Snyderville Basin Water Reclamation District

Impact of EDCs on Trout in an Effluent Dominated Stream

National River Rally 2010

Snowbird, Utah

Michael Luers

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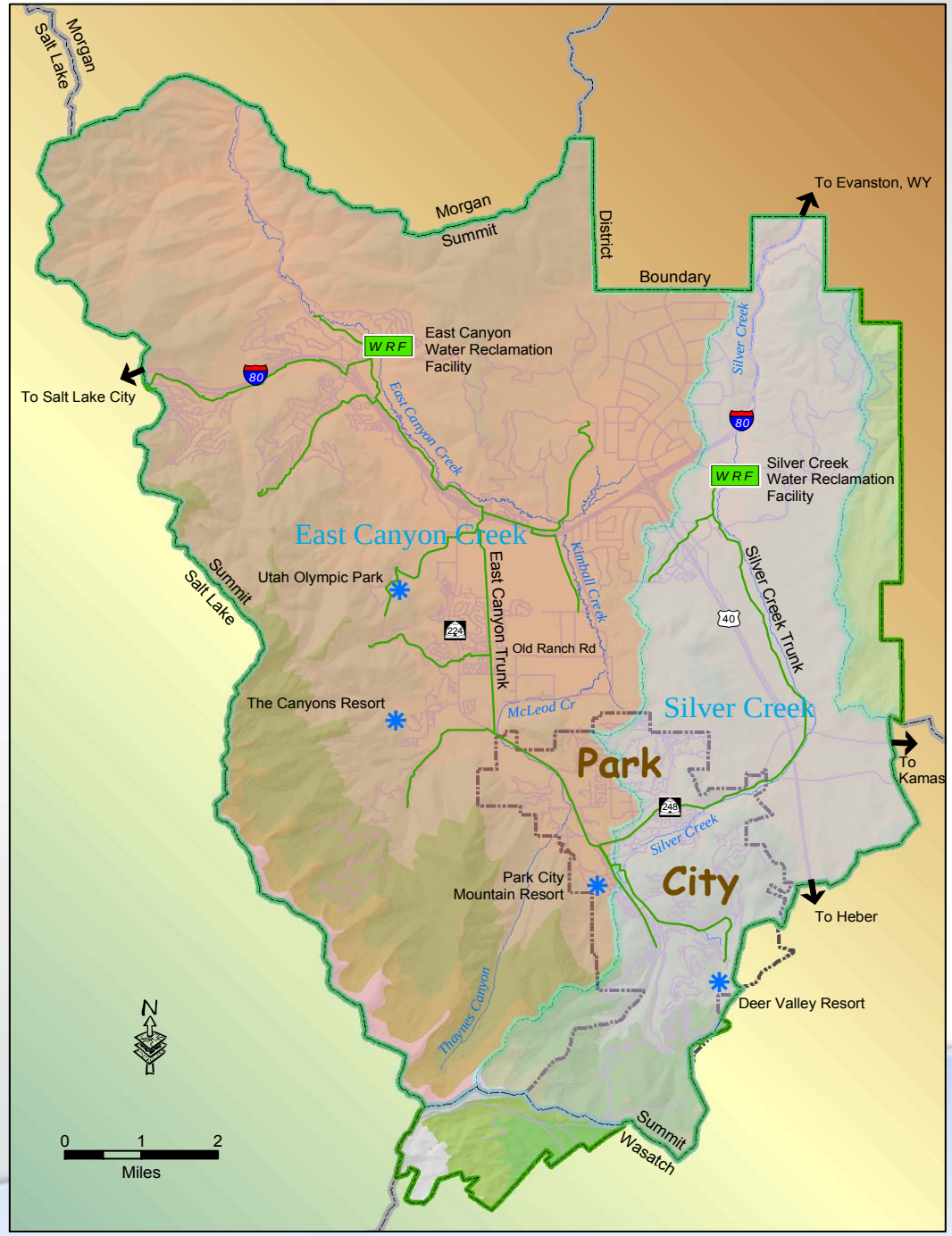
Presentation Summary

- SBWRD Background information
- Introduction to endocrine disrupting compounds (EDCs), pharmaceuticals and personal care products (PPCPs)
- Implications for aquatic life
- SBWRD's research efforts


Morgan
Salt Lake
Morgan
Summit
District
Boundary
To Evanston, WY
East Canyon
Water Reclamation
Facility
WRF
80
To Salt Lake City
East Canyon Creek
Silver Creek
Silver Creek
Water Reclamation
Facility
WRF
East Canyon Creek
Kimball Creek
Silver Creek Trunk
Utah Olympic Park
Summit
Salt Lake
East Canyon Trunk
224
Old Ranch Rd
40
The Canyons Resort
McLeod Cr
Silver Creek
Park
To
Kamas
248
Silver Creek
City
Park City
Mountain Resort
To Heber
Deer Valley Resort
Thaynes Canyon
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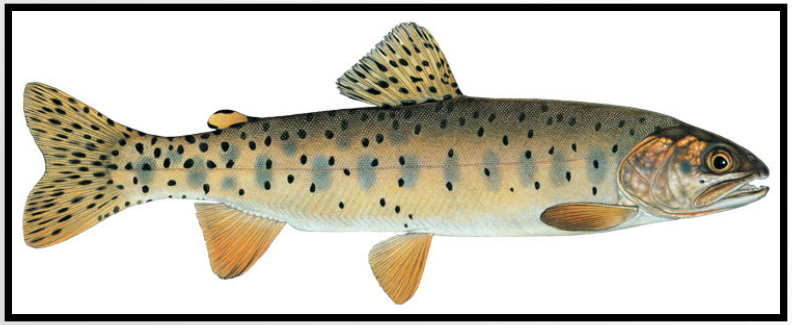
0
1
2
Miles
Summit
Wasatch

East Canyon Creek provides habitat for sensitive trout species and is a source of drinking water

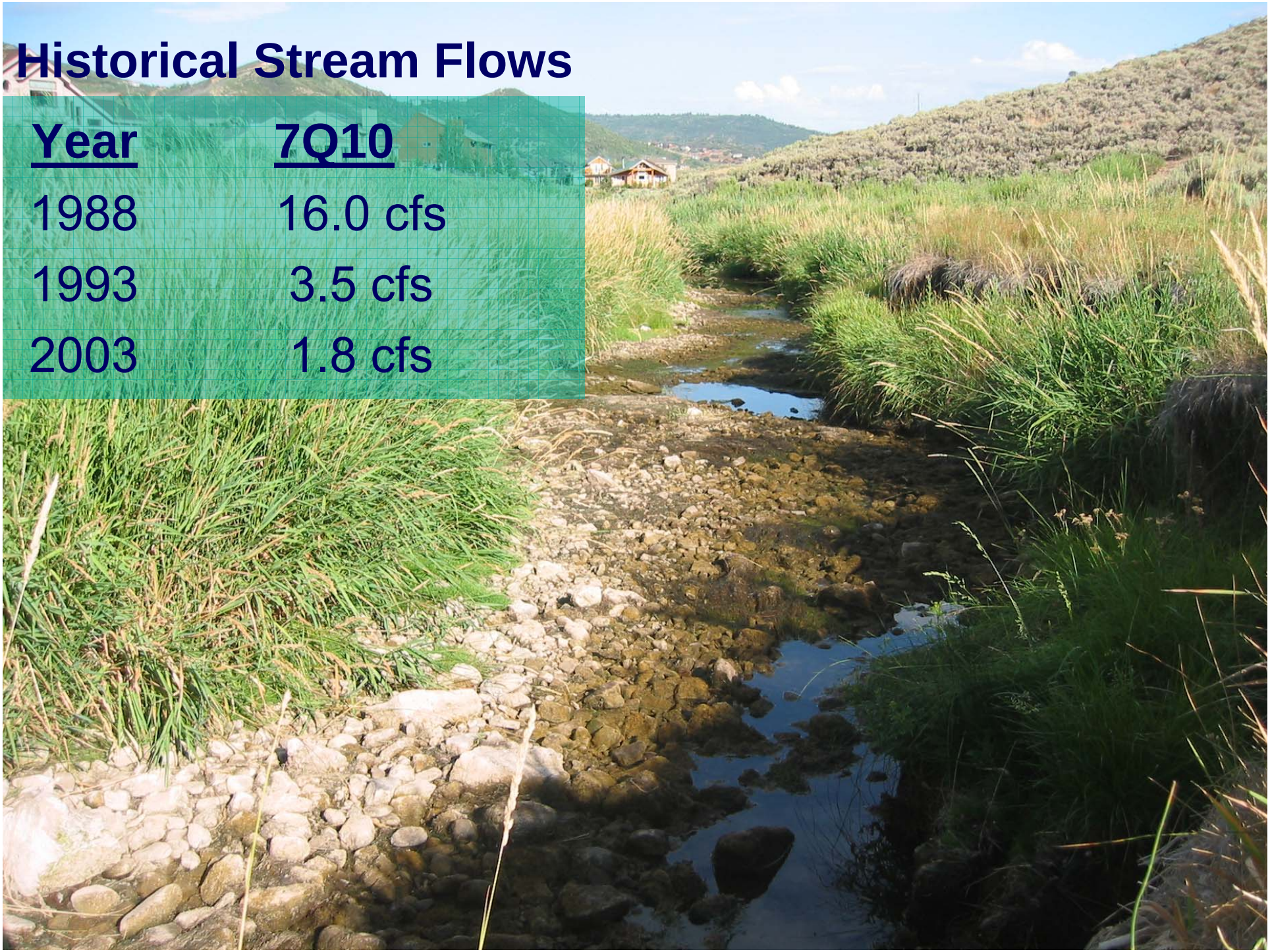
Brown Trout
(*Salmo trutta*)



Bonneville Cutthroat
(Oncorhynchus clarki)

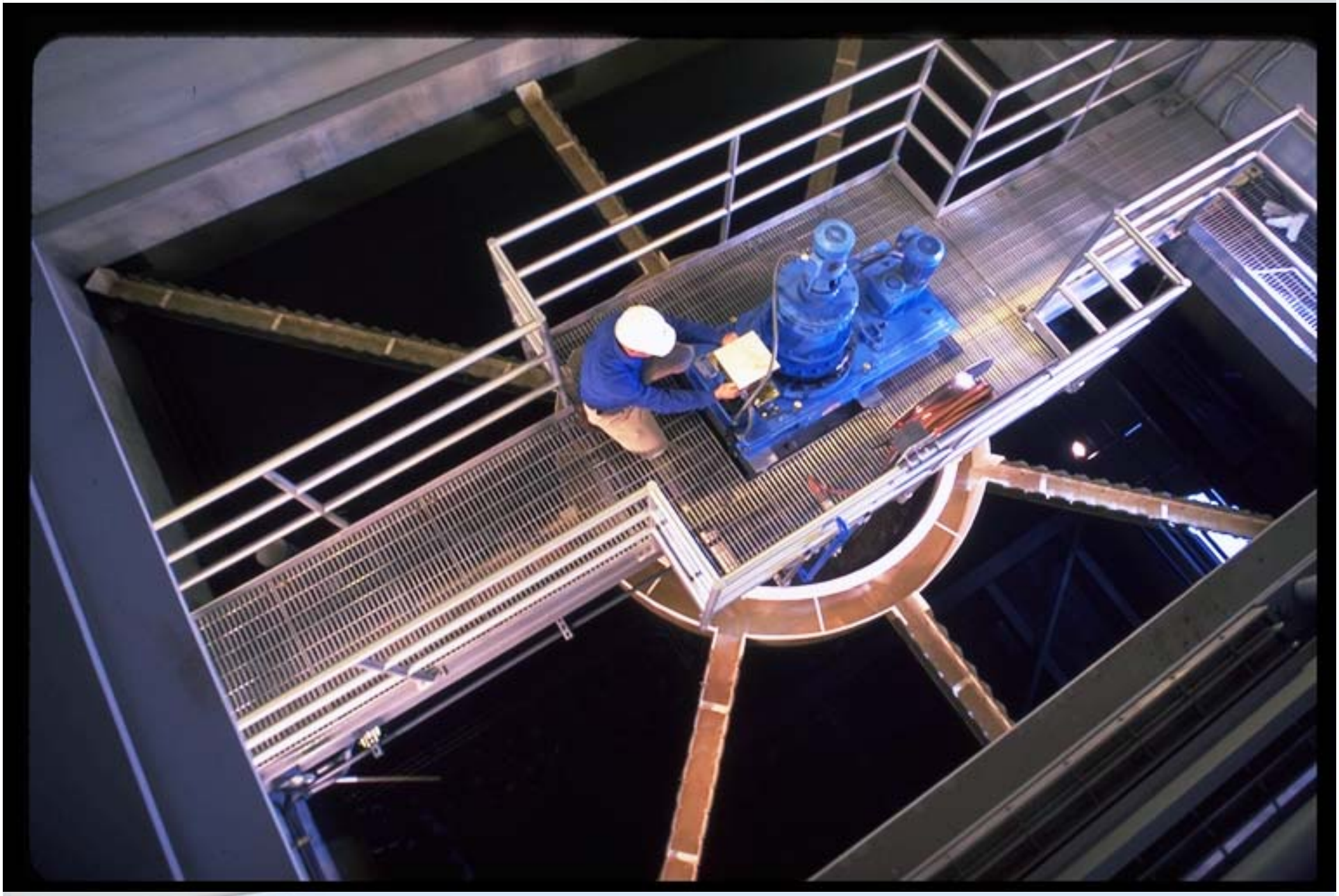
Historical Stream Flows

Year	7Q10
1988	16.0 cfs
1993	3.5 cfs
2003	1.8 cfs



East Canyon Creek
Water Quality Impairments

- Primary Concern -
  - Excessive Nutrients
    - Phosphorus & Nitrogen
  - Low Dissolved Oxygen (D.O. Sags)
- Related Problems -
  - algae and macrophyte growth
  - reduced fishery
  - potential taste & odor problems
  - Increased temperatures and poor channel conditions



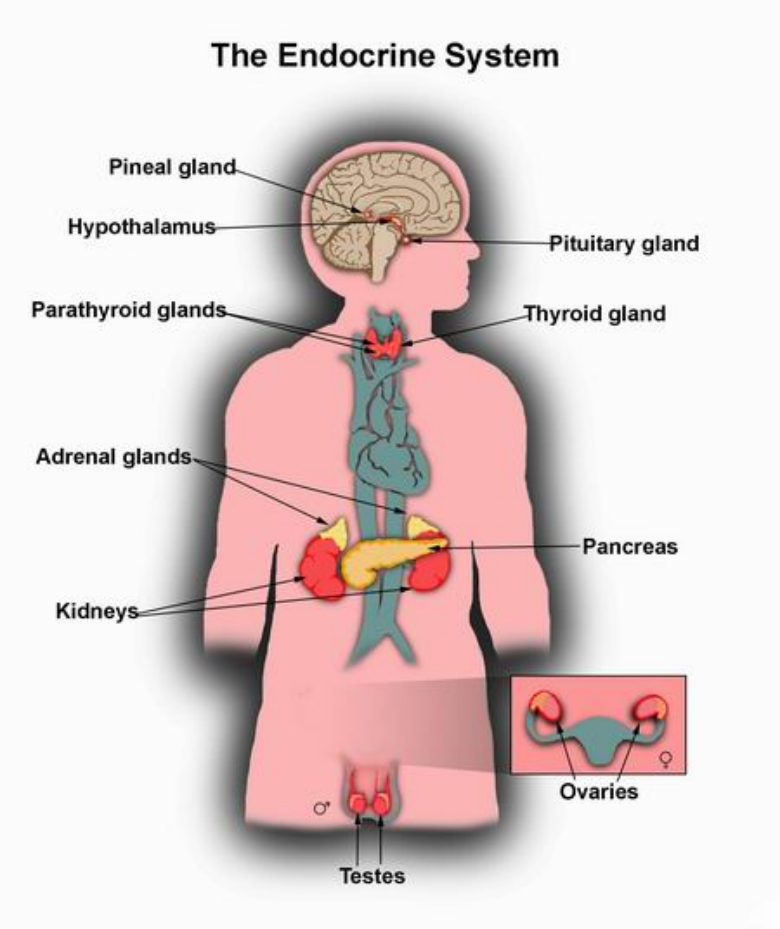
SBWRD is Concerned About EDCs Discharged to East Canyon Creek

What Is The Endocrine System?

The Endocrine System: Combination of glands and hormones that assist in reproduction, growth and development

Compounds that block, mimic, stimulate or inhibit the endocrine system – Endocrine Disrupting Compounds (EDC's)

Natural and synthetic estrogen based hormones are of greatest concern in our situation



Potential Sources of Endocrine Disrupting Compounds (EDCs)

- Natural and Synthetic Hormones
- Pharmaceuticals and Personal Care Products
- Pesticides
- Detergents
- Industrial Compounds

Some of these products contain Endocrine Disrupting Compounds (EDCs)

antibacterial hand soap
triclosan

birth control pill
ethinyl estradiol

coffee
caffeine

polycarbonate plastic
bisphenol-a

fire extinguisher
TDCPP, TCEP, TCPP

insect repellent chemical
DEET

Compounds shown represent only a small portion of all compounds to be analyzed

First the facts:

- Over 3,000 prescription drugs available for use in the U.S.
- Average geriatric patient uses 7-10 different medications per day
- Wastewater is the primary pathway of residues to the aquatic environment

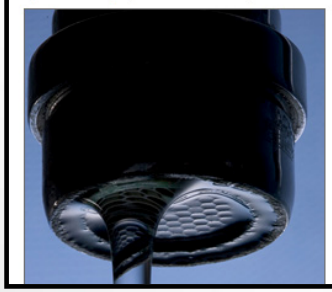
Detection of Trace Level EDCs Possible by Advances in Analytical Methods

Liquid Chromatography/Mass Spectrometer

Public Perception of EDCs in Water is a Challenge for Water Professionals

AP: Drugs found in drinking water

Updated 36d ago | Comments 147 | Recommend 76 E-mail | Save | Print | RSS



By Jeff Donn, Martha Mendoza and Justin Pritchard, Associated Press

A vast array of pharmaceuticals — including antibiotics, anti-convulsants, mood stabilizers and sex hormones — have been found in the drinking water supplies of at least 41 million Americans, an Associated Press investigation shows.

To be sure, the concentrations of these pharmaceuticals are tiny, measured in quantities of parts per billion or trillion, far below the levels of a medical dose. Also, utilities insist their water is safe.

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AWWA Urges Science-Based Approach in Addressing Pharmaceutical ...
FOXBusiness - 6 hours ago

A Glass of H2O-My
Washington Post - Apr 14, 2008

Feds Not Addressing Drugs in

Senators rip EPA over lack of knowledge on drugs in water

By MARTHA MENDOZA – **17 hours ago**

WASHINGTON (AP) — The Environmental Protection Agency was lambasted during a Senate hearing Tuesday for allowing the American public to learn that traces of pharmaceuticals are in much of the nation's drinking water from an Associated Press investigative series, not the federal government.

Intersex Fish Raises Pollution Concerns in US

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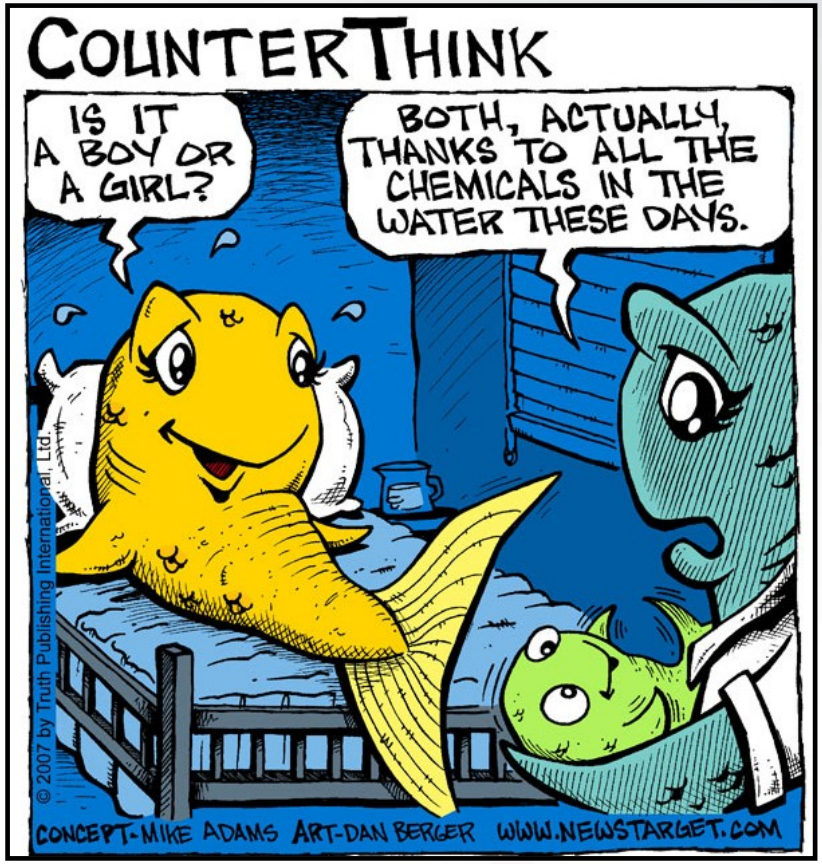
US: September 8, 2006

TODAY'S ENVIRONMENT NEWS

AUSTRALIA:
Coral Flourishing At Bikini Atoll Atomic Test



Natural and Synthetic Hormones Thought to be the EDCs of Greatest Concern

Microconstituent	MRL[1] (ng/L)	Type/Purpose
Acetaminophen	1.0	Pain Relief
Caffeine	3.0	Stimulant
Carbamazepine	5.0	Anti-Epileptic
Cotinine	1.0	Stimulant
Diazepam	1.0	Anti-Anxiety
Estrone	1.0	Natural Hormone
Estradiol	1.0	Natural Hormone
Ethinyl Estradiol - 17∝	1.0	Synthetic Hormone
Fluoxetine	1.0	Anti-Depressant
Progesterone	1.0	Natural Hormone
Sulfamethoxazole	1.0	Antibiotic
Testosterone	1.0	Natural Hormone
Trimethoprim	1.0	Antibiotic
Triclosan	5.0	Anti-Microbial

[1]Method Reporting Limit

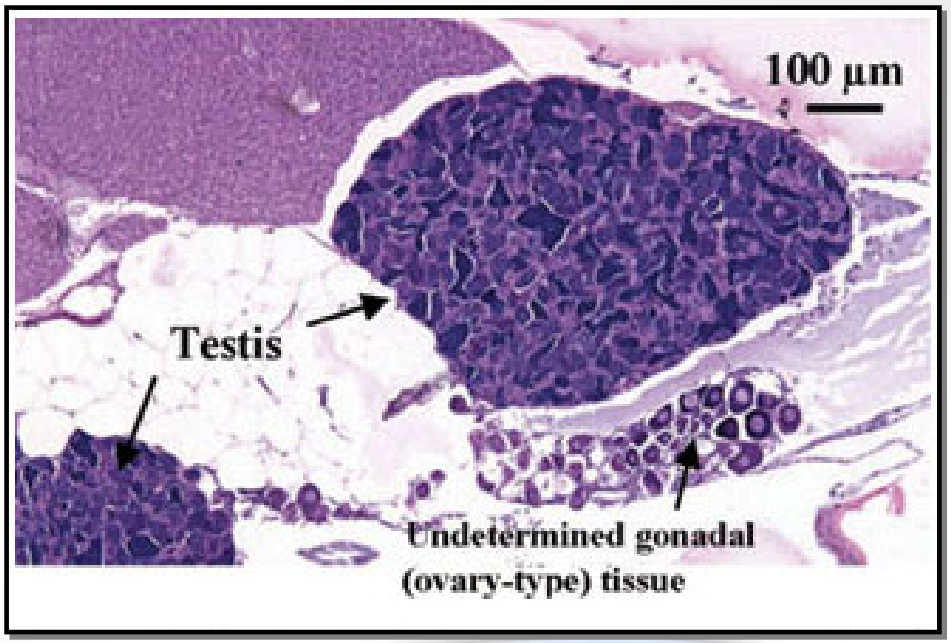
Sources of Estrogens

- **Mature woman**
  - 4.8 µg estriol
  - 3.5 µg estradiol
  - 8.0 µg estrone
- **Post Menopause Woman**
  - 7 µg/day (all 3)
- **Men**
  - 7 µg/day (all 3)
- **Pregnant Woman**
  - 6,000 µg estriol
  - 600 µg estrone
  - 259 µg estradiol
- **Synthetic Hormones**
  - 26% of ethyl estradiol in birth control pills is excreted
- **Hormone & estrogen** replacement therapy
  - 65% estradiol excreted
  - 15% estrone excreted

Current Literature Describes Potential Effects of EDC Exposure for Fish

Estrogenicity (feminization)

- Vitellogenin induction in male fish
- Intersex fish
- Skewed sex ratios
- Population collapse



(Nash et al, 2004)

Concentrations of Estrogens that begin to affect Male Fish

Inducement of vitellogenin production

- ≈ 5 ng/L 17β-estradiol
- estriol is 30 times less potent than above
- ≈ 3.2 ng/L for estrone
- ≥ 1 ng/L for 17α-ethinylestradiol

Inducement of intersex

- ≈ 10 ng/L for estrone, or 17β-estradial
- estriol is 100 times less potent than above
- ≈ 4 ng/L for 17α-ethinylestradiol
- estrogenic substances are additive

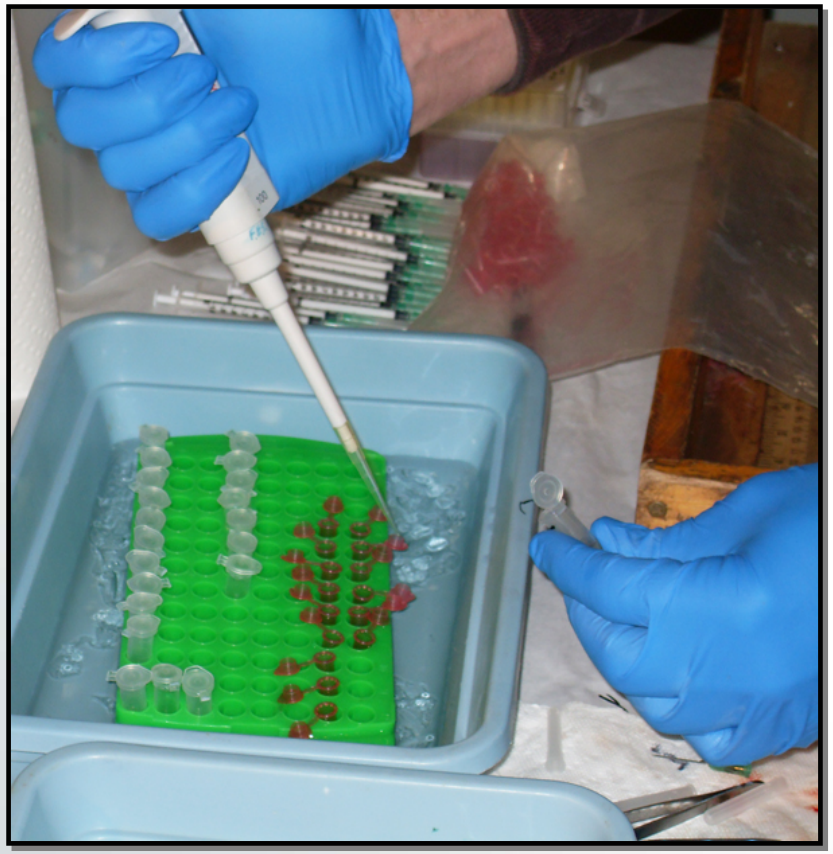
White sucker

Boulder Creek

Estrogenicity and the Environment

"The occurrence of feminized fish is associated with effluent discharges … the incidence and severity is positively correlated with the proportion of treated sewage effluent in receiving waters."

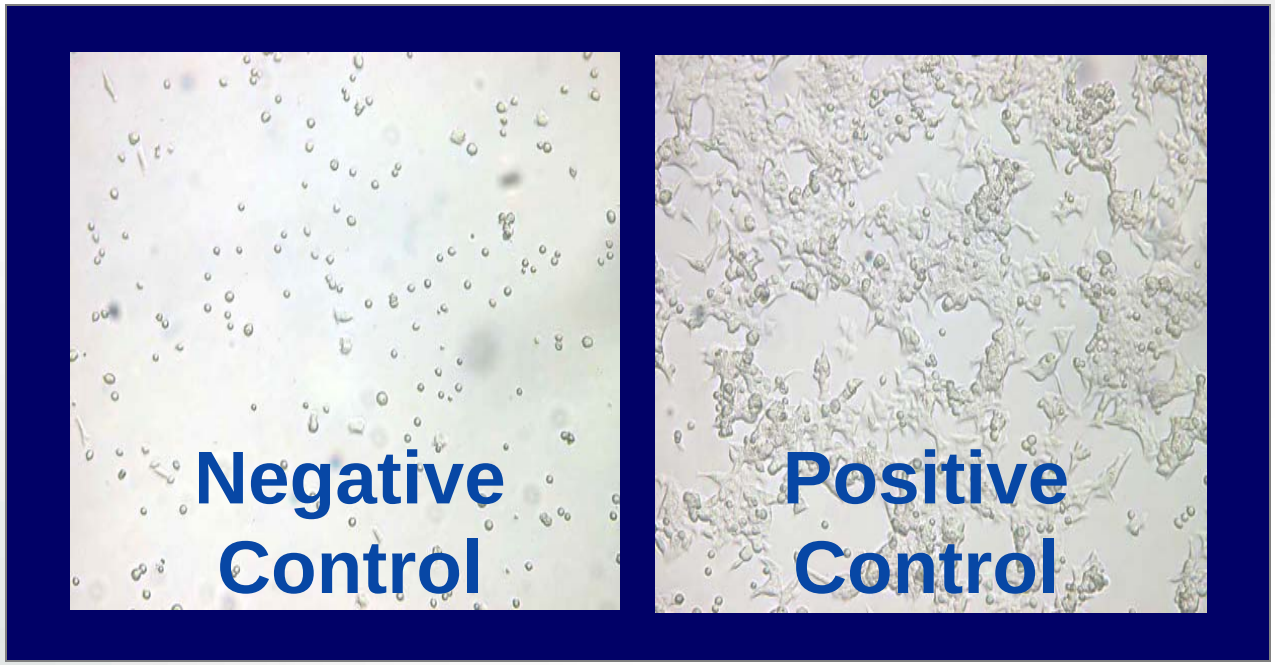
Vitellogenin (Vtg) is a Biomarker of Estrogen Exposure in Male Fish



- Egg yolk protein
- Vtg not normally found in male fish
- Vtg detected after exposures less than 1.0 ng/L (ppt)

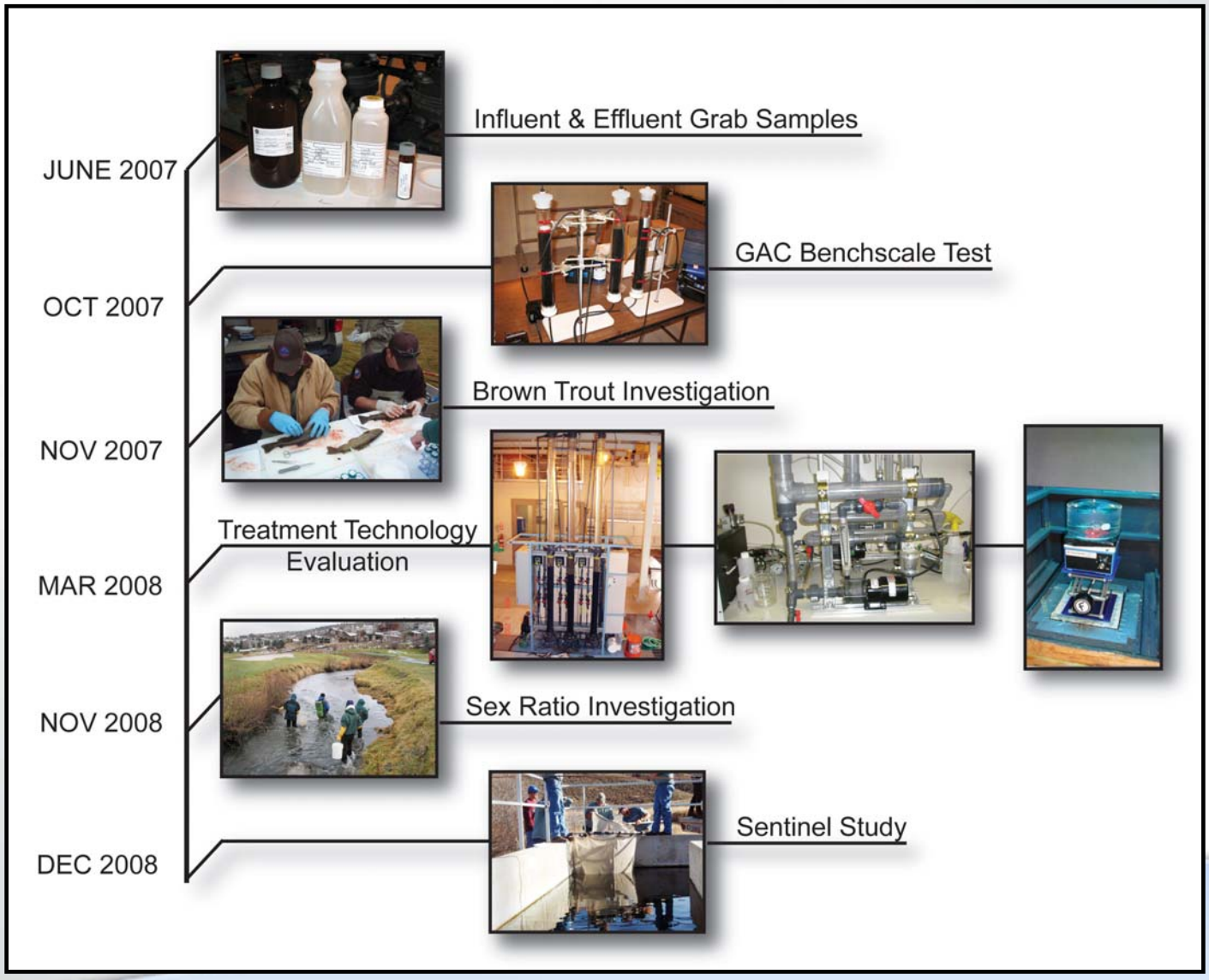
Estrogen Activity Measured by E-Screen Bioassay

Breast cancer cell line with growth response to estrogen



Reported as estradiol equivalents (MRL = 0.030 ppt)

Timeline of Research Efforts

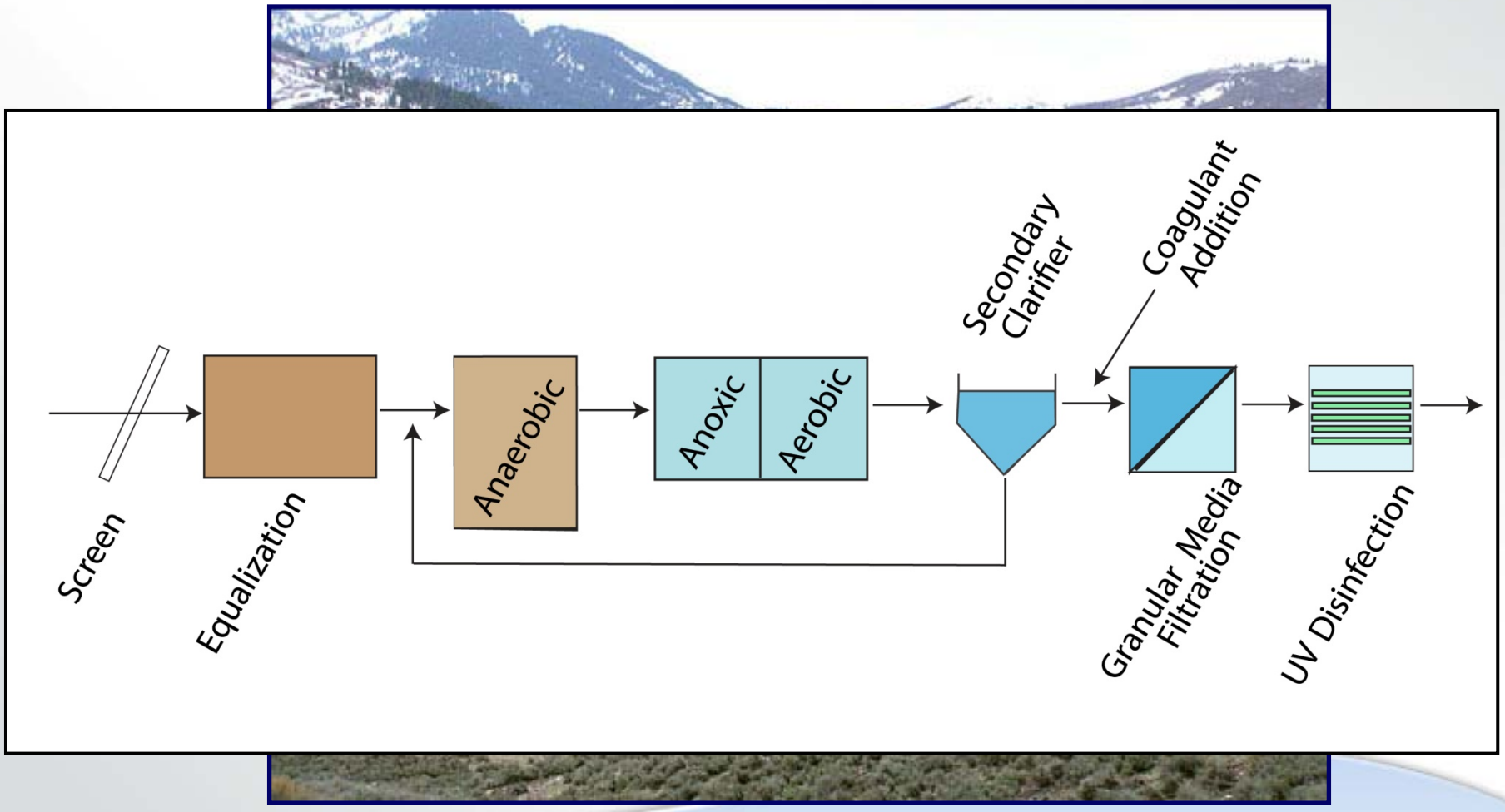


Initial Sampling

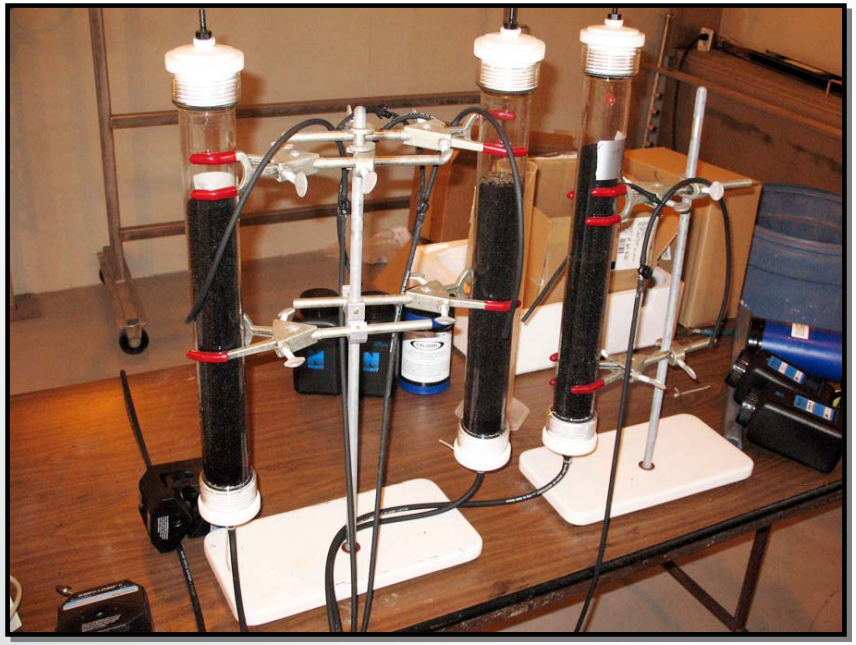
JUNE 2007

SBWRD Collects Influent & Effluent Grab Samples

Despite advanced treatment, EDCs & PPCPs detected in the effluent to East Canyon Creek



Valuable Lessons Learned Along the Way



OCT 2007
GAC Benchscale Test

NOV 2007
Brown Trout Investigation

Historical EDC/PPCP Detections

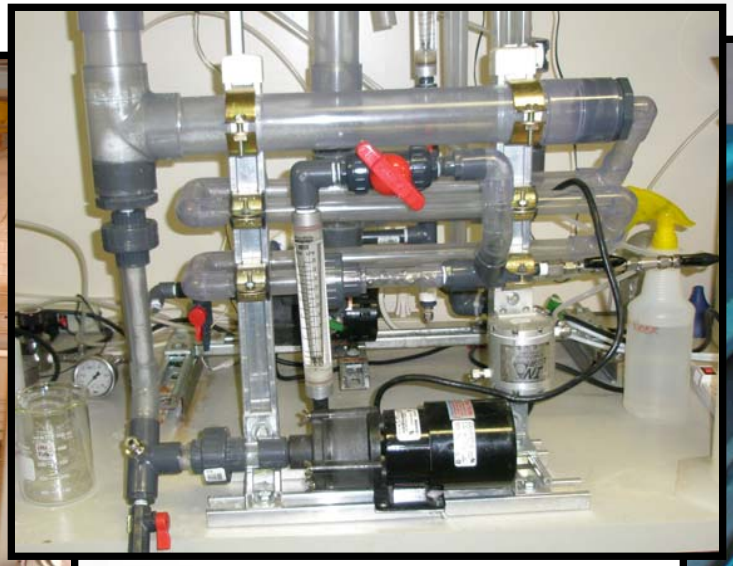
Constituent	Samples	Detection Frequency	AVG (ng/L)	MRL (ng/L)
E-Screen Bioassay	18	100%	0.69	0.03
Cotinine	15	100%	29	1.0
Sulfamethoxazole	24	100%	846	1.0
Gemfibrozil	19	95%	85	1.0
Trimethoprim	22	95%	73	1.0
Carbamazepine	34	94%	81	5.0
Triclosan	20	90%	36	5.0
Ibuprofen	19	89%	29	1.0
Caffeine	24	88%	23	3.0
Fluoxetine	24	88%	50	1.0
Diazepam	17	47%	87	1.0
Ethinyl Estradiol- 17∝	34	29%	5.5	1.0
Estrone	34	26%	47	1.0
Estradiol	34	18%	1.6	1.0
Acetaminophen	24	13%	2.9	1.0
Iopromide	20	n/a	12[1]	5.0
Testosterone	28	n/a	1.2[1]	1.0
DEET	1	n/a	437[1]	25
TDCPP	1	n/a	222[1]	25
Tris (2-chloroethyl) phosphate	1	n/a	166[1]	25

[1]Result shown is a single detection (not an average)

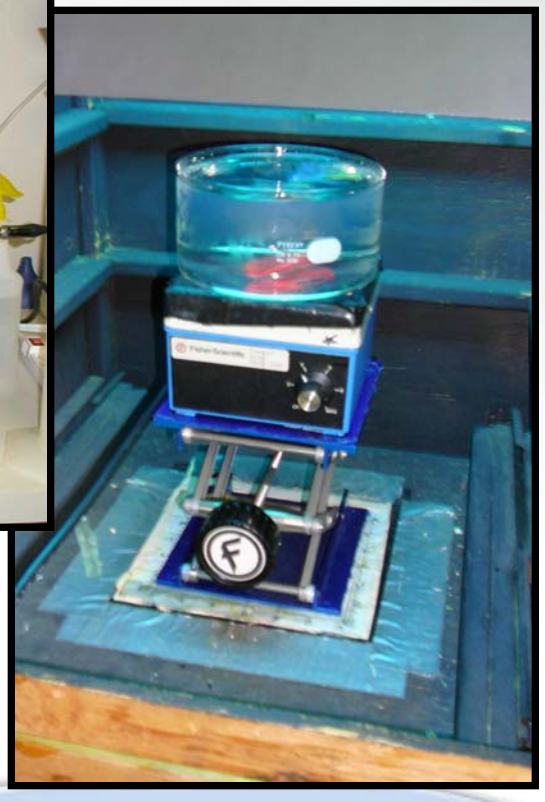
Treatment Technology Evaluation

GAC Filtration

Ozone/Peroxide

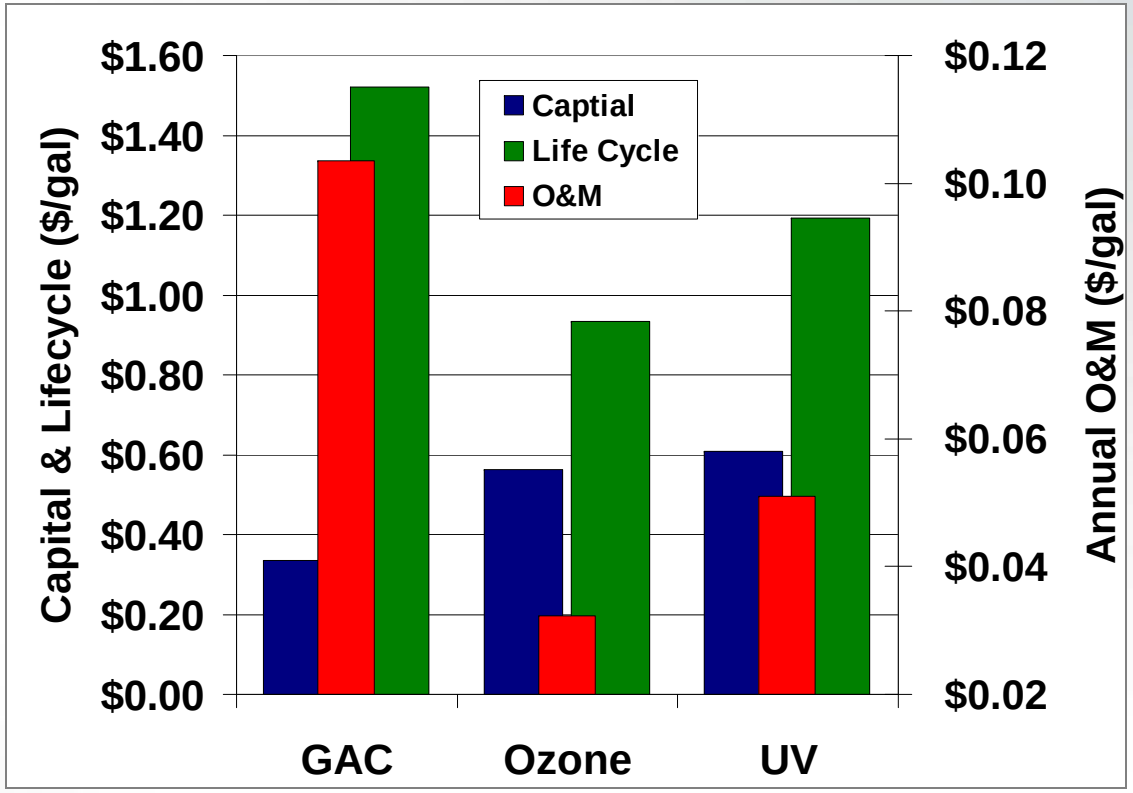


UV/Peroxide



NF/RO not considered due to cost and concentrate disposal constraints

Ozone Recommended as EDC Treatment Technology of Choice Based on both Lifecycle Cost and Effectiveness at Reducing Estrogenic Activity



Costs for 7.2 MGD Facility

Bench & Pilot Scale Testing of GAC Sorption, Ozone, and UV.

Ozone and GAC Sorption Treatment Resulted in No Measurable Estrogenic Activity. UV Resulted in Reduced Estrogenic Activity.

What should the treatment target be?

Literature review of environmentally safe levels for the two most common constituents:

Estrogen Activity

Carbamazepine

Measurable estrogen effects at 1 ppt (Purdom et al, 1994)

Carbamazepine toxicity values at ppm (acute) and ppb (chronic)

Efforts to Identify Impacts of Effluent on Downstream Trout

NOV 2008
Sex Ratio Investigation

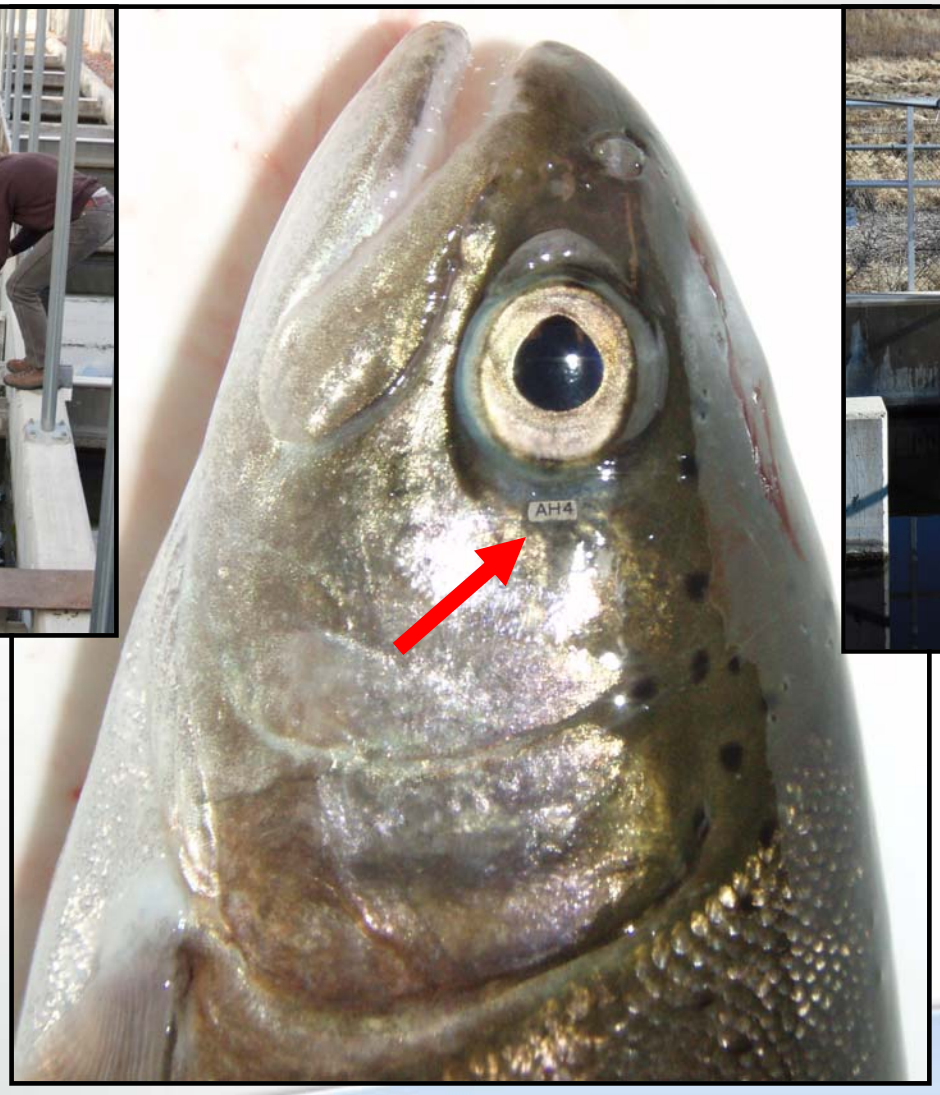
DEC 2008
Sentinel Study

Study Objectives

- Determine if EDC concentrations are high enough to induce vitellogenesis by holding sentinel fish in the effluent
- Determine if downstream fish populations were being feminized by conducting a field investigation of sex ratios
- Evaluate fish tissues

Sentinel Study Methods

Holding pen at fish hatchery



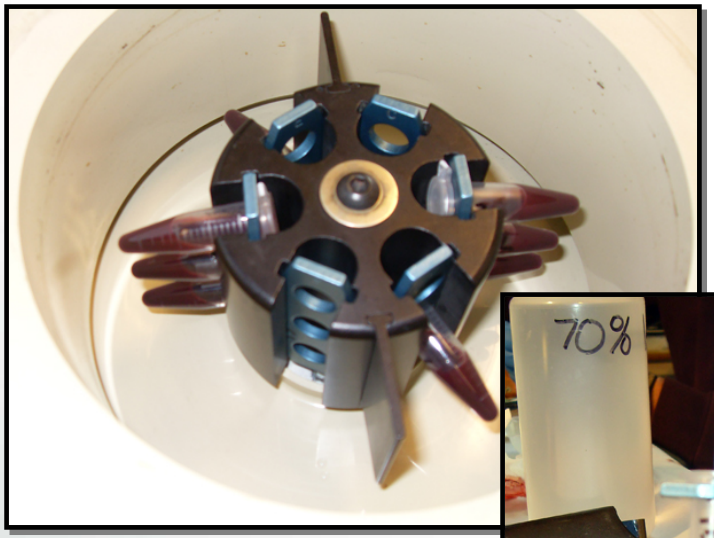
Holding pen in effluent aeration basin

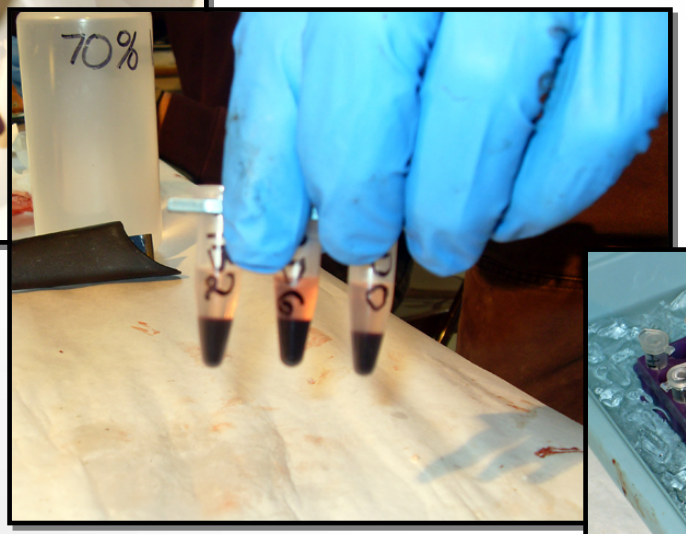
Sentinel Study Methods

Blood Sample (0.5mL) Collected From Each Fish

Sentinel Study Methods

Vtg Analysis Requires Blood Plasma





Sentinel Study Results

	Control		ECWRF	
	Baseline	3 weeks	Baseline	3 weeks
Vitellogenin (ng/ml)	0.343 ± 0.09	0.110 ± 0.03	0.136 ± 0.05	
Total length (mm)	255.2 ± 3.6	265.6 ± 3.9	250.0 ± 4.9	263.9 ± 5.3
Total weight (g)	188.3 ± 8.0	207.9 ± 9.8	181.4 ± 9.6	216.6 ± 11.8
GSI		0.21 ± 0.07		0.19 ± 0.06

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Total weight (g)	188.3 ± 8.0	207.9 ± 9.8	181.4 ± 9.6	216.6 ± 11.8
GSI		0.21 ± 0.07		0.19 ± 0.06

Sex Ratio Investigation Methods

Electrofishing

Transport

Holding

Sex Ratio Investigation Methods

Gender Determination: Palpitation or Necropsy

Summary of Fish Collected For the Sex Ratio Investigation

71 Fish Captured

- 43 Released (Sexually Mature)
- 28 Harvested (Gender by Necropsy)
- 5 Additional Fish Sampled Upstream (Negative Control)

Sex Ratio Investigation Results

Altered Sex Ratio Not Seen

38 Female (54%) to 33 Male (46%)

Vtg Not Detected in Male Fish

4 to 1 Dilution of Effluent in Stream

Compounds Found in Sentinel and Stream Fish Tissues*

Common Name	Pharmaceutical Name	Fillet Downstream	Liver Downstream	Fillet Upstream	Sentinel Fillet	Sentinel Liver
Caffeine	Caffeine	ND	1.2	ND	ND	2.4
Benadryl	Diphenhydramine	0.295	2.85	ND	0.187	6.77
Hypertension	Propranolol	ND	0.90	ND	ND	1.2
Blood pressure control	Diltiazem	ND	0.205	ND	0.03	0.46
Tegretol	Carbamazepine	ND	ND	ND	0.49	1.0
Antidepressant	Paroxetine	ND	ND	ND	0.66	8.8
Prozac (metabolite)	Norfluoxetine	ND	20.0	ND	ND	81.7
Prozac	Fluoxetine	ND	18.5	ND	ND	61.0
Zoloft (metabolite)	Desmethylsertraline	ND	140.0	ND	10.2	533.3
Zoloft	Sertraline	ND	ND	ND	ND	92.0
Valium	Diazepam	ND	ND	ND	2.6	9.0
Cholesterol control	Gemfibrozil	ND	ND	ND	ND	22.3

*Results are presented as an average of all positive test results, Results in units of nanograms/gram

Regulators have four main options to control EDCs and PPCPs:

1. Banning the inclusion of some EDCs in consumer products
2. Directly banning or regulating the use and disposal of constituents in consumer products that can make it to the water system
3. Aquatic life criteria for individual microconstituents
4. Human health criteria for individual microconstituents
5. Use bioassays

Proper disposal of unused meds in Utah

- Utah DEQ provides one time grant of $1,000 available to law enforcement agencies
- 30 bins in 10 of 29 counties
- Over 10,000 lbs collected since 2007
- Find bins and events at:
  www.medicationdisposal.utah.gov/

Hospital waste found less estrogenic than residential waste

Location	Concentration
Hospital	3.3
Residential	25

Results from E-Screen Bioassay grab sample

Concentration shown as ng/L (ppt) of Estradiol Equivalents

Strictly concentration, flows needed to determine mass balance

Observations

- Additional research needed to understand which of the compounds are responsible for vitellogenin induction in male fish
- Bioassays and biomarkers are cost effective indicators of estrogenicity potential
- EDC's can be removed using advanced treatment technologies
- Water professionals need to be prepared to address EDC concerns with the public

Conclusions:

- EDCs detected at low concentrations in treatment plant effluent
- Effluent EDCs concentrations high enough to induce vitellogenesis in male trout, with no dilution
- ECWRF effluent does not appear to have altered the sex ratio of the brown trout (with 4 to 1 dilution)
- Stream flow can attenuate the EDC problem

Snyderville Basin Water Reclamation District

Questions?

For more info visit: http://www.sbwrd.com