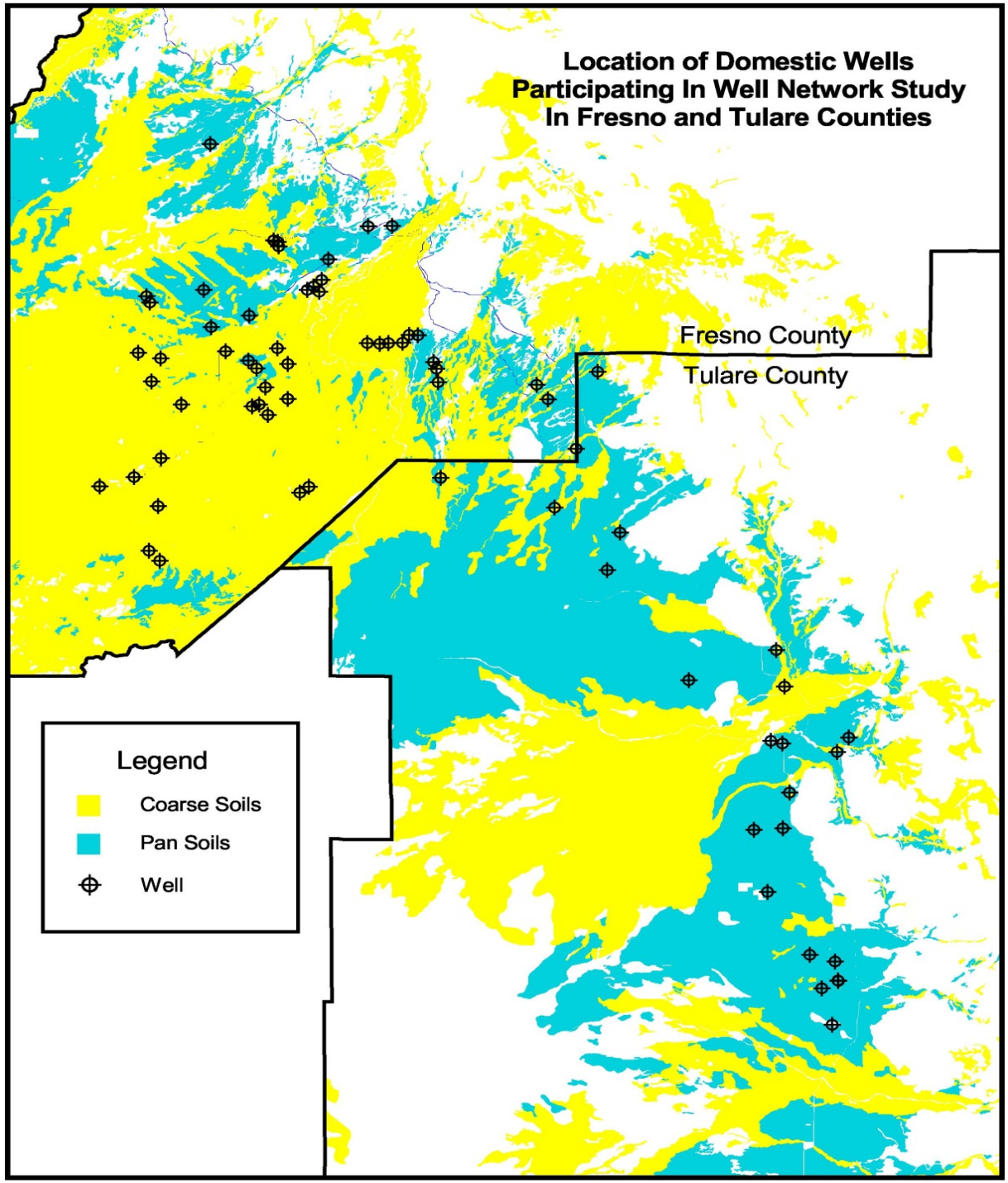
- Canals, ditch banks, and recharge areas – 2 options



Statewide Approximately 3800 Sections Have Been Identified As Ground Water Protection Areas

Domestic Well Monitoring Network

- Determine trends in pesticide concentration in regulated areas (GWPAs).
- Previous age-dating study indicated a median travel time to wells in this area around 6-7 years - potential use for determining effectiveness of regulatory actions required commitment to long-term project.
- 1999: Targeted 40 wells each in Leaching and Runoff GWPAs. 67 wells continuously monitored – 31 in Leaching GWPAs; 36 in Runoff GWPAs.
- Owners of wells with previous detection(s) contacted for permission to monitor annually. Samples taken in the Spring.
- Pesticide screen includes: simazine, ACET, DACT, diuron, bromacil, norflurazon, desmethyl norflurazon (DMN). Nitrate added to analysis in 2000 in response to owners' request.



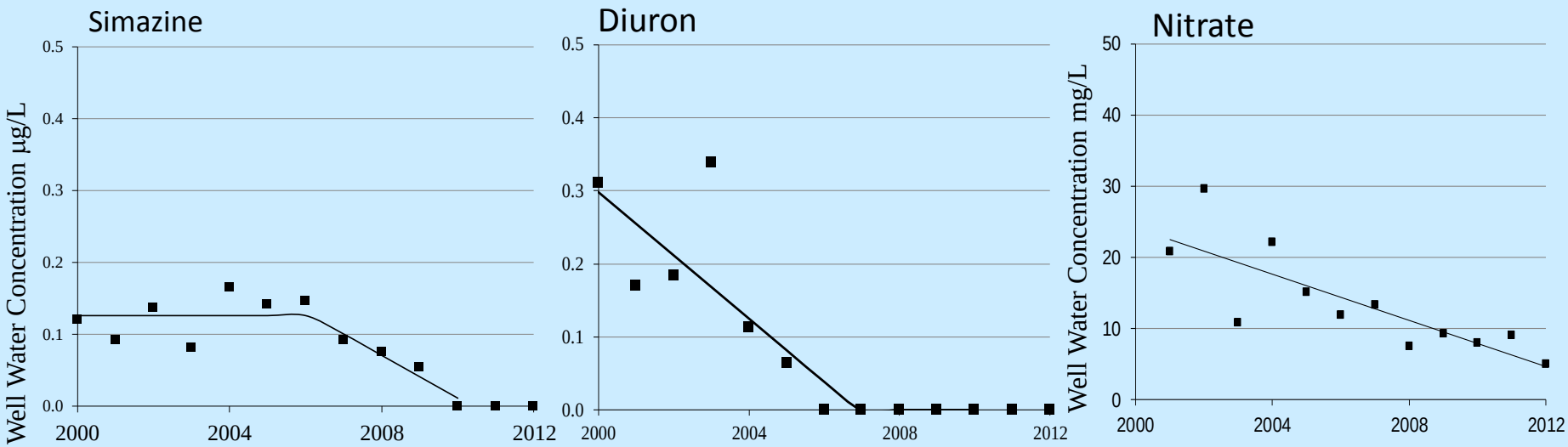
Location of domestic wells in Monitoring Well Network in leaching and runoff GWPAs in Fresno and Tulare Counties

Cropping Pattern

- Leaching GWPAs
  - Grapes and Tree crops
- Runoff GWPAs
  - Citrus

Domestic monitoring well network single well analysis: Well 34

Reporting limit set at 0.05 ug/L



- Concentrations were observed to fall below the reporting limit, e.g. simazine and diuron.
- Left-censored data set.

Statistical Analysis

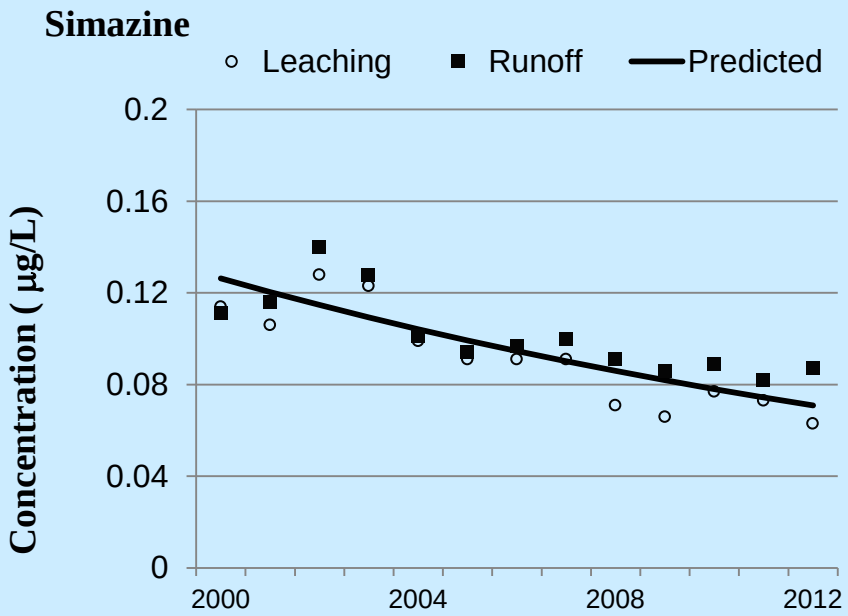
- Mixed model analysis: Results to be generalized to wells outside of network so wells were designated as a random effect. Time was also a random effect and GWPA designation was a fixed effect.

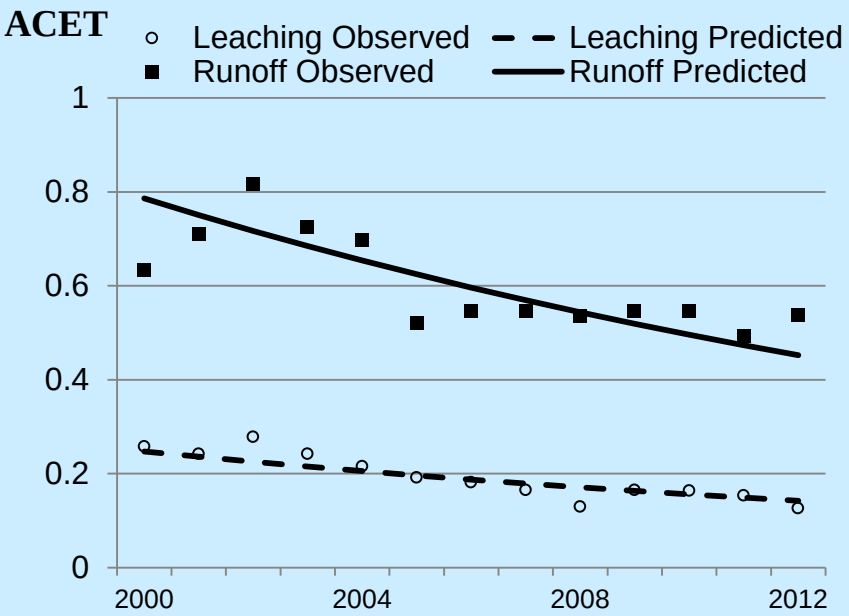
- Left-censored data set: Maximum likelihood analysis implemented through PROC NLMIXED. Time was a repeated measure.

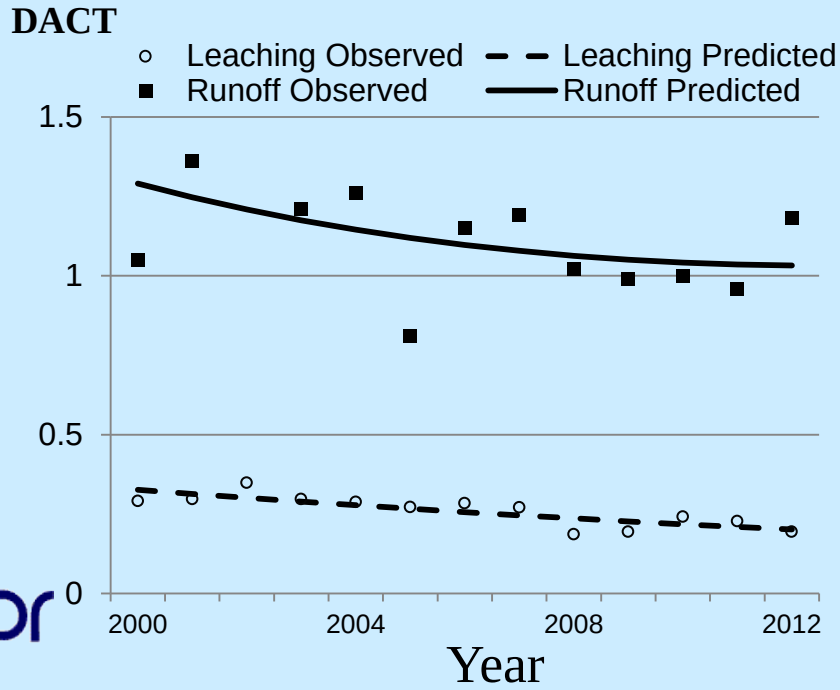
- GWPA comparison: Simazine, ACET, DACT, and nitrate measured in nearly all wells so model included potential differences in concentration between GWPA designation and interactive effects.

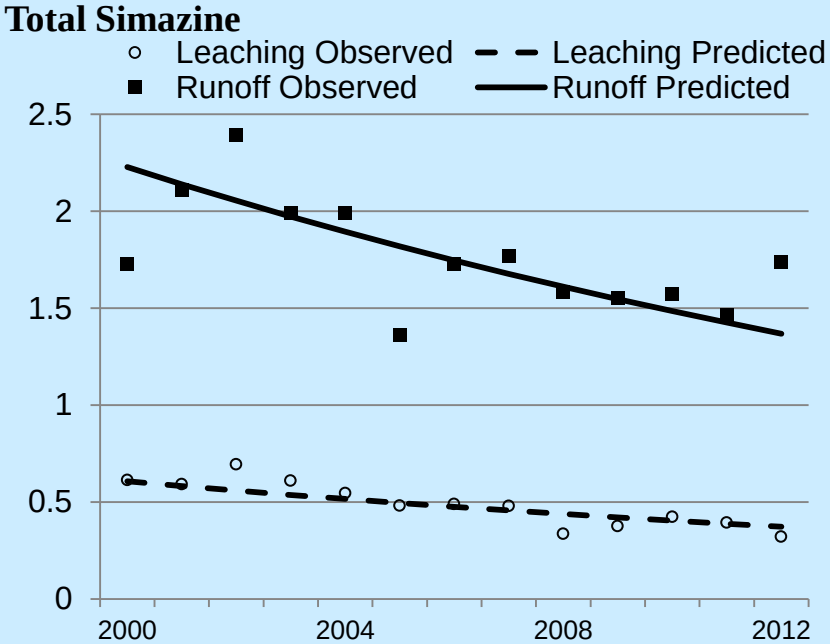
- Regression within GWPA designation: Frequency of diuron, bromacil, and norflurazon detections were greater in runoff GWPAs so regressions conducted within each GWPA designation.

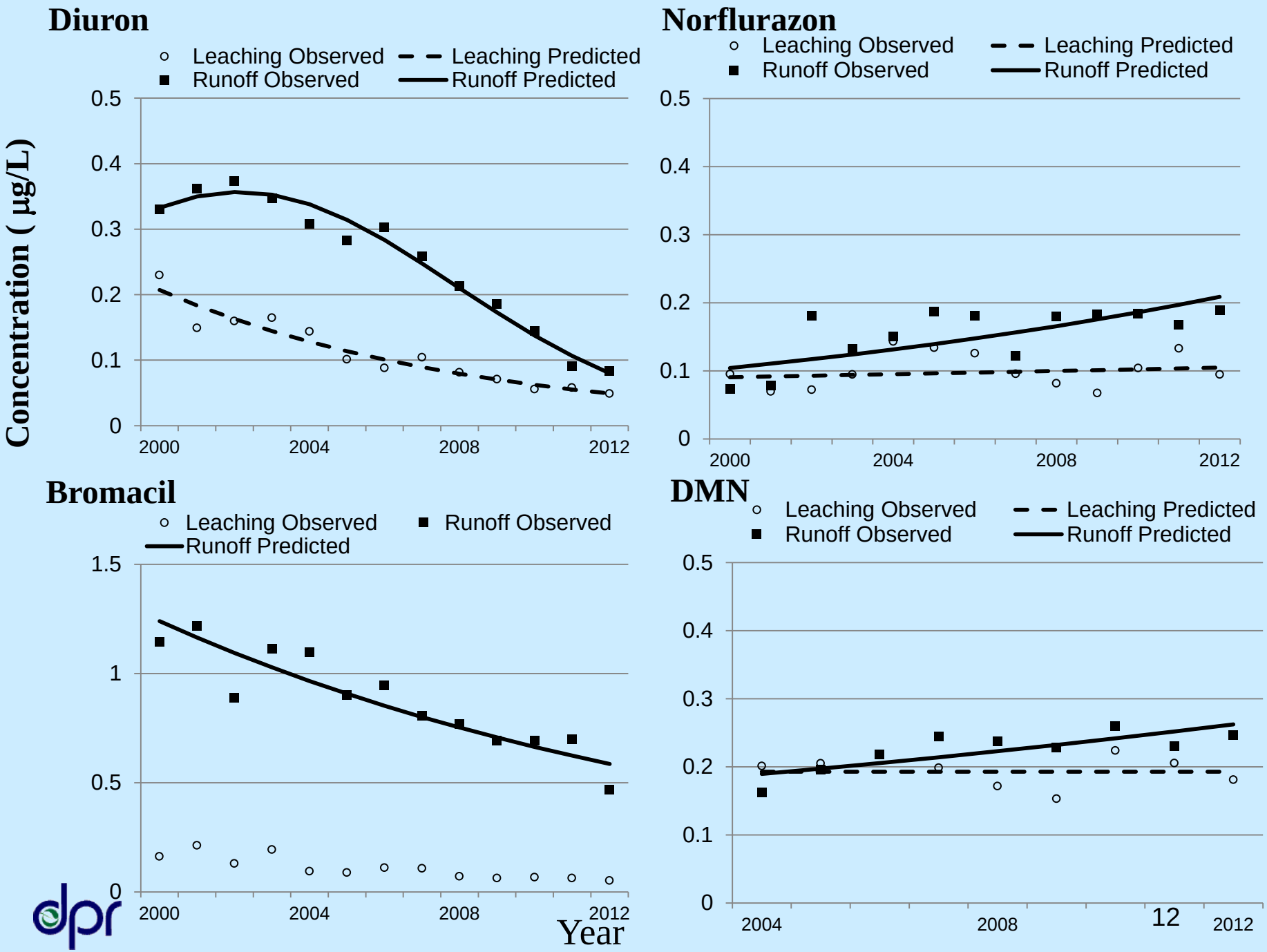
Domestic Monitoring Well Network: Overall Pooled Analysis










Diuron
Leaching Observed
Leaching Predicted
Runoff Observed
Runoff Predicted
Concentration (µg/L)
0.5
0.4
0.3
0.2
0.1
0
2000
2004
2008
2012
Norflurazon
Leaching Observed
Leaching Predicted
Runoff Observed
Runoff Predicted
0.5
0.4
0.3
0.2
0.1
0
2000
2004
2008
2012
Bromacil
Leaching Observed
Runoff Observed
Runoff Predicted
1.5
1
0.5
0
2000
2004
2008
2012
Year
DMN
Leaching Observed
Leaching Predicted
Runoff Observed
Runoff Predicted
0.5
0.4
0.3
0.2
0.1
0
2004
2008
2012

Regressions Conducted for Each Well

GWPA Classification and	Simazine	Total Simazine	Diuron	Bromacil	Total Norflurazon	Nitrate
	---------- # of wells ----------					
Leaching GWPA						
Decrease	21	18	7	1	5	13
No Change	6	9	5	1	10	13
Increase	1	4	2	1	3	5
Total	28	31	14	3	18	31
Runoff GWPA						
Decrease	19	15	22	15	1	9
No Change	12	19	6	7	9	23
Increase	0	1	2	3	14	4
Total	31	35	30	25	24	36
All Wells						
Decrease	40	33	29	16	6	22
No Change	18	28	11	8	19	36
Increase	1	5	4	4	17	9
Total	59	66	44	28	42	67

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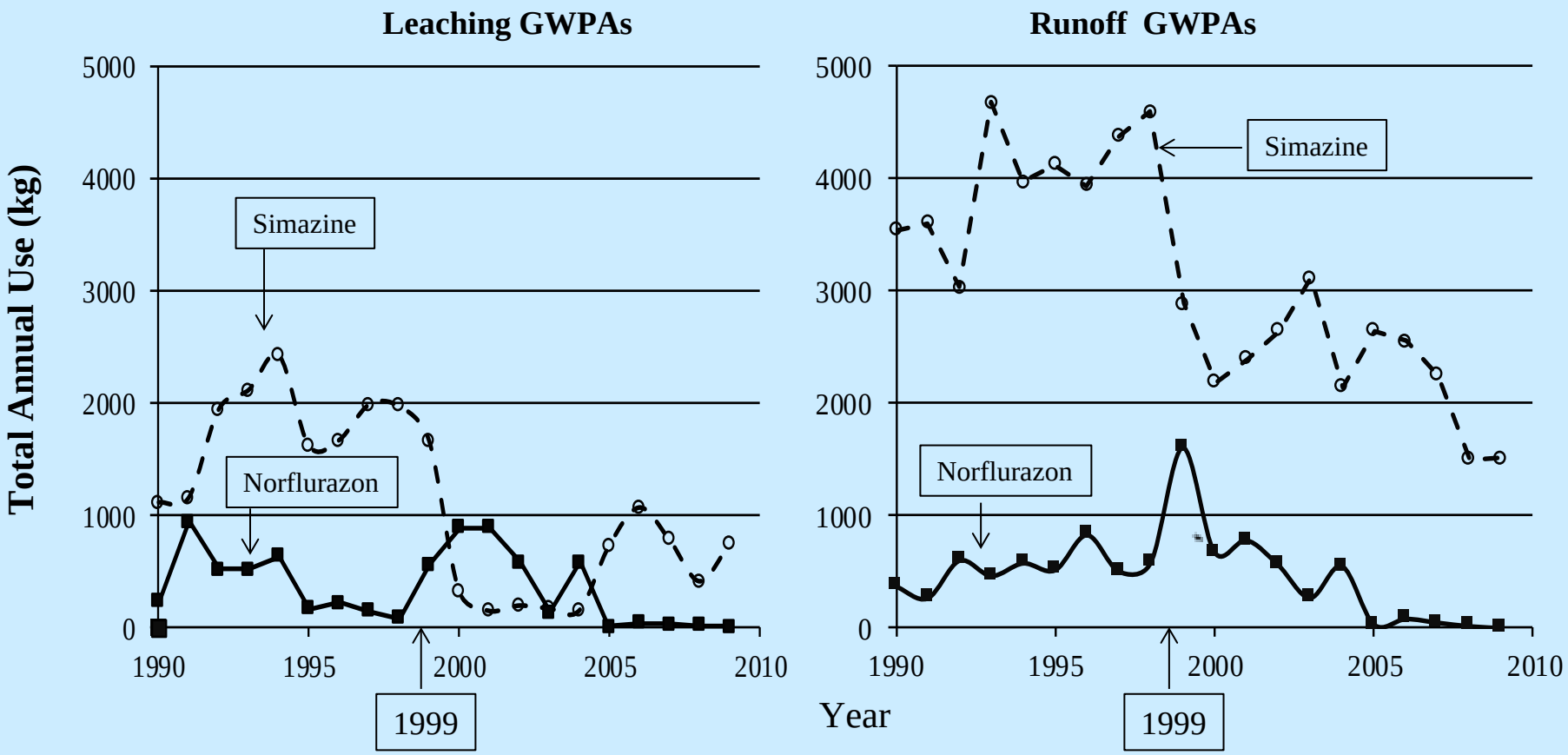
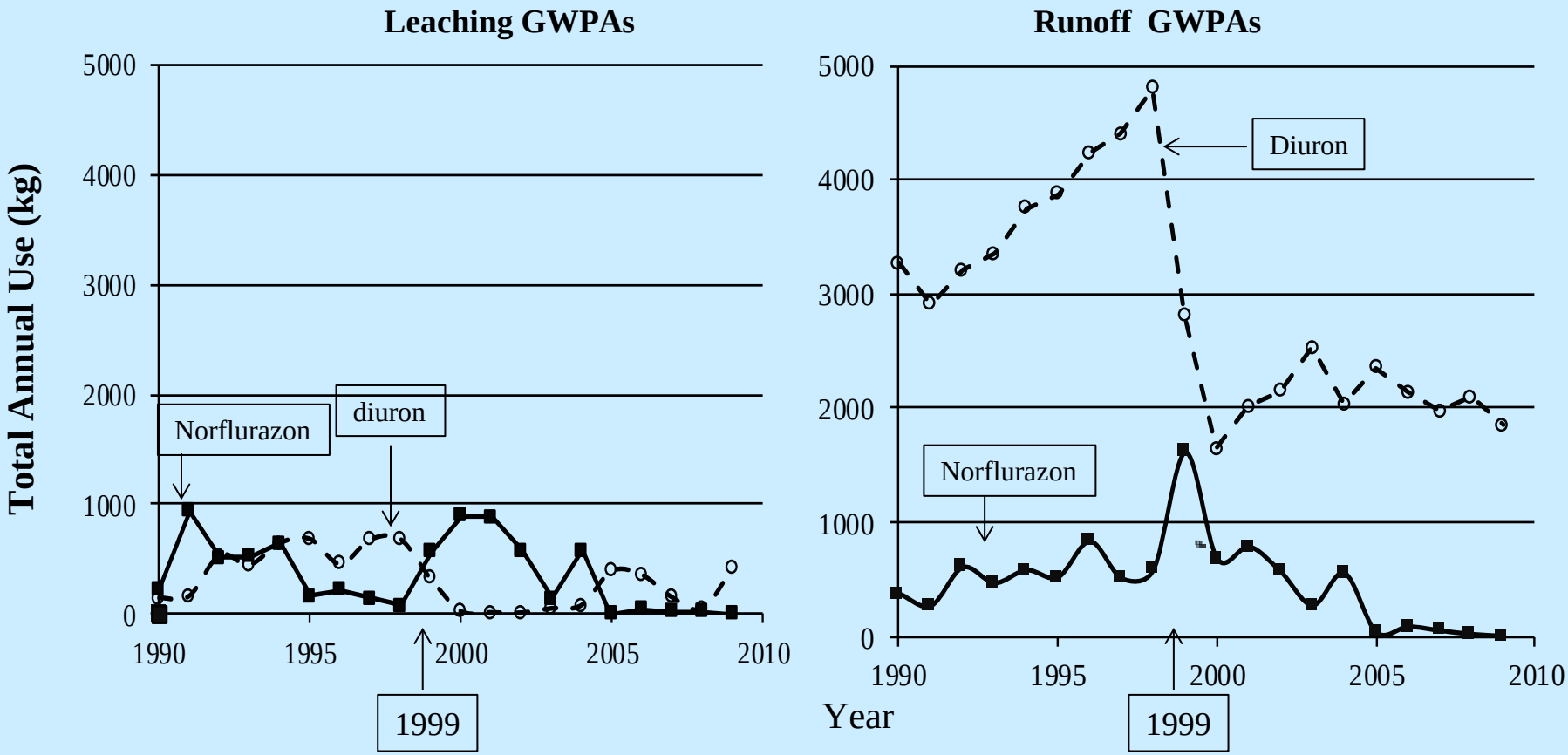
- Red circles: Norflurazon was not listed as 6800(a) until 2001.
- Blue circles: 50 of the 59 sections in the network became PMZs in 1999.

Annual simazine use in sections made PMZs in 1999

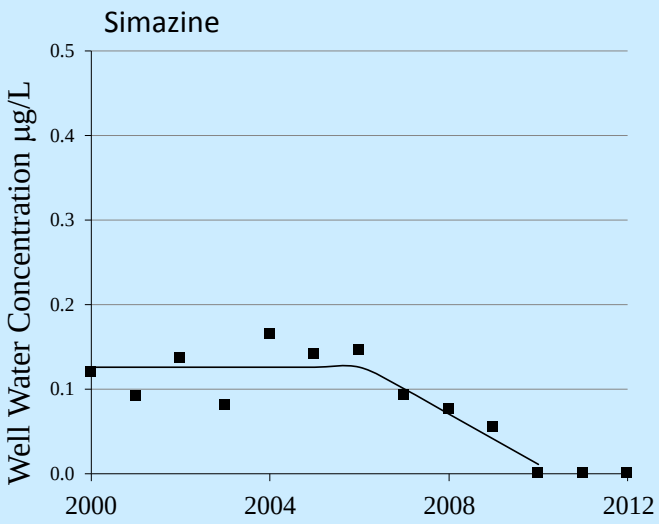


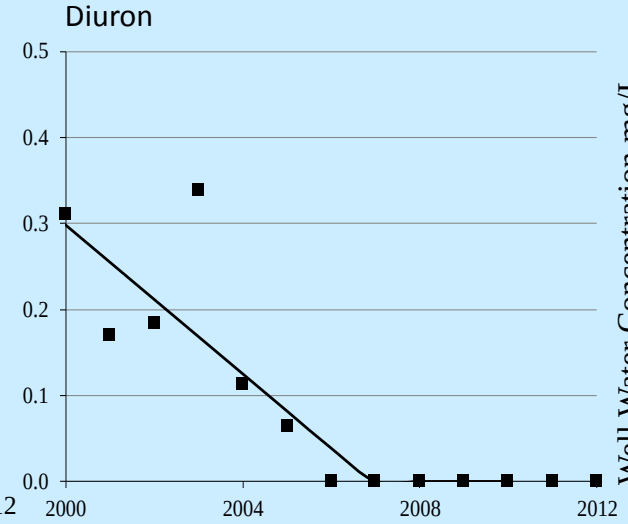
- Indicates that grower response to listing was to use a non-regulated product: norflurazon was not listed as 6800(a) until 2001.
- Total section annual use of simazine was greater in runoff GWPAs.

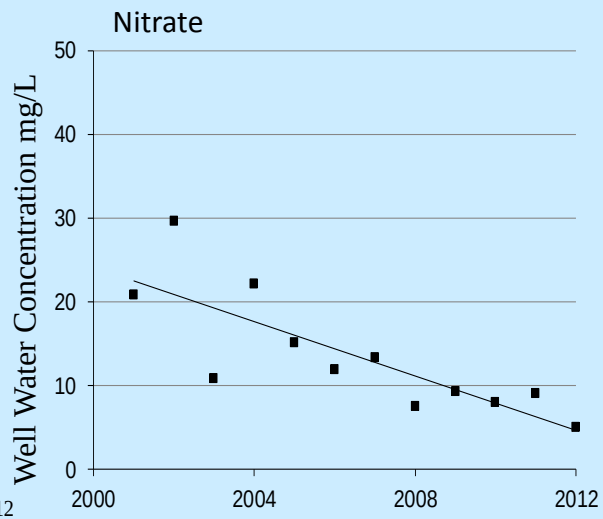
Annual diuron use in sections made PMZs in 1999



Domestic monitoring well network single well analysis: Well 34

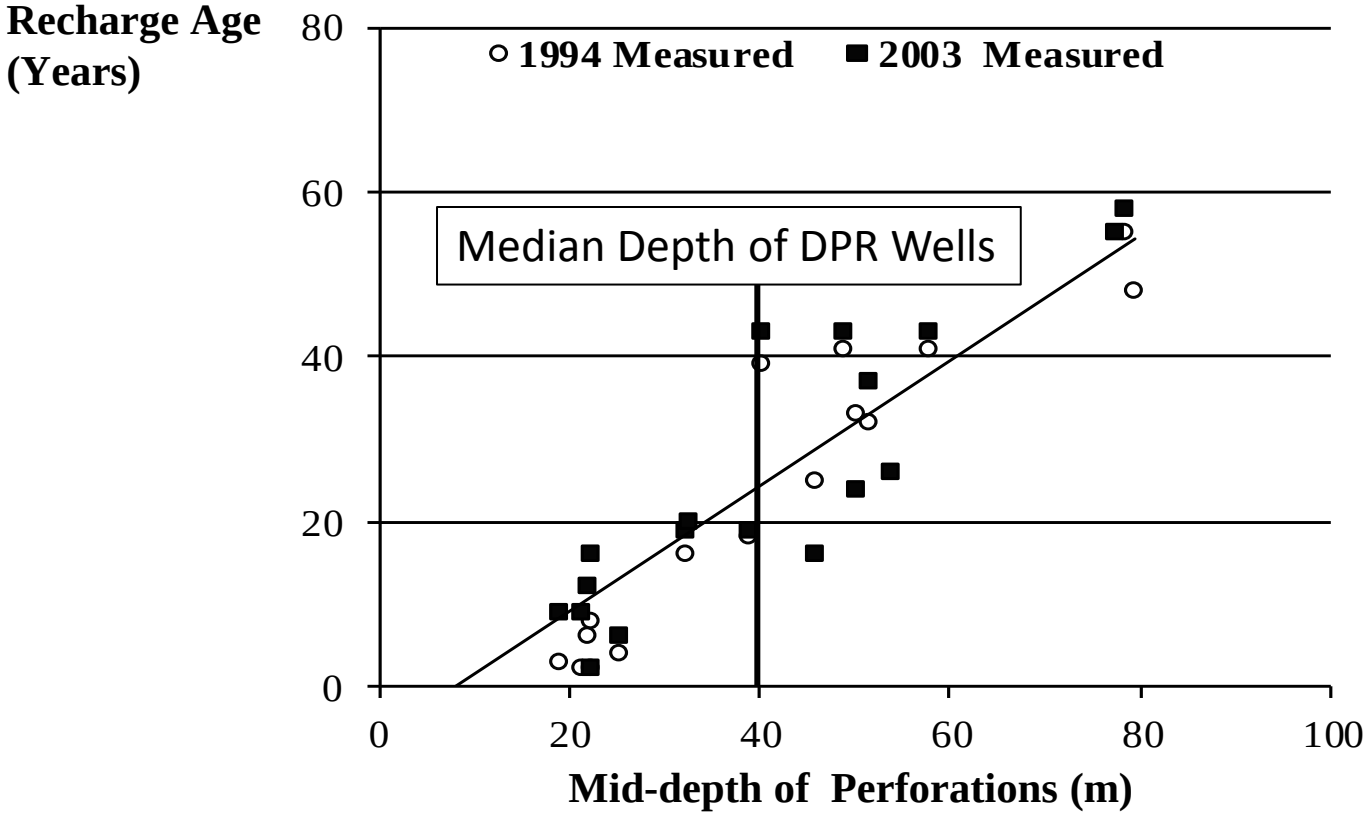






- Nitrate decreased along with pesticide residues in a number of wells.
- There are no restrictions or regulation for use of nitrate so no reason for growers to change use practices
- Indicates that potential changes in management practices such as adoption of efficient irrigation may also contribute to observed decreases.

Relationship of Mid-depth of Perforations in USGGS Monitoring Wells to Estimated Recharge Age of Water
Burow et al 2007



- USGS Monitoring wells near Fresno in GWPAs - perforations 1.5 m in length.
- At 40 m monitoring well GW recharge age around 20 years.
- Median DPR domestic well depth at 40 m from 49 wells.
- Domestic well response appears faster then predicted from monitoring wells.

Well Construction: Potential Accelerated Mixing

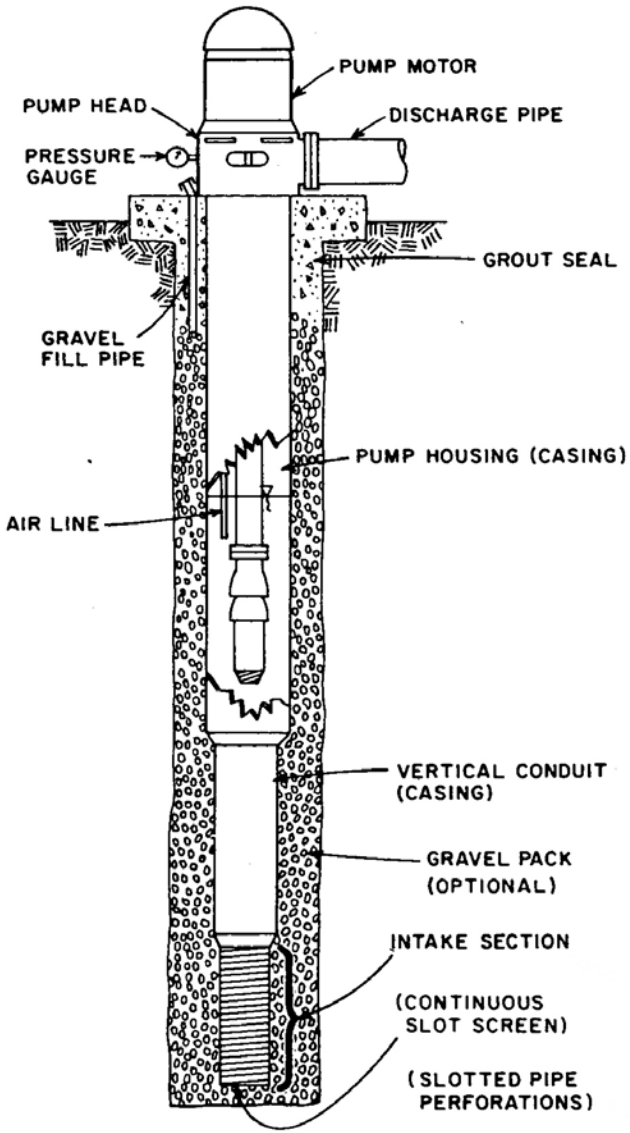
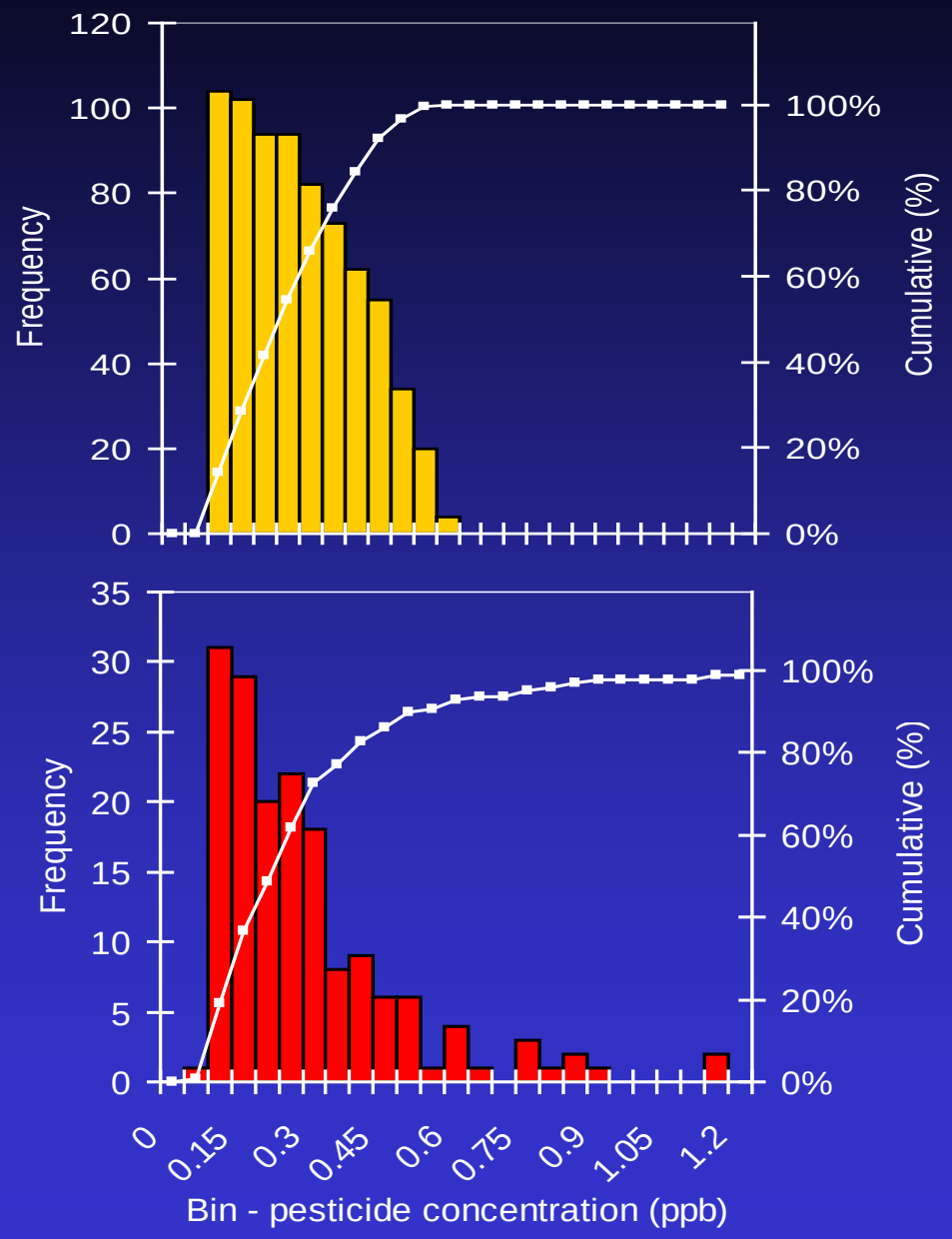


Fig. 3.2. Components of a well.

- Well logs for 32 wells:
  - Perforation length for 22 wells; ranged 4 to 42 m; median 7 m
  - Gravel pack length for 15 wells; ranged 11 o 50 m: median 34 m

- Current cooperative study with Matt Landon of USGS to provide age-dating for 30 of the domestic wells with well logs. A sweet of chemicals and isotopes analyzed providing distribution for the ages of water that recharges the well using lumped parameter models.

Verification of Probabilistic Model



Model predictions

- Water application at 160% plant demand

25th percentile = 0.14 ppb

50th percentile = 0.23 ppb

75th percentile = 0.35 ppb

95th percentile = 0.48 ppb

Observed data

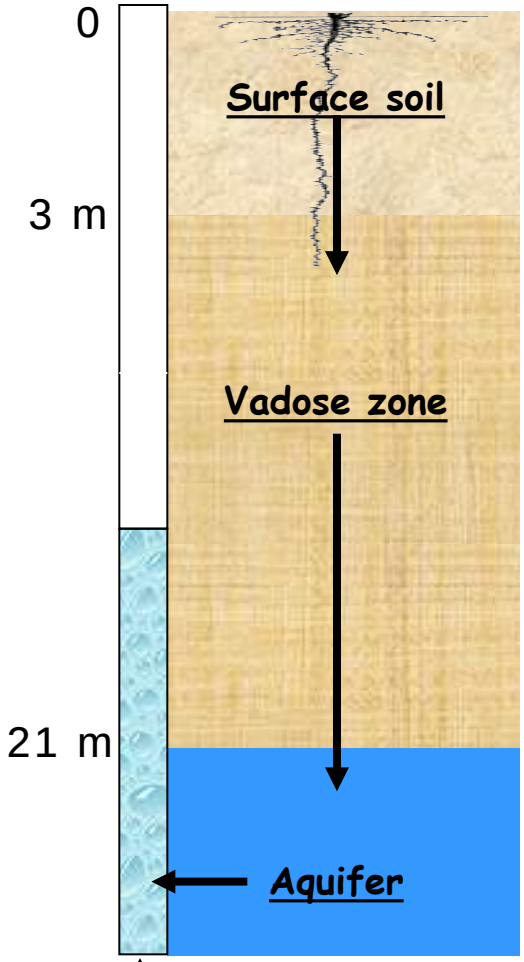
25th percentile = 0.12 ppb

50th percentile = 0.21 ppb

75th percentile = 0.32 ppb

95th percentile = 0.74 ppb

Conceptual Model for Movement to GW



Surface soil: 1 year - LEACHM model estimates distribution of annual mass that moves below 3 meters

Vadose zone: 4 years aging (overwatering) – Time to move to 21 meters, GWPA cutoff value, estimated at modeled velocity. Residue mass moved below 3 meters diluted into 0.5 meter of annual recharge then aged according to longest TFD $\frac{1}{2}$ life.

Aquifer: 6 years aging – Time for residue that enters aquifer to move to well so residues aged at longest TFD $\frac{1}{2}$ life to produce estimate of well water concentration.

Well

If the aquifer modeled is shallower, or if a hydrolysis half-life is assumed, or if the travel time is faster then comparison to actual data will be skewed to higher concentrations. Knowledge of aquifer mixing in terms of well construction might be key to more accurately estimate well water concentrations.