# *US EPA's Risk Management Research on Endocrine Disrupting Chemicals*

Bryan Boulanger and Marc Mills
U.S. EPA Endocrine Disruptors Program

2006 STAR Progress Review Workshop

# *Underlying RM Science Questions*

- What are the major sources and environmental fates of EDCs?
- How can unreasonable risks be managed?

from ***Research Plan for EDCs*** (1998)

# *Endocrine Disrupting Chemicals: Goal 4 Risk Management Research*

- Policy Relevant Questions
- Approach
  - Understand sources of EDCs
  - Remediation of EDC-contaminated Media


Working collaboratively within ORD, Regions and outside research groups to leverage resources

# *Why do RM research on EDCs?*

Research has shown:

- Waste streams are releasing EDCs to the environment.
- In-stream ecological effects have been observed below waste stream outfalls
- EDC exposure and health effects in humans not well understood
- EDCs detected in DW source waters

# *NRMRL areas of research*

- Wastewater Treatment Plants (WWTPs)
- Concentrated Animal Feed Operations (CAFOs)
- Drinking Water

from ***Research Plan for EDCs*** (1998)


Why do WWTPs emit endocrine active effluents?

# *WWTPs Designed for…*

- BOD removal
- Suspended solids removal
- pH neutralization
- N, P removal
- Pathogen removal

Trace organics (EDCs)?

# *WWTP Performance Factors*

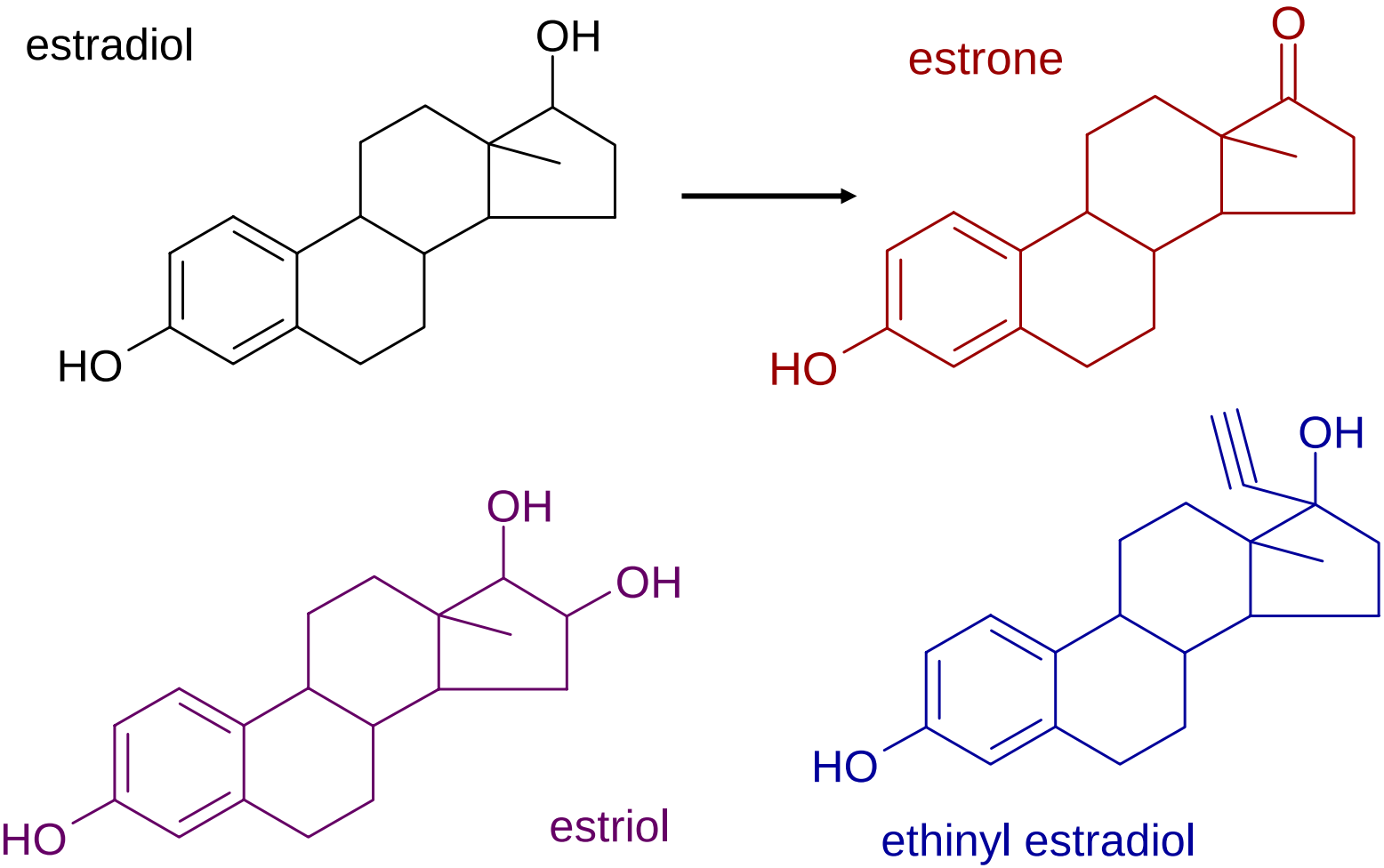
Effluent levels determined by -

- Influent character
- Plant design
  - Biological treatment
    - Aerobic, anaerobic
  - Solids separations
  - Contact times
- Operations/maintenance

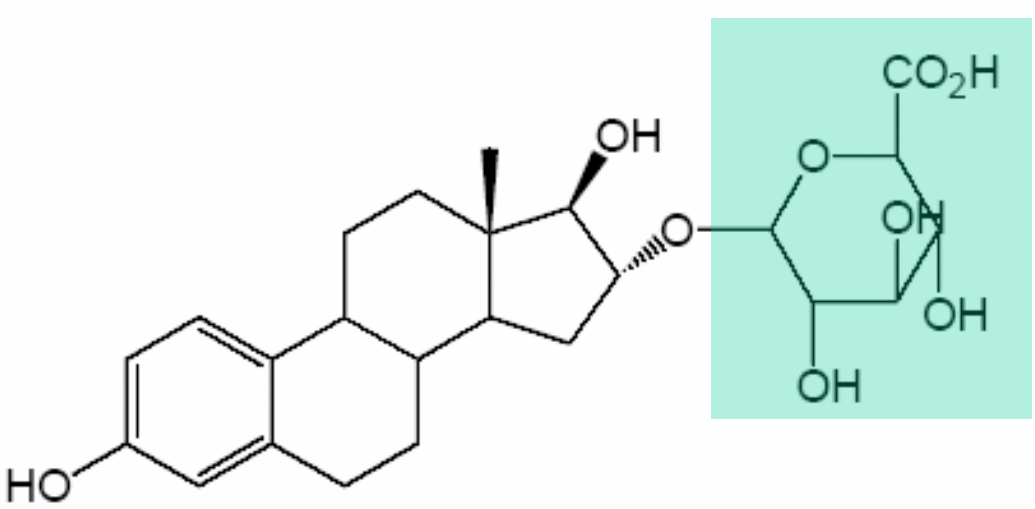
# *NRMRL's EDCs in WWT Research*

- Analytical methods development
  - GC/MS methods for 8 hormones and APs – expanding effort
  - Adapting bioassays for field application
- Bench scale research
  - AP biodegradation studies
  - Steroid hormone studies
- Field scale research
  - NC Biosolids study
  - Chicago Digester study
  - OW POTW Survey
  - Grailville constructed wetland
  - ORSANCO/USEPA REG3/USEPA ORD Ohio River Study
- Pilot scale research

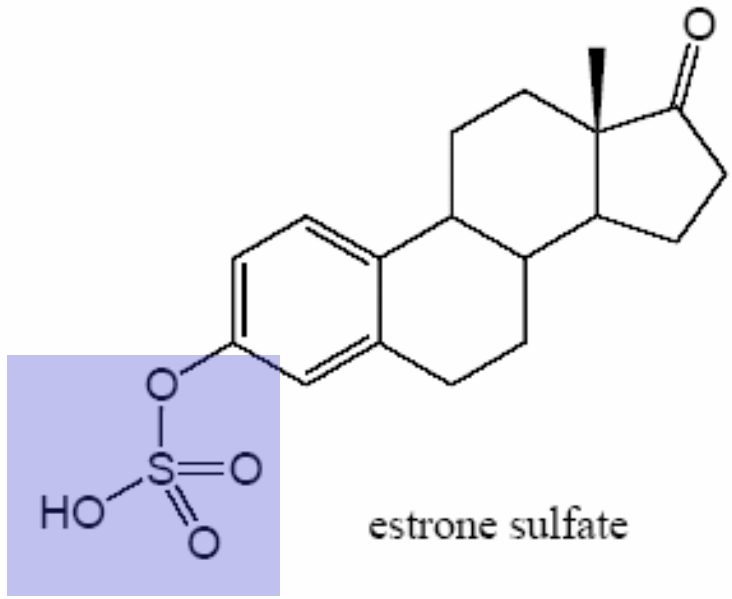
# Influent Estrogens



# Excreted Hormones are Conjugated




estriol glucoronide




estrone sulfate

# Estrogen Conjugates in Swine Lagoon Waste

## Standards Available

Estrone-3-sulfate
Estrone-3-glucuronide
Estradiol-3-sulfate
Estradiol-3-glucuronide
Estradiol-17-glucuronide
Estradiol-3-glucuronide-17-sulfate
Estradiol-3,17-disulfate
Estriol-3-sulfate
Estriol-3-glucuronide

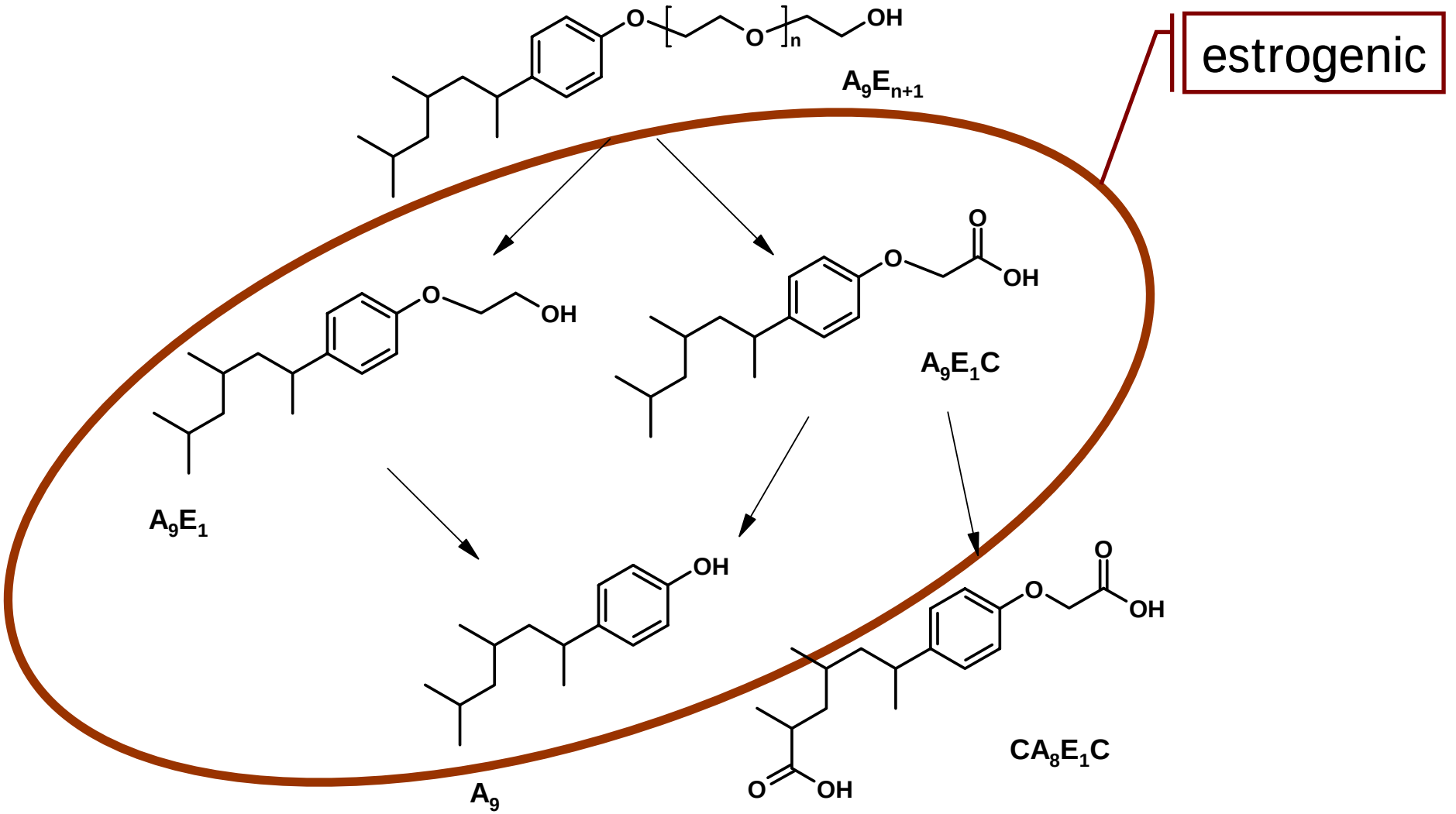
Estradiol-17-sulfate
Estradiol-3-sulfate-17-glucuronide
Estradiol-3,17-diglucuronide
Estriol-16-sulfate
Estriol-17-sulfate
Estriol-16-glucuronide
Estriol-17-glucuronide
Estriol-3-sulfate-16-glucuronide

## No Standards Available

Estriol-3-sulfate-17-glucuronide
Estriol-16-sulfate-3-glucuronide
Estriol-16-sulfate-17-glucuronide
Estriol-17-sulfate-3-glucuronide
Estriol-17-sulfate-16-glucuronide
Estriol-3,16-disulfate,17-glucuronide
Estriol-3,17-disulfate,16-glucuronide
Estriol-16,17-disulfate,3-glucuronide
Estriol-3,16-diglucuronide,17-sulfate
Estriol-3,17-diglucuronide,16-sulfate
Estriol-16,17-diglucuronide,3-sulfate
Estriol-3,16-disulfate
Estriol-3,17-disulfate
Estriol-16,17-disulfate
Estriol-3,16-diglucuronide
Estriol-3,17-diglucuronide
Estriol-16,17-diglucuronide
Estriol-3,16,17-trisulfate
Estriol-3,16,17-triglucuronide

Found  Not Found  Undetermined

# Nonylphenol Biological Transformation



# Source Characterization

- **National Effluent Study (NERL/NRMRL) – completed**
  - 50 plants surveyed
  - 22 % of the effluents were estrogenic
- **OW Influent/Effluent Survey (OW/NRMRL/NERL) – In progress**
  - OW funded survey of influent/effluent of WWTPs for ~450 chemical, physical, and biological analytes
  - ORD will do EDC chemistry (NRMRL) and effluent bioassays (NERL)
  - Precursor to larger Nationwide Survey (>50 plants)
- **Effluent and Receiving Waters studies (ORSANCO/NERL/NRMRL - Ohio R., Wheeling and ALCOSAN)– in progress**
  - Scoping study in progress this fall
  - Spring is schedule for larger deployment at multiple plants

# Bench scale research

**Objective**

- **Evaluate the fate of selected EDCs (alkylphenols and steroid hormones) under conditions common to wastewater treatment and sediments**

  Aerobic, Anaerobic, Sulfate reducing, Methanogenic


**Results to date**

- **Alkylphenols**
  - Biodegradation of NP occurs under aerobic conditions.
  - Relatively low yield of NP degrading organisms may explain inefficiency of WWTPs.
  - NP isomers degrade aerobically at various rates and the most estrogenic isomers appear to degrade faster.
  - NP is very persistent under the anaerobic conditions (nitrate reducing, sulfate reducing, and methanogenic).

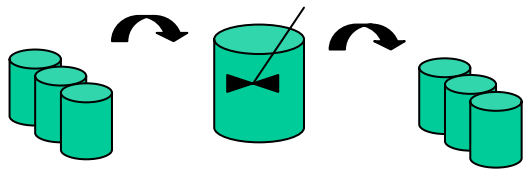
# Chicago Digester Study

- Objective: **To evaluate the removal efficiency of selected EDCs in sludge digesters.**
  - A series of parallel sludge digesters will be sampled over time for the influent and effluent concentrations of selected EDCs.
  - In parallel, an inert, non-toxic tracer study will be performed to evaluate residence time distribution and effective reactor volume.
- **Target analytes**
  - **Alkylphenols (APs) and Bisphenol**
  - **Hormones**


- **Collaborations:**
  - **USEPA NRMRL**
  - **USEPA REG 5 Water Division**
  - **USEPA REG CRL**
  - **MWRDGC**

- Experimental Design:
  - Reactors
    - Three replicate digesters
    - Sampling over 3 solids retention times, ~ 60 days
  - Digester operations
    - Digester design parameters
    - Daily operational parameters
      - Feed schedules, flows, and loadings
      - Operating characteristics (temp, pH, VSS, etc)
- Sampling
  - Daily sampling: one 1-liter grab samples collected during each 8-hr shift (3/day) and composited

- Status
  - QAPP in progress
  - Expected to start study in late Summer-early Fall



# On-site WWT Research

- **Grailville Constructed Wetland**
  - Objective: Constructed Wetland designed/operated for nutrient/pathogen removal will be evaluated for efficacy at managing EDCs
  - Collaborators
    - NRMRL WSWRD
    - NERL - MIRB
    - Grailville

- **Status**
  - Preliminary samples collected for screening the EDC concentrations
  - Evaluating matrix interferences
  - QAPP in progress based on EDC levels in influent/effluents

- **Future planned research** for On-site WWT
  - Septic systems
  - Constructed wetlands

# Field Application of Biosolids

- **North Carolina Study**
  - Anaerobically digested and lightly limed biosolids
  - Applied to fescue field in Sept 2004
  - Measure APEO concentration
    - Background: -5 wks, -1day
    - After application: 0 day, 2 wks, 4 wks, 9 wks, 14 wks
    - depths: 0-5 cm, 10-15 cm, 20-25 cm
  - Data not yet finalized

- **Biosolids - EDCs research**
  - Evaluate other biosolids types
  - Include steroid hormones along with the alkylphenols
  - Continue to leverage against microbial biosolids studies


EDCs and CAFOs
Risk Management
Research

# CAFOs Risk Management Research Questions

- Are EDCs present in animal wastes?
- Does typical operation result in EDC risk?
- Do typical waste management practices effectively treat EDCs?
- Do RM tools exist that will treat EDCs?
- What new RM tools need to be developed?

# *Expected Products from CAFOs RM Research*

- Better understanding:
  - wastes concentrations
  - fate and transport in soils
  - efficacy of CAFO waste management
- Identification of the RM needs to reduce EDC effluent from CAFOs

# *CAFO EDC research*

- Methods development
- Evaluate CAFO operations as release points:
  - Swine, Poultry, Cattle, Dairy operation
- Evaluate management strategies of CAFOs
- Leverage
  - Projects in Water Quality CAFO program (ie Lizzie, NC Demo Site)
  - With NERL and NHEERL on interlab study

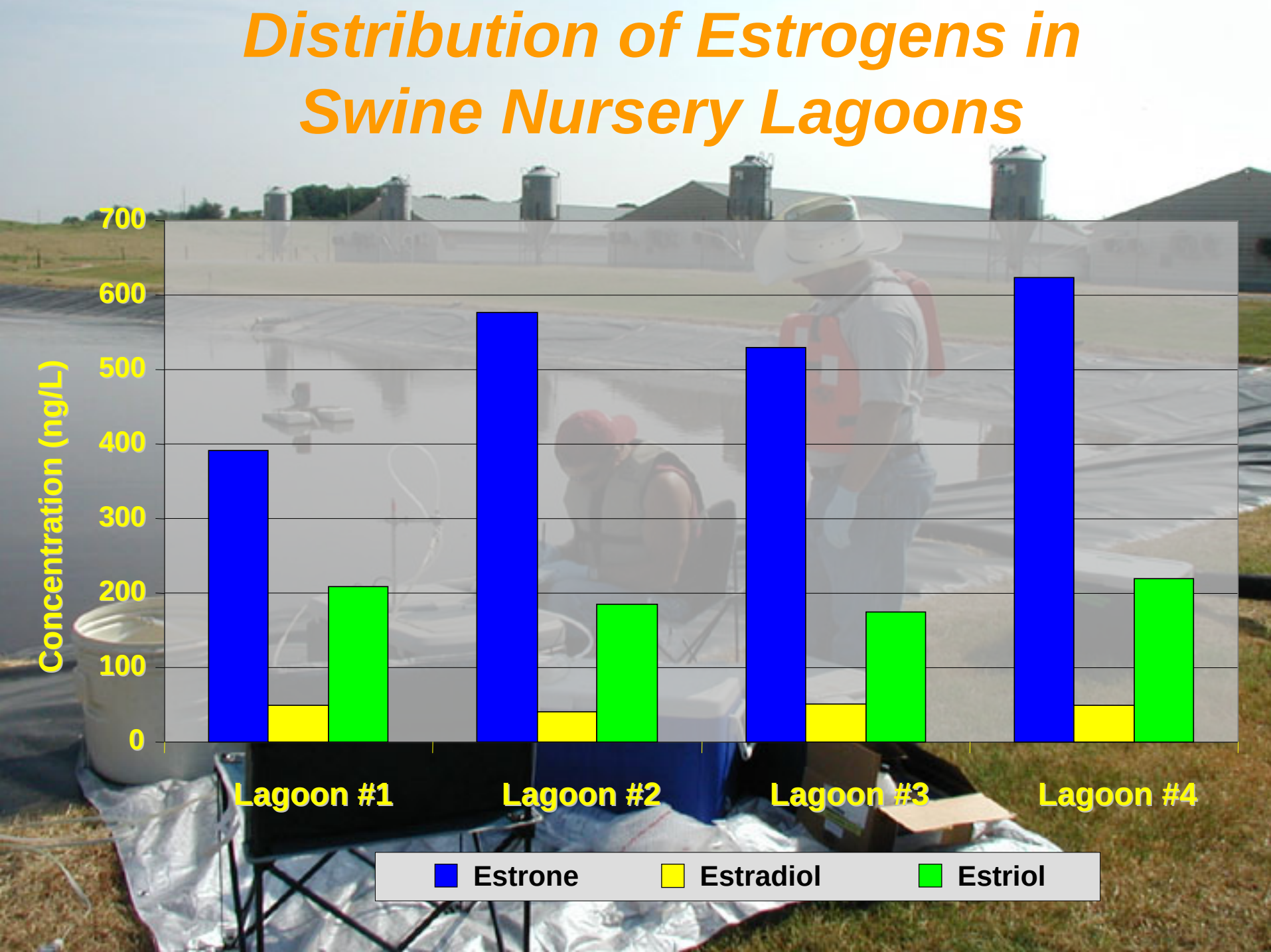
# *CAFO Contributions of Estrogens*

- **Cattle: Growth-enhancing hormones added**
  - **Estrogens (estradiol, estradiol benzoate)**
  - **Androgens (trenbolone acetate, testosterone propionate)**
  - **Progestins (progesterone)**

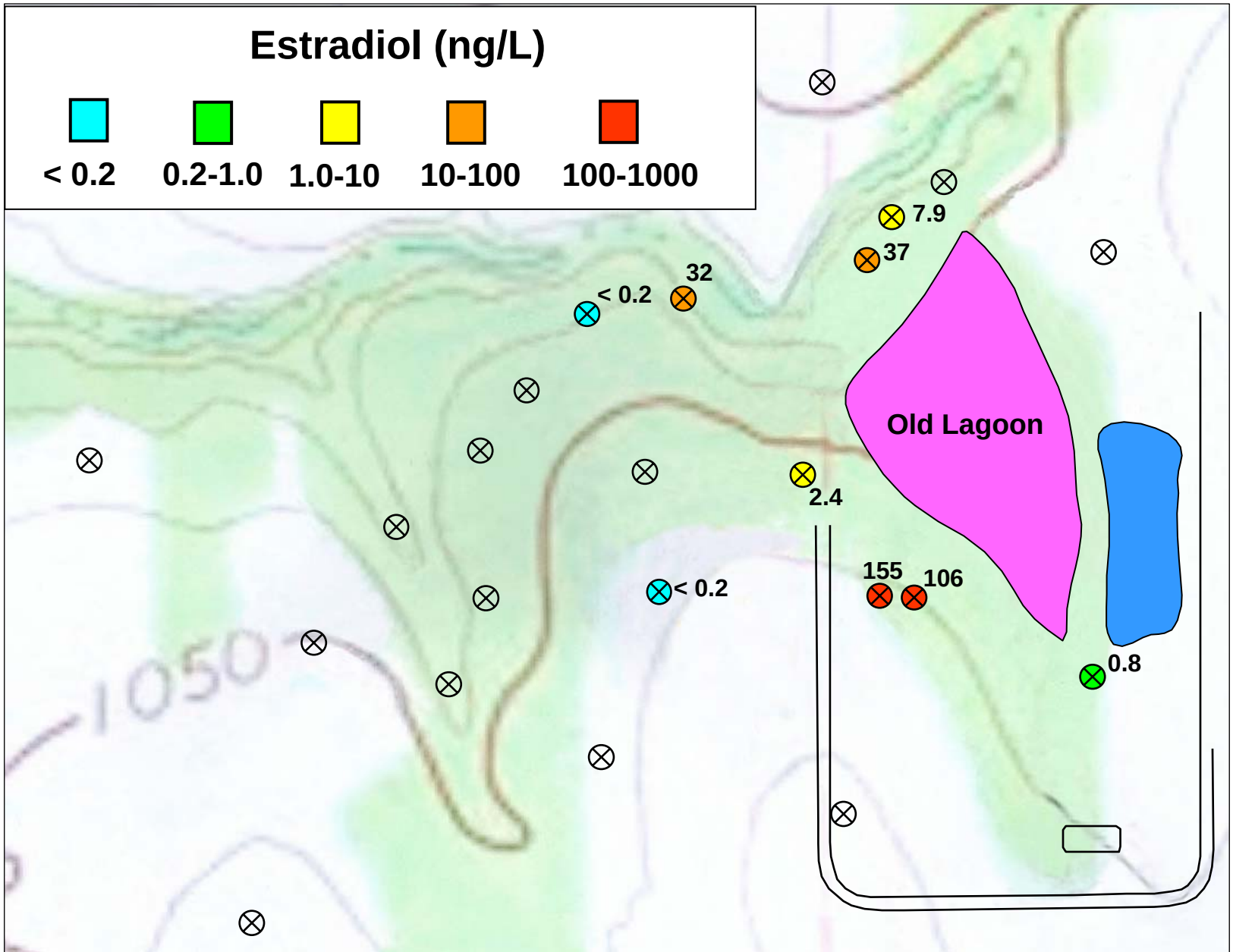
- **Poultry:**
  - **No growth hormones added**
  - **Natural production of estrogens and testosterone**

- **Swine:**
  - **No growth hormones added**
  - **Natural production of estrogens and testosterone**

# Distribution of Estrogens in Swine Nursery Lagoons



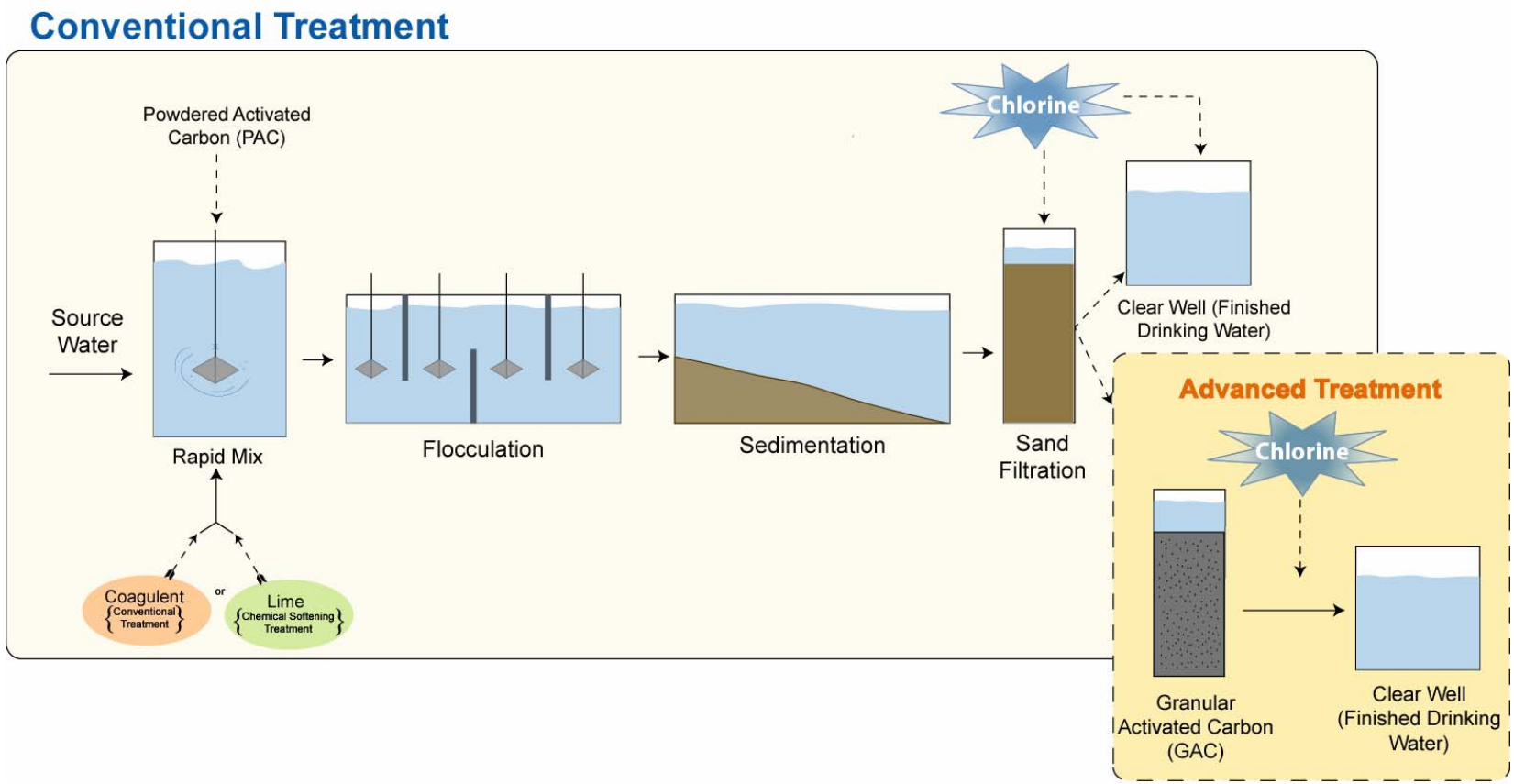
# Estradiol Concentrations (08/04)



# *CAFO Summary*

- **We have limited field data that show CAFOs can contaminate ground and surface waters with estrogens, but:**
  - studied field site represents worst case scenario for ground water evaluation
  - need to monitor long-term fate at each site

# Drinking water research – Unit operations



# Drinking water research – Methods development

- Methods development for estrogenic and androgenic hormones

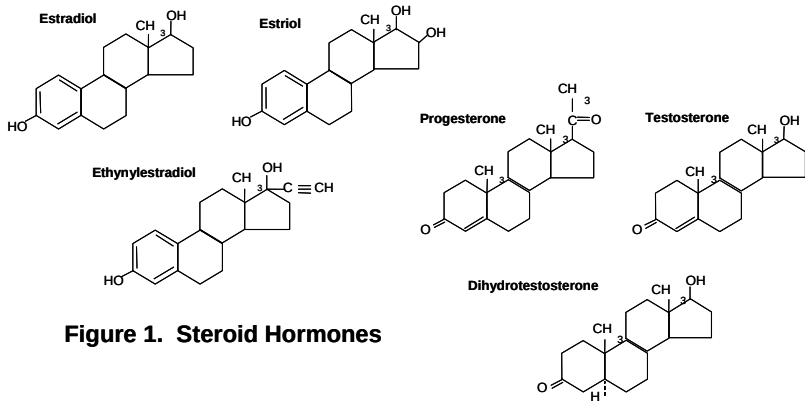
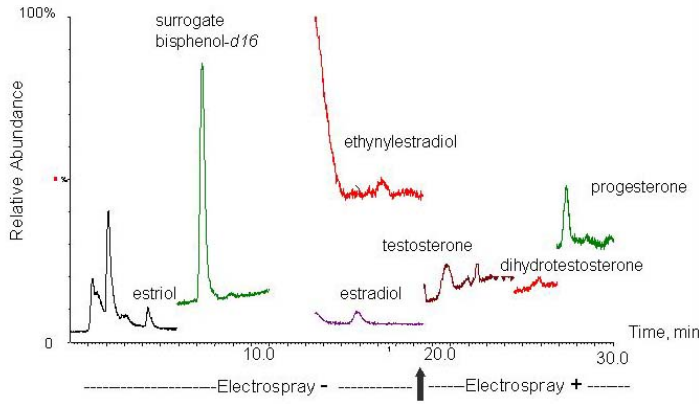


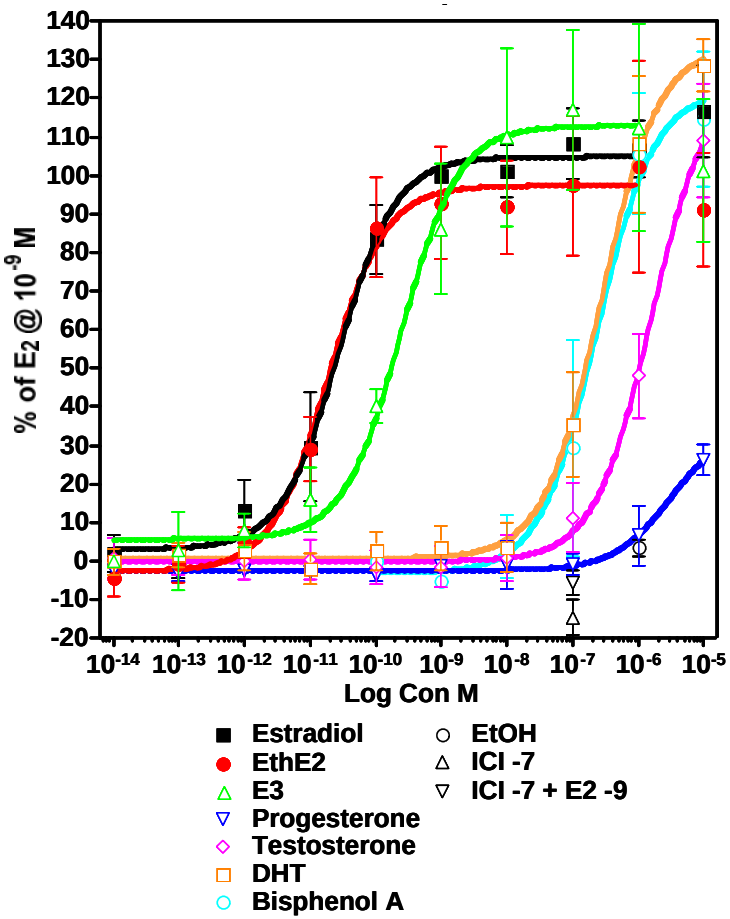

**Figure 1. Steroid Hormones**

- LC-MS methods for surface waters and treated waters developed



# Drinking water research- Bioassay development

- Bioassay development for drinking water treatment operations research
- Adaptation of the MVLN assay for Estrogenic response




**Dose-Response Curves for the Steroid Hormones in the MVLN Assay**

# Summary

## Risk Management research program

- Process to identify research in place that
  - Focuses on most relevant chemicals, sources and RM strategies
  - Allows refocusing as information increases
- Initial projects underway
- Collaborations working
- Initial results having high impact

# NRMRL's future EDC research

- **WW research areas**
  - On-site wastewater treatment
  - Tertiary wastewater treatment
  - Water reuse
  - Leverage against other emerging pollutant programs (ie PFOA)
- **CAFO research areas**
  - Expand characterization of sources
    - More types of CAFOs
    - Conjugated and unconjugated forms of hormones
  - Characterize existing and innovative treatment
  - Collaborative effort on field scale study with NRMRL/NERL/NHEERL
  - Leverage efforts with NRMRL's WQ CAFOs program (focused on Pathogens and Nutrients management)
- **Drinking Water research areas**
  - Continue unit process work at pilot scale
  - Develop full plant scale data set
  - Surveys of EDCs in source water, treated water, and tap water.
  - Innovative treatment technologies effects on EDCs

Thank you

and now - Q&A