# Determining the Source: Generating a Comprehensive Approach for Remediating Microbial Pollution in Rural Drainages

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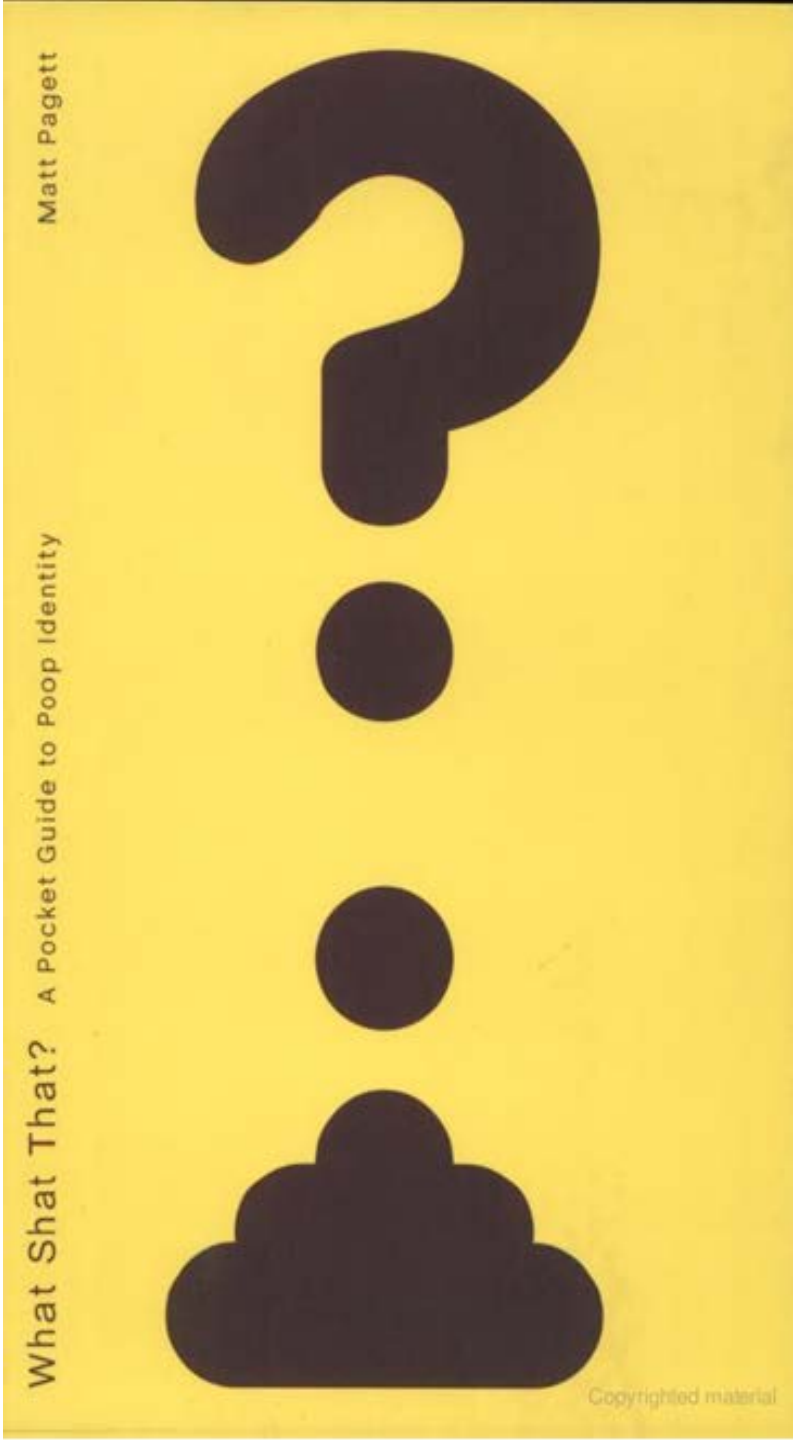
Photonics
Biosystems 2013




# Matching the feces to the species

- Do this smartly ***with*** citizens
- Build on what we already know
- Search for the obvious sources first
- Engage the correct agencies
- Apply the appropriate fix

# ...There's Something Foul in ...* Boise Creek

*B.S. (*c.* 1600)

- Fecal Coliform (FC) TMDL integrated with stormwater NPDES permit requirements.
- Characterizing the nature and intensity of FC pollution in the drainage network has been limited to road crossings and public rights of way.
- We are proposing to gain access to more of the creek through stewardship and other outreach activities.
- Outreach is targeted by using statistical power analysis to identify important stream segments and adjacent landowners.

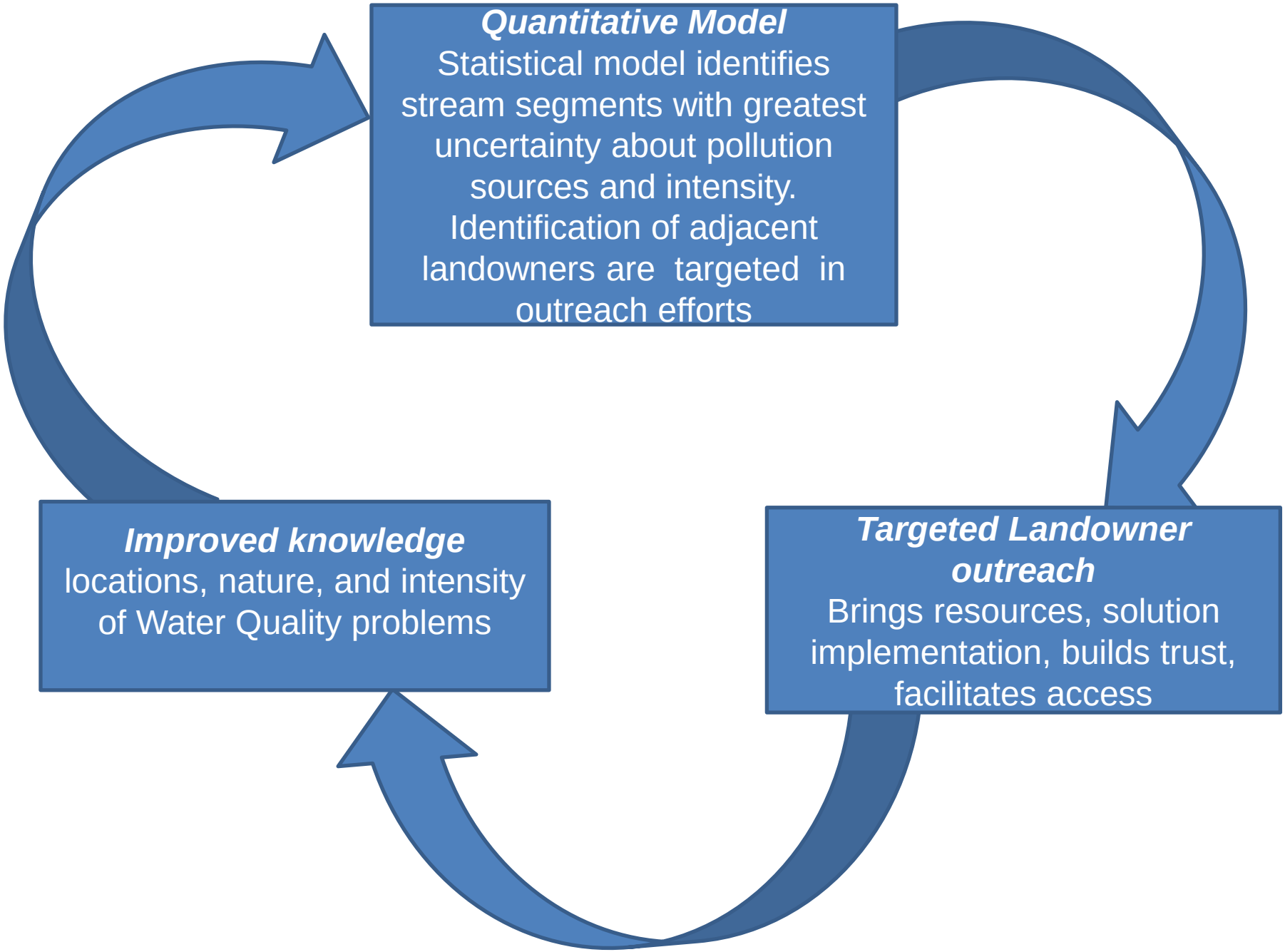
# When there is an identifiable source, who is responsible and what effective tools do they have to clean it up?

**Our goal is a resilient and locally sustainable program focused on community engagement where agencies work as resource providers to improve water quality.**

- **activate cleanup mechanisms appropriate to the source  such as septic maintenance/ replacement, or improved agricultural best management practices**
- **monitor water quality conditions after cleanup to lead to NPDES permit compliance and removal from the State's 303(d) list.**

# Objective, repeatable process to identify sources

a) coordinate with KCD staff to expand cooperative partnerships with rural landowners;
b) cooperatively implement agricultural BMP's;
c) implement riparian revegetation projects; and,
d) expand water quality monitoring to establish better baseline data and determine locations contributing pollutants to the stormwater system.


Quantitative Model
Statistical model identifies stream segments with greatest uncertainty about pollution sources and intensity. Identification of adjacent landowners are targeted in outreach efforts
Targeted Landowner outreach
Brings resources, solution implementation, builds trust, facilitates access
Improved knowledge
locations, nature, and intensity of Water Quality problems

# Determining Sampling Effort

$$n >= (2s^2)/(\delta^2)\,(t_{\alpha,2\,(n-1)} + t_{\beta(1),\,2(n-1)})^2$$

- **n = the number of samples required to achieve reasonable statistical power (β)**
- **β is the probability of NOT committing a Type II error – aka the Statistical Power (*rejecting the null hypothesis when you shouldn't*)**
- **α is the probability of NOT committing at Type I error (*not rejecting the null hypothesis when you should*)**
- **δ is the minimum detectable difference**
- **$s^2$ is the variance**

**Zar (1984)**

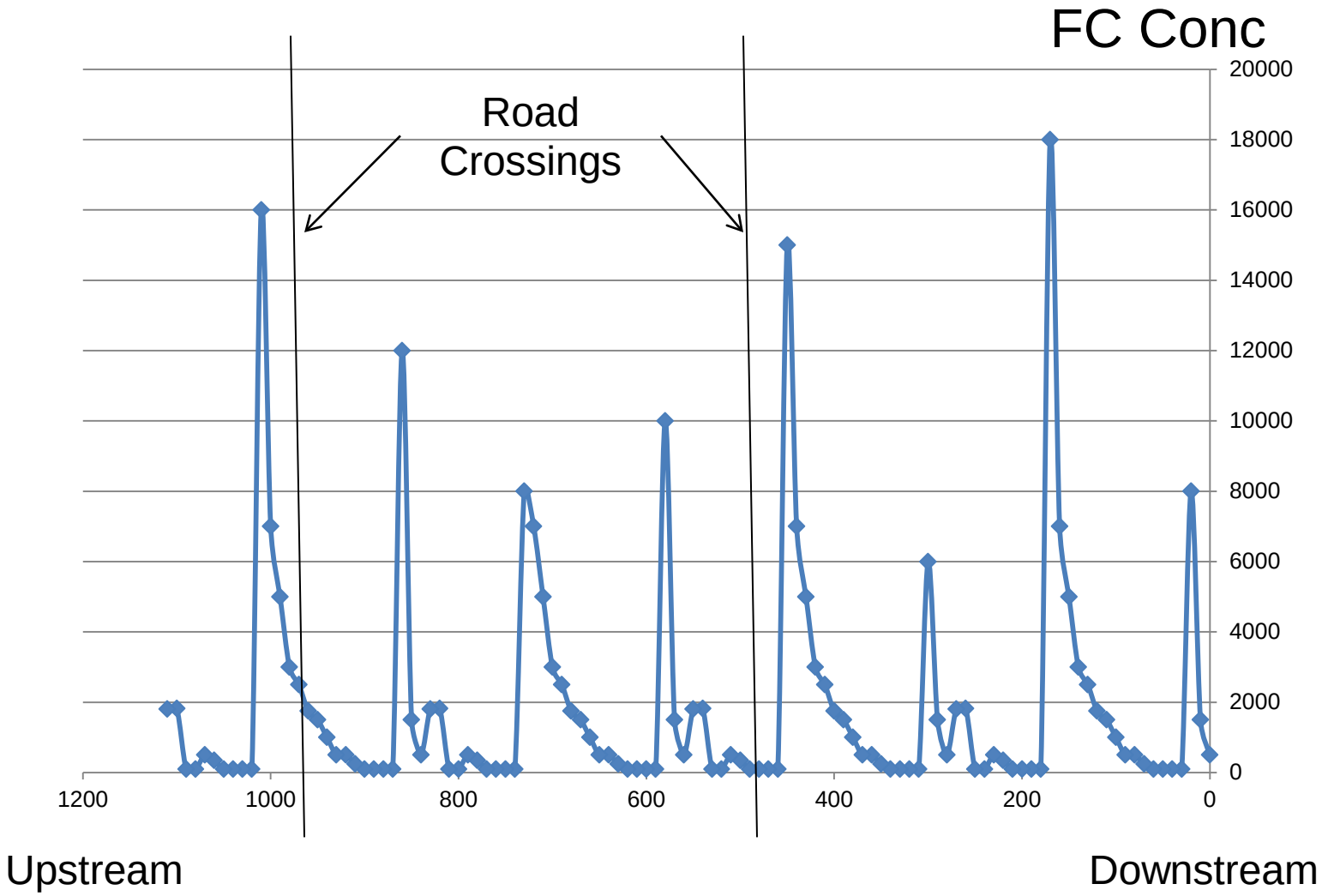
# Critical Values of t

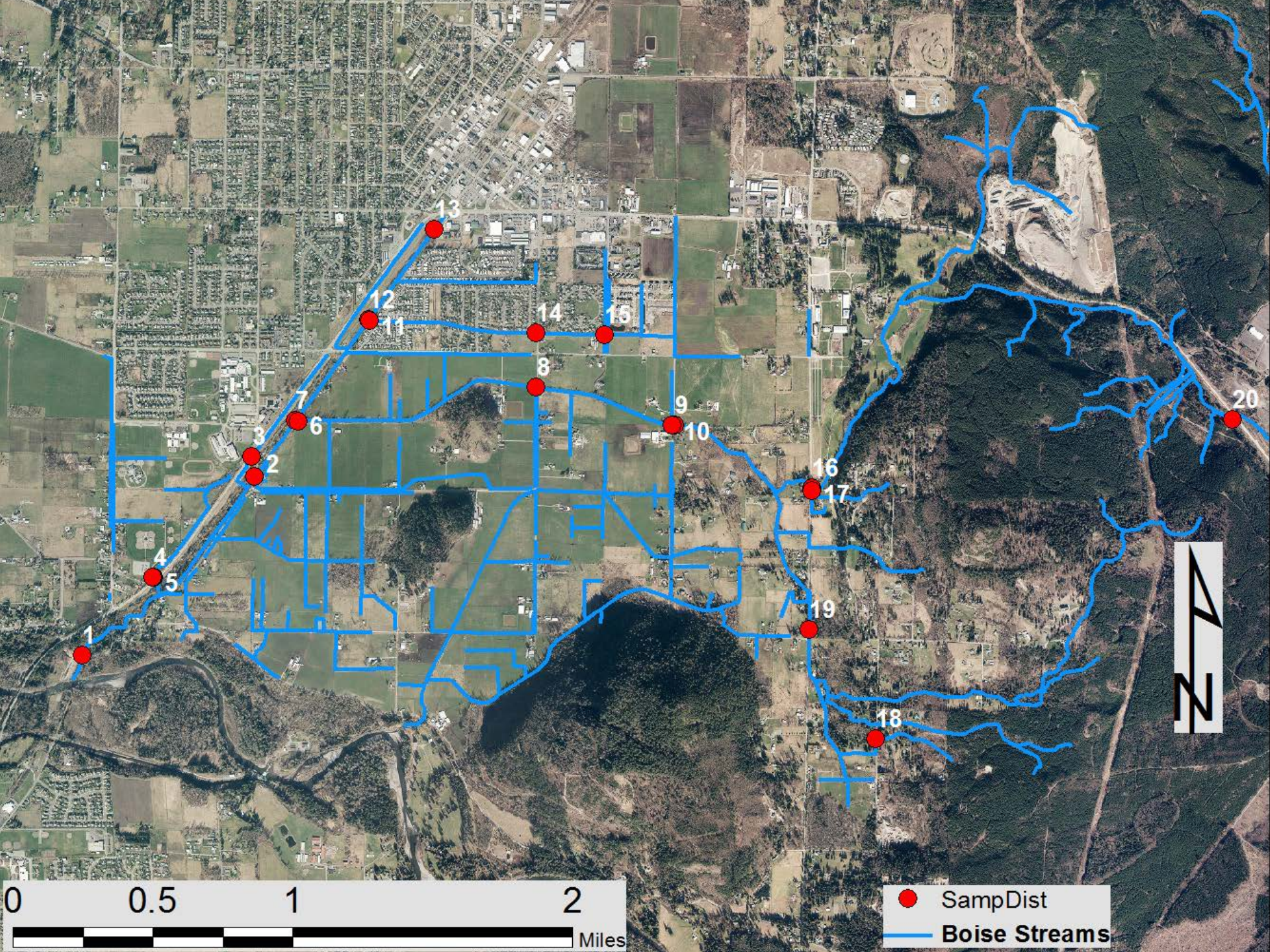
| df | Significance for a directional (one-tailed) test | | | |
|---|---|---|---|---|
| | .05 | .025 | .01 | .005 |
| | Significance for a non-directional (two-tailed) test | | | |
| | .10 | .05 | .02 | .01 |
| 1 | 6.314 | 12.706 | 31.821 | 63.657 |
| 2 | 2.920 | 4.303 | 6.965 | 9.925 |
| 3 | 2.353 | 3.182 | 4.541 | 5.841 |
| 4 | 2.132 | 2.776 | 3.747 | 4.604 |
| 5 | 2.016 | 2.571 | 3.365 | 4.032 |
| 6 | 1.943 | 2.447 | 3.143 | 3.707 |
| 7 | 1.895 | 2.365 | 2.998 | 3.499 |
| 8 | 1.860 | 2.306 | 2.896 | 3.355 |
| 9 | 1.833 | 2.262 | 2.821 | 3.250 |
| 10 | 1.812 | 2.228 | 2.764 | 3.169 |
| 11 | 1.796 | 2.201 | 2.718 | 3.106 |
| 12 | 1.782 | 2.179 | 2.681 | 3.055 |
| 13 | 1.771 | 2.160 | 2.650 | 3.012 |
| 14 | 1.761 | 2.145 | 2.624 | 2.977 |
| 15 | 1.753 | 2.131 | 2.602 | 2.947 |

| df | Significance for a directional (one-tailed) test | | | |
|---|---|---|---|---|
| | .05 | .025 | .01 | .005 |
| | Significance for a non-directional (two-tailed) test | | | |
| | .10 | .05 | .02 | .01 |
| 16 | 1.746 | 2.120 | 2.583 | 2.921 |
| 17 | 1.740 | 2.110 | 2.567 | 2.898 |
| 18 | 1.734 | 2.101 | 2.552 | 2.878 |
| 19 | 1.729 | 2.093 | 2.539 | 2.861 |
| 20 | 1.725 | 2.086 | 2.528 | 2.845 |
| 21 | 1.721 | 2.080 | 2.518 | 2.831 |
| 22 | 1.717 | 2.074 | 2.508 | 2.819 |
| 23 | 1.714 | 2.069 | 2.500 | 2.807 |
| 24 | 1.711 | 2.064 | 2.492 | 2.797 |
| 25 | 1.708 | 2.060 | 2.485 | 2.787 |
| 30 | 1.697 | 2.042 | 2.457 | 2.750 |
| 40 | 1.684 | 2.021 | 2.423 | 2.704 |
| 60 | 1.671 | 2.000 | 2.390 | 2.660 |
| 120 | 1.658 | 1.980 | 2.358 | 2.617 |
| > 120 | 1.645 | 1.960 | 2.326 | 2.576 |

If the observed t is greater than or equal to the tabled t, reject the Null Hypothesis (Ho), otherwise accept the Null Hypothesis

# Change our approach/ thinking from non-point to point sources

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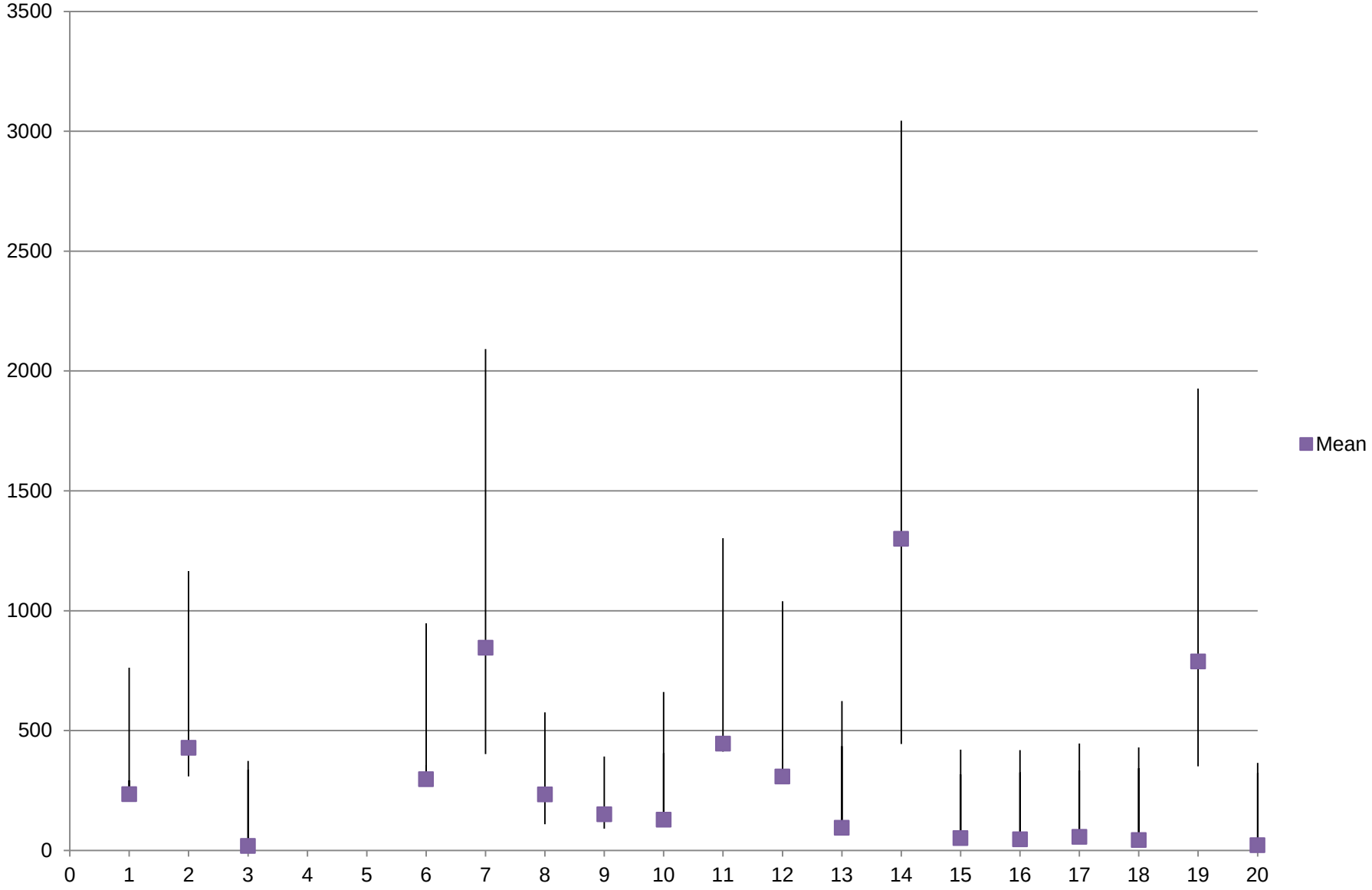
SampDist
Boise Streams

# Fecal Coliform Concentration (cfu/100mL)
# August, 2013



| From | To | Strm Dist (ft) | Mean conc | Var1 | Mean conc2 | Var2 | $S_{x1-x2}$ | MinDetDif ($\delta$) | $(2s^2)/(\delta^2)$ | $(t_{\alpha,2(n-1)}+t_{\beta(1),2(n-1)})^2$ | $n>=(2s^2)/(\delta^2)(t_{\alpha,2(n-1)}+t_{\beta(1),2(n-1)})^2$ | Optimal Stream Dist (ft) between Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 16 | *12017* | 22 | 476.67 | 46 | 16696.67 | 53.50 | 24.8 | 9.3 | 18.5 | 172 | 70 |
| 19 | 9 | *5300* | 788 | 35056.67 | 150 | 107.10 | 76.55 | 638.2 | 0.0 | 18.5 | 1 | 9946 |
| 18 | 19 | *3550* | 44 | 262360.00 | 788 | 35056.67 | 222.64 | 744.8 | 0.2 | 18.5 | 3 | 1073 |
| 17 | 9 | *3261* | 57 | 13136.67 | 150 | 107.10 | 46.98 | 93.7 | 0.5 | 18.5 | 9 | 350 |
| 16 | 9 | *3261* | 46 | 16696.67 | 150 | 107.10 | 52.92 | 103.8 | 0.5 | 18.5 | 10 | 339 |
| 15 | 14 | *1300* | 51 | 289.87 | 1300 | 560000.00 | 305.58 | 1248.7 | 0.1 | 18.5 | 2 | 586 |
| 14 | 11 | *3261* | 1300 | 560000.00 | 445 | 5470.00 | 306.99 | 855.0 | 0.3 | 18.5 | 5 | 683 |
| 13 | 12 | *2155* | 94 | 32656.17 | 308 | 15456.67 | 89.55 | 214.5 | 0.3 | 18.5 | 6 | 334 |
| 12 | 7 | *2344* | 308 | 15456.67 | 845 | 734.70 | 51.95 | 536.7 | 0.0 | 18.5 | 0 | 6756 |
| 11 | 7 | *2344* | 445 | 5470.00 | 845 | 734.70 | 32.16 | 400.0 | 0.0 | 18.5 | 0 | 9793 |
| 10 | 8 | *2689* | 128 | 7900.00 | 233 | 228576.67 | 198.53 | 105.3 | 7.1 | 18.5 | 132 | 20 |
| 9 | 8 | *2689* | 150 | 107.10 | 233 | 228576.67 | 195.23 | 83.2 | 11.0 | 18.5 | 204 | 13 |
| 8 | 6 | *4757* | 233 | 228576.67 | 297 | 321.10 | 195.32 | 63.3 | 19.0 | 18.5 | 352 | 14 |
| 7 | 2 | *1265* | 845 | 734.70 | 428 | 5026.67 | 30.99 | 416.7 | 0.0 | 18.5 | 0 | 6176 |
| 6 | 2 | *1265* | 297 | 321.10 | 428 | 5026.67 | 29.85 | 131.7 | 0.1 | 18.5 | 2 | 664 |
| 4 | 1 | *2471* | 11 | 97.87 | 235 | 7312.17 | 35.14 | 224.3 | 0.0 | 18.5 | 1 | 2719 |
| 3 | 1 | *5512* | 19 | 145.07 | 235 | 7312.17 | 35.25 | 216.3 | 0.1 | 18.5 | 1 | 5605 |
| 2 | 1 | *5031* | 428 | 5026.67 | 235 | 7312.17 | 45.35 | 193.3 | 0.1 | 18.5 | 2 | 2469 |
| | | *64472* | | | | | | | | | *903* | *71* |
| | | | | | | | | | | | | Total N |

| From | To | Strm Dist (ft) | Mea |
|---|---|---|---|
| 20 | 16 | 12017 | |
| 19 | 9 | 5300 | |
| 18 | 19 | 3550 | |
| 17 | 9 | 3261 | |
| 16 | 9 | 3261 | |
| 15 | 14 | 1300 | |
| 14 | 11 | 3261 | |
| 13 | 12 | 2155 | |
| 12 | 7 | 2344 | |
| 11 | 7 | 2344 | |
| 10 | 8 | 2689 | |
| 9 | 8 | 2689 | |
| 8 | 6 | 4757 | |
| 7 | 2 | 1265 | |
| 6 | 2 | 1265 | |
| 4 | 1 | 2471 | |
| 3 | 1 | 5512 | |
| 2 | 1 | 5031 | |
| | | 64472 | |

| From | To | $n>=(2s^2)/(\delta^2)\ (t_{\alpha,2\,(n-1)}+t_{\beta(1),\,2(n-1)})^2$ | Optimal Stream Dist (ft) between Samples |
|---|---|---|---|
| 20 | 16 | 172 | 70 |
| 19 | 9 | 1 | 9946 |
| 18 | 19 | 3 | 1073 |
| 17 | 9 | 9 | 350 |
| 16 | 9 | 10 | 339 |
| 15 | 14 | 2 | 586 |
| 14 | 11 | 5 | 683 |
| 13 | 12 | 6 | 334 |
| 12 | 7 | 0 | 6756 |
| 11 | 7 | 0 | 9793 |
| 10 | 8 | 132 | 20 |
| 9 | 8 | 204 | 13 |
| 8 | 6 | 352 | 14 |
| 7 | 2 | 0 | 6176 |
| 6 | 2 | 2 | 664 |
| 4 | 1 | 1 | 2719 |
| 3 | 1 | 1 | 5605 |
| 2 | 1 | 2 | 2469 |
| | | *903* | *71* |
| | | | Total N |

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| 172 | 70 |
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| 1 | 2719 |
| 1 | 5605 |
| 2 | 2469 |
| 903 | 71 |
| | Total N |

| From | To | Strm Dist (ft) | Mea |
|---|---|---|---|
| 20 | 16 | 12017 | |
| 19 | 9 | 5300 | |
| 18 | 19 | 3550 | |
| 17 | 9 | 3261 | |
| 16 | 9 | 3261 | |
| 15 | 14 | 1300 | |
| 14 | 11 | 3261 | |
| 13 | 12 | 2155 | |
| 12 | 7 | 2344 | |
| 11 | 7 | 2344 | |
| 10 | 8 | 2689 | |
| 9 | 8 | 2689 | |
| 8 | 6 | 4757 | |
| 7 | 2 | 1265 | |
| 6 | 2 | 1265 | |
| 4 | 1 | 2471 | |
| 3 | 1 | 5512 | |
| 2 | 1 | 5031 | |
| | | 64472 | |

| From | To | $n>=(2s^2)/(\delta^2)\ (t_{\alpha,2\,(n-1)}+t_{\beta(1),\,2(n-1)})^2$ | Optimal Stream Dist (ft) between Samples |
|---|---|---|---|
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| 13 | 12 | 6 | 334 |
| 12 | 7 | 0 | 6756 |
| 11 | 7 | 0 | 9793 |
| 10 | 8 | 132 | 20 |
| 9 | 8 | 204 | 13 |
| 8 | 6 | 352 | 14 |
| 7 | 2 | 0 | 6176 |
| 6 | 2 | 2 | 664 |
| 4 | 1 | 1 | 2719 |
| 3 | 1 | 1 | 5605 |
| 2 | 1 | 2 | 2469 |
| | | *903* | *71* |
| | | | Total N |

| | Optimal Stream Dist (ft) between Samples |
|---|---|
| 172 | 70 |
| 1 | 9946 |
| 3 | 1073 |
| 9 | 350 |
| 10 | 339 |
| 2 | 586 |
| 5 | 683 |
| 6 | 334 |
| 0 | 6756 |
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| 132 | 20 |
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| 352 | 14 |
| 0 | 6176 |
| 2 | 664 |
| 1 | 2719 |
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| 903 | 71 |
| | Total N |

| From | To | Strm Dist (ft) | Mea |
|---|---|---|---|
| 20 | 16 | 12017 | |
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| 17 | 9 | 3261 | |
| 16 | 9 | 3261 | |
| 15 | 14 | 1300 | |
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| 13 | 12 | 2155 | |
| 12 | 7 | 2344 | |
| 11 | 7 | 2344 | |
| 10 | 8 | 2689 | |
| 9 | 8 | 2689 | |
| 8 | 6 | 4757 | |
| 7 | 2 | 1265 | |
| 6 | 2 | 1265 | |
| 4 | 1 | 2471 | |
| 3 | 1 | 5512 | |
| 2 | 1 | 5031 | |
| | | 64472 | |

| From | To | $n>=(2s^2)/(\delta^2)\ (t_{\alpha,2\,(n-1)}+t_{\beta(1),\,2(n-1)})^2$ | Optimal Stream Dist (ft) between Samples |
|---|---|---|---|
| 20 | 16 | 172 | 70 |
| 19 | 9 | 1 | 9946 |
| 18 | 19 | 3 | 1073 |
| 17 | 9 | 9 | 350 |
| 16 | 9 | 10 | 339 |
| 15 | 14 | 2 | 586 |
| 14 | 11 | 5 | 683 |
| 13 | 12 | 6 | 334 |
| 12 | 7 | 0 | 6756 |
| 11 | 7 | 0 | 9793 |
| 10 | 8 | 132 | 20 |
| 9 | 8 | 204 | 13 |
| 8 | 6 | 352 | 14 |
| 7 | 2 | 0 | 6176 |
| 6 | 2 | 2 | 664 |
| 4 | 1 | 1 | 2719 |
| 3 | 1 | 1 | 5605 |
| 2 | 1 | 2 | 2469 |
| | | *903* | *71* |
| | | | Total N |

$n_{Max} = 100$

| | Optimal Stream Dist (ft) between Samples |
|---|---|
| 172 | 70 |
| 1 | 9946 |
| 3 | 1073 |
| 9 | 350 |
| 10 | 339 |
| 2 | 586 |
| 5 | 683 |
| 6 | 334 |
| 0 | 6756 |
| 0 | 9793 |
| 132 | 20 |
| 204 | 13 |
| 352 | 14 |
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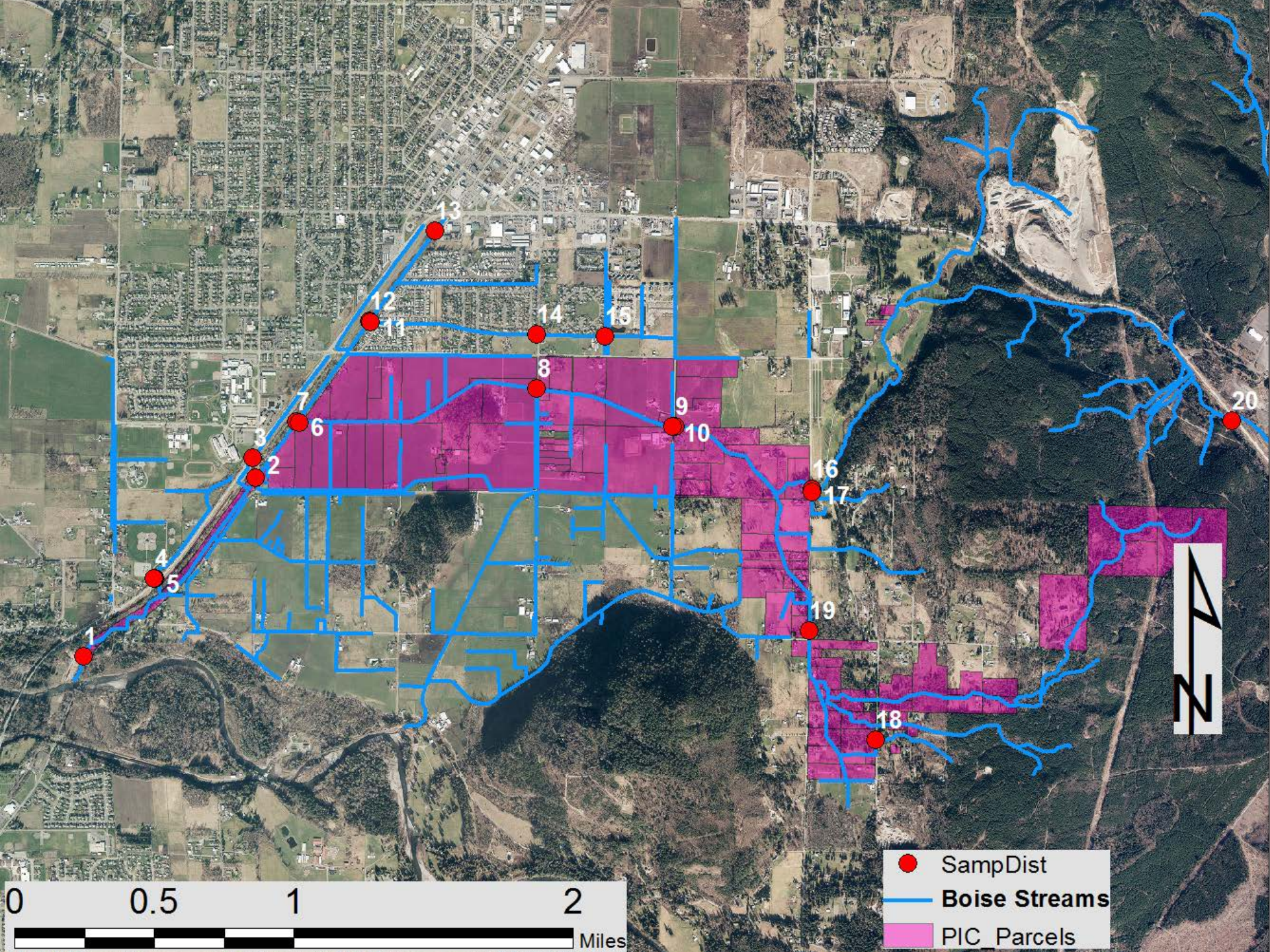
| 2 | 664 |
| 1 | 2719 |
| 1 | 5605 |
| 2 | 2469 |
| 903 | 71 |
| | Total N |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Boise Streams
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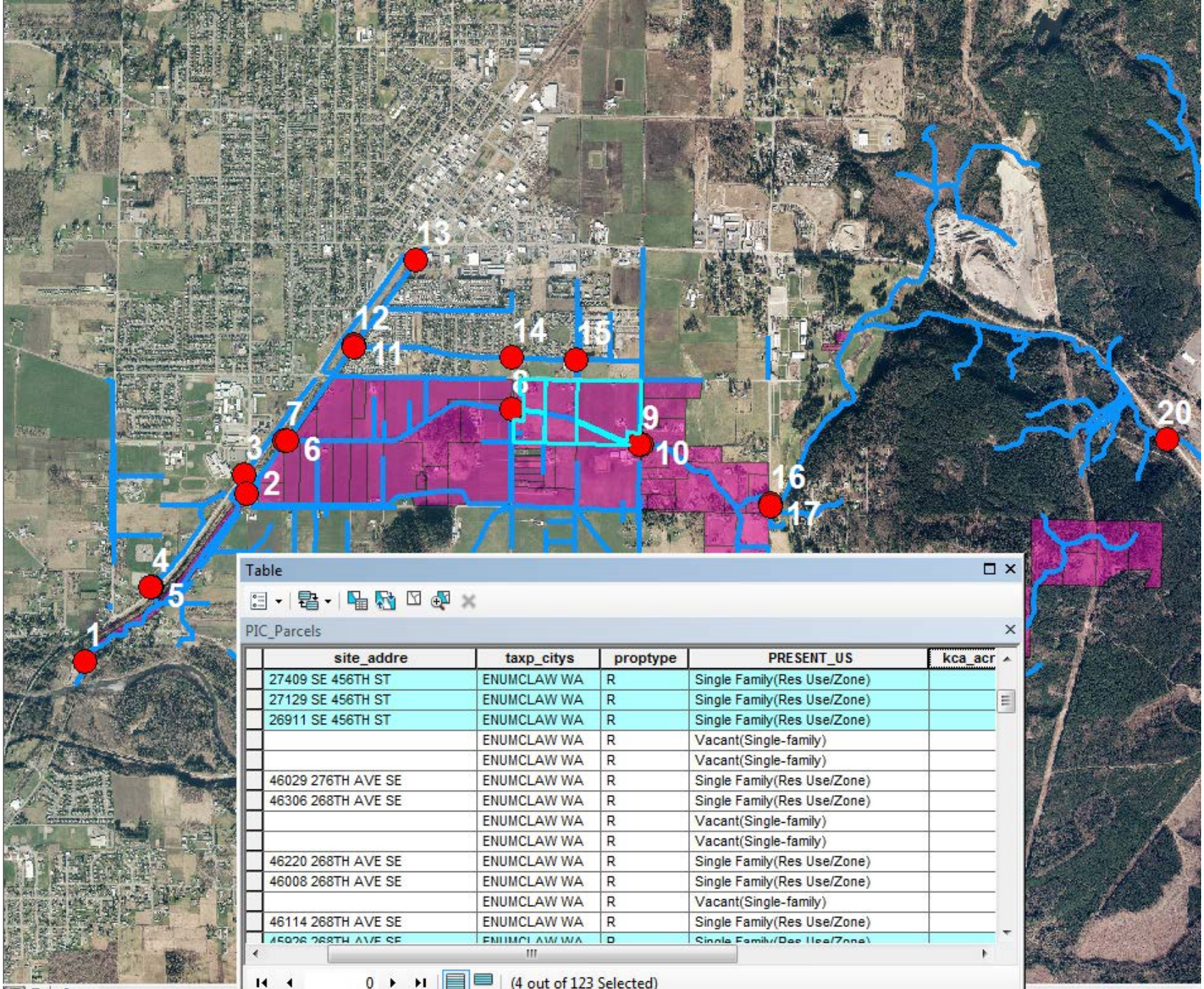
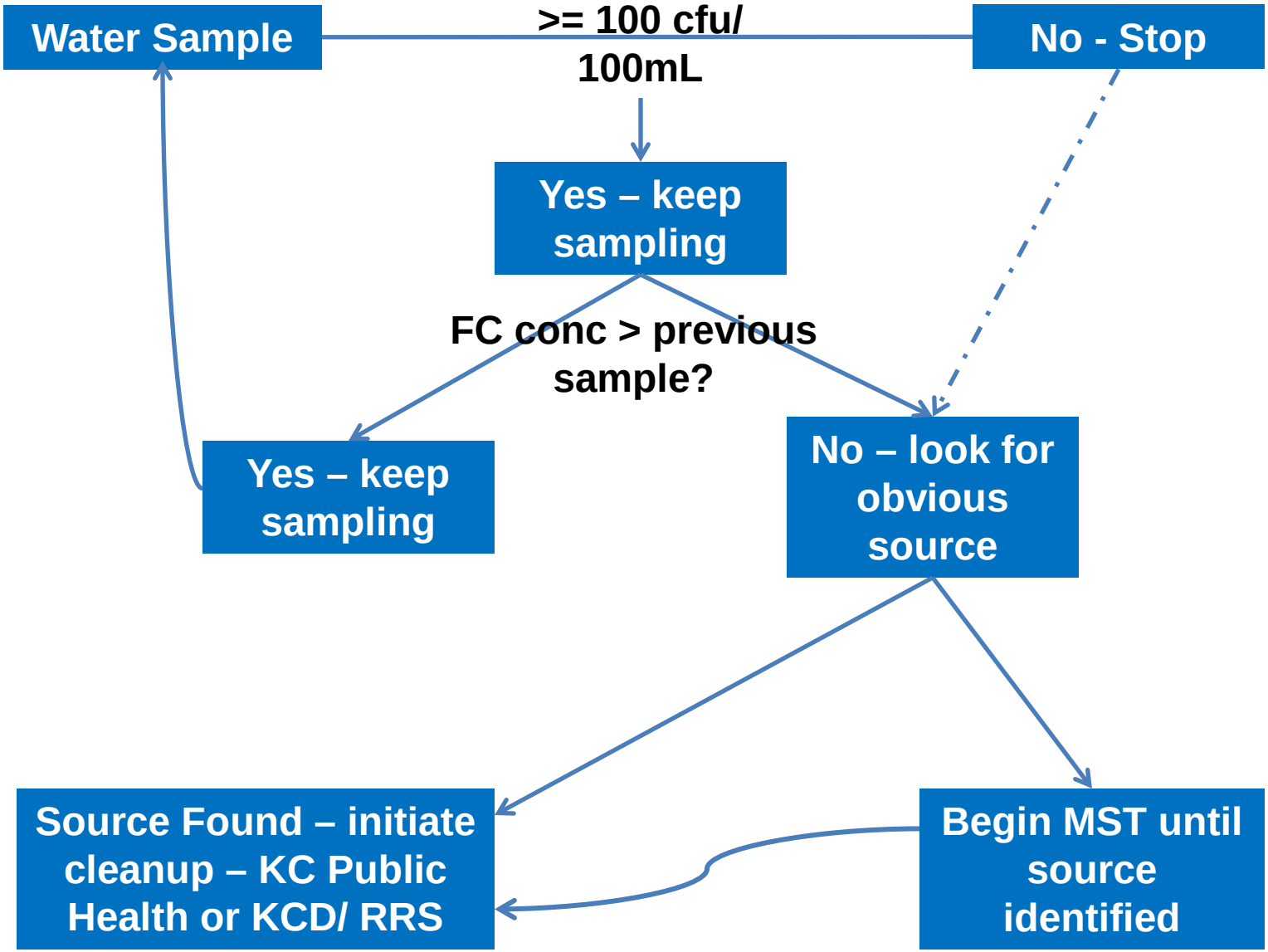



| site_addre | taxp_citys | proptype | PRESENT_US | kca_acr |
|---|---|---|---|---|
| 27409 SE 456TH ST | ENUMCLAW WA | R | Single Family(Res Use/Zone) | |
| 27129 SE 456TH ST | ENUMCLAW WA | R | Single Family(Res Use/Zone) | |
| 26911 SE 456TH ST | ENUMCLAW WA | R | Single Family(Res Use/Zone) | |
| | ENUMCLAW WA | R | Vacant(Single-family) | |
| | ENUMCLAW WA | R | Vacant(Single-family) | |
| 46029 276TH AVE SE | ENUMCLAW WA | R | Single Family(Res Use/Zone) | |
| 46306 268TH AVE SE | ENUMCLAW WA | R | Single Family(Res Use/Zone) | |
| | ENUMCLAW WA | R | Vacant(Single-family) | |
| | ENUMCLAW WA | R | Vacant(Single-family) | |
| 46220 268TH AVE SE | ENUMCLAW WA | R | Single Family(Res Use/Zone) | |
| 46008 268TH AVE SE | ENUMCLAW WA | R | Single Family(Res Use/Zone) | |
| | ENUMCLAW WA | R | Vacant(Single-family) | |
| 46114 268TH AVE SE | ENUMCLAW WA | R | Single Family(Res Use/Zone) | |
| 45926 268TH AVE SE | ENUMCLAW WA | R | Single Family(Res Use/Zone) | |


Water Sample
>= 100 cfu/ 100mL
No - Stop
Yes – keep sampling
FC conc > previous sample?
Yes – keep sampling
No – look for obvious source
Source Found – initiate cleanup – KC Public Health or KCD/ RRS
Begin MST until source identified

# ...and then what?

- KCD and RRS are actively engaged with landowners
  - Education
  - Ag BMPs
- Waiting to hear the fate of our pending proposal to Ecology
- NPDES and TMDL mandates
  - Education and outreach
  - Screen 100% of Boise Creek MS4

# Acknowledgements


- King Conservation District
  - Erin Ericson
  - Sofia Gidlund
- King County Stormwater Services
  - Jeanne Dorn
  - Jill Coyle
  - Blair Scott
  - Doug Navetski
- City of Enumclaw
  - Chris Searcy
  - Lindsey Winborn