Bitterroot Modeling TAC

Introductory Meeting

Montana DEQ

Water Quality Planning Bureau

Discussion Outline

- Bitterroot TAC Introductions
- Water Quality Status Report
- DEQ Perspective
- Water Quality Threats
- Project History
- Purpose
- SWAT Technical Overview
- Progress Briefing
- Advisory Group Format

BITTERROOT TAC INTRODUCTIONS

Michael Pipp

- Project Sponsor
- Data Management Section Supervisor
- Previous Modeler

New Face to DEQ

- Modeling Position
  - Kyle Flynn
    - Technical Expertise – Hydrology/Hydraulics
      - Previously a WRE Consultant
      - Modeling Work
        - » HEC-1, HEC-HMS
        - » SWMM
        - » HEC-RAS, GeoRAS
    - Background
      - Townsend, MT
      - Ag/Ranch & Tourism/Recreation Background

Technical Advisory Committee

- HDR Engineering
  - Michael Kasch
- Montana Bureau of Mines and Geology
  - John Lafave
- Montana DEQ
  - Kyle Flynn/Pete Schade/Michael Pipp
- Montana Extension Service
  - Rob Johnson (or delegate)
- Montana State University
  - Phil Farnes
- Missoula County WQD
  - Jon Harvala

Technical Advisory Committee

- Plum Creek Timber
  - Brian Sugden
- Ravalli County Planning
  - Patrick O'Herren
- Rocky Mountain Rsch. Station
  - Kevin Hyde
- University of Montana
  - Scott Woods/Rob Ahl
- USFS
  - Terry Carlson

TAC Mission

- Provide technical support and peer review for Soil Water Assessment Tool (SWAT) model construction, calibration and validation, and scenario development.

Why We Are All Here

- Basin-wide expertise
- Brain Dump

WATER QUALITY STATUS

Bitterroot 303(d) Listings

- 2004 List
  - 33 WQL Segments
    - Nutrients 10
    - Sediment 17
    - Temperature 03
    - Flow 12
    - Habitat 21
    - Other (metals) 04
  - Several require reassessment due to sufficient credible data standards

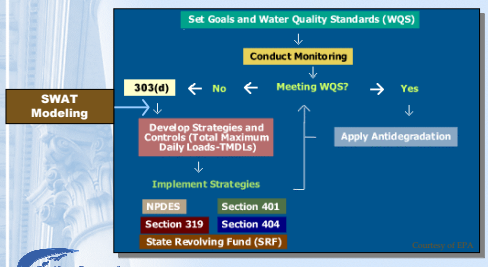
Hydrologic Unit Code 17010205 **Watershed** BITTERROOT

ID	Segment ID	Waterbody Segment	List Category	Size	Use Class	Use Support: Aquat Life	Cold Water Fish	Warm Water Fish	Drink Water	Swim (Rec)	Agri	Bul	Probable Causes of Impairment	Probable Sources of Impairment
1	MT76H001_010	BITTERROOT RIVER, from the confluence of East Fork to Hamilton Cr	5	24.3 M	B-1	P	P		F	F	F	F	Other habitat alterations Metals Copper	Bank or Shoreline Modification/Destabilization Agriculture Grazing-related Erosion Habitat Modification (other than hydromodification) Source Unknown
2	MT76H001_020	BITTERROOT RIVER, from Hamilton Cr to Eightmile Cr	5	30.5 M	B-1	P	P		X	P	F	F	Siltation Thermal modifications Flow alteration Nutrients	Agriculture Urban Runoff/Storm Sewers Habitat Modification (other than hydromodification) Crop-related Erosion
3	MT76H001_030	BITTERROOT RIVER, from Eightmile Cr to the mouth. (Lake Pub 5)	5	29.4 M	B-1	P	P		F	F	F	F	Nitrate Siltation Other habitat alterations Nutrients Metals Copper Lead	Urban Runoff/Storm Sewers Bank or Shoreline Modification/Destabilization Agriculture Grazing-related Erosion Land Clearance Habitat Modification (other than hydromodification) Sediment resuspension
4	MT76H002_040	MCCOY CREEK, from headwaters to the mouth (East Fork Bitterroot R)	5	10.1 M	B-1	P	P		X	X	F	F	Nutrients Siltation	Source Unknown
5	MT76H002_070	LAZY CREEK, tributary to East Fork Bitterroot. HUC 8010	5	5.7 M	B-1	P	P		X	X	X	X	Siltation Other habitat alterations	Silviculture Logging Road Construction/Maintenance

F = Full Support P = Partial Support T = Threatened N = Not Supported X = Not Assessed

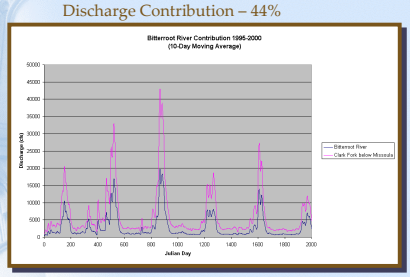
http://nris.state.mt.us/wis/environet/2004Home.html

Decision Process

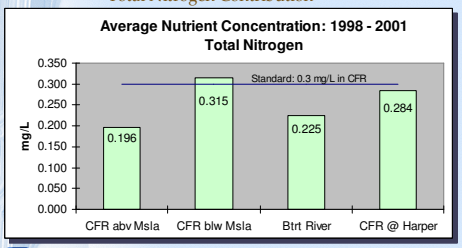


DEQ PERSPECTIVE

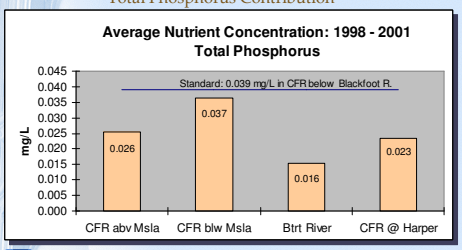
Bitterroot Influence on CFR Discharge Contribution – 44%



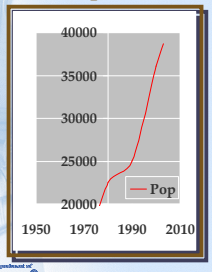
Bitterroot Influence on CFR
Total Nitrogen Contribution



Bitterroot Influence on CFR
Total Phosphorus Contribution



Population Growth



- Recent Trend
  - 44% Population Growth (1990-2000)
  - Fastest in MT
  - Actual Numbers (25,010-36,070)
  - 7% Growth (2000-2003)

WATER QUALITY THREATS

Permitted Point Sources

- Four municipalities
  - (Darby, Hamilton, Stevensville, Lolo)
- 1 CAFO
- 1 Industrial
- 10 Stormwater

Nonpoint Sources

- Septic Systems
- Urban/Suburban Runoff
- Riparian Conversion/Encroachment
- Agricultural Return Flows
- Silviculture/Forest Fires
- Construction
- Flow Alteration
- Dewatering

PROJECT HISTORY

What has been done in the Bitterroot so far?

- Burned Area Research
- Geomorphology Studies
- Groundwater Characterizations
- Groundwater Model for Lolo Area
- Surface Water Hydrologic Studies
- Water Quality Monitoring
  - Surface/ground
- Water Resources/Irrigation Studies

What is DEQ Currently Doing?

- Basin-wide Synoptic Sampling
  - Bitterroot Tributaries
  - Lolo Creek

Tributary Watersheds:	Watershed Area (mi2)	Percent in Bitterroot NF	Proposed Number of Sampling Sites:
East-side Tributaries:			
Threemile Creek	71	16%	4
Ambrose Cr. (tributary to Threemile)	(24)	17%	2
North Burnt Fork Creek	98	69%	3
Sleeping Child Creek	89	88%	3
Rye Creek	66	65%	3
North Fork Rye Cr. (tributary to Rye)	(18)	61%	2
West-side Tributaries:			
Sweathouse Creek	30	63%	3
Bear Creek	35	71%	2

What is DEQ Currently Doing?

- Basin-wide Synoptic Sampling
  - Bitterroot Main-stem

STORET Station ID:	Description:	Latitude	Longitude
BWMDARBYBR	Darby Bridge	45.97333	114.14083
BWMMAINSTBR	Hamilton Main St. Bridge	46.24750	114.17722
BWMSILVBR	Hamilton Silver Bridge	46.27833	114.16111
BWMBELCROS	Bell Crossing Bridge (N. Victor)	46.44361	114.12333
BWMPKRJORR	Poker Joe Railroad Trestle	46.58027	114.07750
BWMFLRNCBR	Florence Bridge	46.63305	114.04916
BWMBUKHSBR	Buckhouse Bridge (Missoula 93)	46.83166	114.05361

Other Calibration-Validation Data Sources

- USGS
- Montana DEQ/STORET
- Bitterroot & Lolo National Forests?
- Rocky Mountain Research Station?
- Department of Natural Resources?
- University of Montana?
- Plumb Creek?

MODELING & PROJECT PURPOSE

Modeling 101

- Define objectives/parameters
  - Will the question be addressed?
  - Can it link stressors or management actions to endpoints?
  - Is modeling appropriate for situation?
- Identify applicable models
- Evaluate available data
- Select modeling tool
- Use the simplest tool possible
- Identify sensitivity & uncertainty
- Model

Modeling Objectives

- Model current pollutant loading in the Bitterroot Watershed
- Develop support tool for MT-ID border agreement
- Quantify spatial & temporal distribution of pollutant loads

Modeling Objectives (ctd.)

- Provide information to support TMDL load allocations
  - Estimate load reductions to meet a water quality standard
  - Distinguish between management strategies
- Predict quality from changes in management practices

DEQ Determination

- Watershed-scale numerical model of Bitterroot integral

Why Model

- Data Collection is expensive
- Prediction
  - Response to drivers (e.g. management or climate change)
- Gain a better understanding of water quality
- Interpretation/extension of data sets

Modeling Caveats

- Models are tools
  - should be used in combination with other assessment techniques
- Should reflect our understanding of watershed system
- Answers are no better than our understanding of the system
  - Data Uncertainty
  - Model Uncertainty
- Art or Science?

Model Selection

- The model is physically based.
  - Watersheds can be modeled to evaluate the relative impact of changes in management practices, climate, and vegetation on water quality or other variables of interest.
- The model uses readily available input.
  - Minimum data required to make a run are commonly available from government agencies.

Model Selection

- Mathematical solutions are computationally efficient.
  - Simulation of very large basins or a variety of management strategies can be performed without excessive investment of time or money.
- Long-term impacts can be studied.
  - Gradual buildup of pollutants spanning several decades can be simulated along with resulting impacts on downstream water bodies.

Model Selection

- The model code has been validated
- Non-proprietary

SWAT

TECHNICAL OVERVIEW

http://www.brc.tamus.edu/swat/index.html

SWAT Specifications

SWAT developed to predict the impact of land management practices on water sediment, and chemical yields

- Continuous Simulation Model
- Large Complex Watersheds
- Comprehensive
  - Hydrology
  - Water Quality
  - Crop Growth
  - Management

SWAT Input Requirements

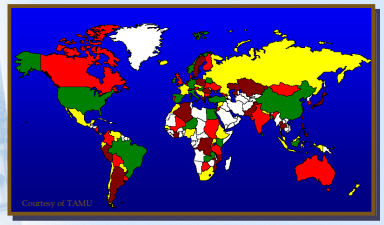
SWAT is designed to use readily available data - most of which can be obtained for free from federal agencies

- Daily Precipitation
- Daily Temperature
- Spatially Explicit Landcover Data (with appropriate parameters)
- Spatially Explicit Soils Data (Statsgo – national coverage, suurgo – intermittent coverage)

SWAT Advantages

- Physically based.
- Uses readily available inputs.
- PC efficient.
- Comprehensive Processes
- Study long-term impacts.
- Simulate management
- The model code has been validated globally.

Applications

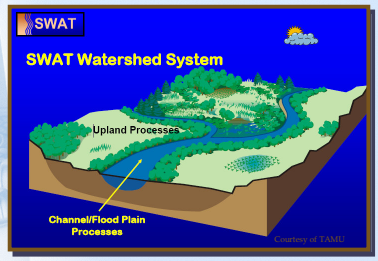


ARS Model Development

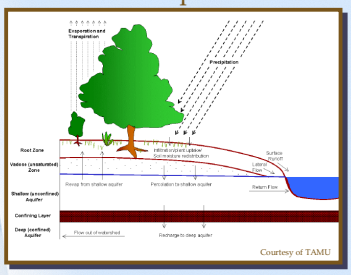
USLE	CREAMS (CLEAN WATER ACT)	EPIC	SWRRB	SWAT
1960's	1970's	1980's		1990's
		GLEAMS	WEPP AGNPS	ANN AGNPS

Courtesy of TAMU

Soil Water Assessment Tool



SWAT Conceptual Model



Computational Units

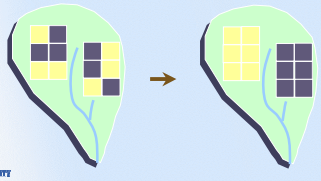
Watershed → Subbasin → HRU

- Spatially Explicit
- Quasi-Distributed
- Hydrologic Response Unit (HRU)
  - Possess unique land use, management, and soil attributes
  - Account for spatial diversity

Hydrologic Response Unit

(HRU) Explanation

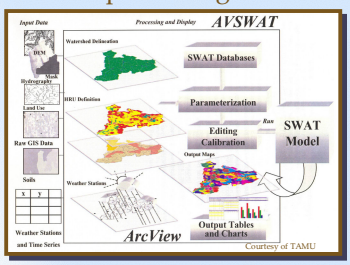
Original HRU Definition



Hydraulic Connectivity

Subbasin → Stream Reach

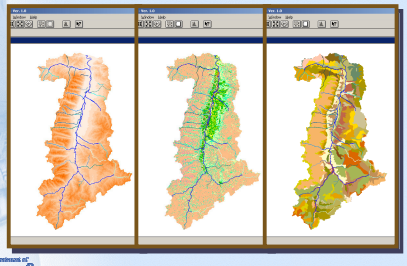
GIS Pre-processing



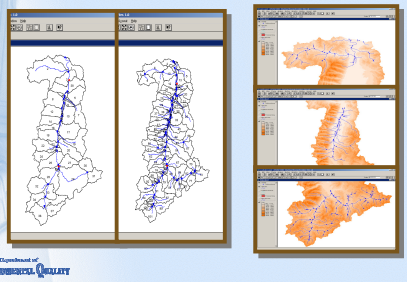
Courtesy of TAMU

SWAT Basic Input Data

DEM Land Use Soils



Subbasin Delineation



HRU Definition

- Specify minimum percentage of subbasin for:
  - Individual Land Cover/Type
  - Individual Soil
- Multiple HRU's generated for each subbasin
  - If 4 types of landcover and 3 soil; max. no. of HRUs = 12
    - 3X4 = 12

GIS Processing & Parameterization

- Subbasin
  - Lat/Long (centroid)
  - Slope
  - T_c
  - Area
  - Field Slope Length

GIS Processing & Parameterization

- Channel
  - Length
  - Main Channel Slope
  - Main Channel Depth
- System Connectivity

SWAT Upland Processes

- Weather
- Hydrology
- Sedimentation
- Plant Growth
- Nutrient Cycling
- Pesticide Dynamics
- Management
- Bacteria

Manual Parameterization

- Weather Data
  - Solar Rn (latitude or user defined)
  - Tmin
  - Tmax
  - Precipitation (P lapse for bands)
  - Wind Speed (Penman-Monteith PET method)
  - RH (Penman-Monteith Preistly-Taylor PET)
- Snowmelt Parameters
  - Degree-day method melt factor
  - Areal depletion curve estimate
  - T lapse (for elevation bands)
  - Rain/Snow Threshold Temperature

Manual Parameterization (ctd.)

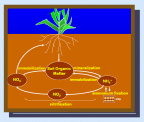
- Surface Hydrology
  - Infiltration indices (CN or Green & Ampt)
  - Peak Flow (modified rational method using T_c)
  - Canopy Storage (LAI functions)
  - PET (Penman, Preistly-Taylor, Hargreaves)
  - Soil Water
    - Percolation (Ks, AWC, bulk density, clay %)
    - Lateral Flow/Shallow Aquifer (slope, length, K_s, flow lag.)
    - Deep Aquifer recharge (delay time for recharge, baseflow threshold, recession coeff. percolation coeff., revap coeff., specific yield)

Manual Parameterization (ctd.)

- Erosion
  - MUSLE
  - Snow cover included
- Nutrient Transport
  - Nutrient soil cycling for concentrations (mainly NO_3, P not very mobile in solution)
  - Time step dependent EMC calculated for mobile concentration
  - Organic fraction delivered via sediment

SWAT Management

- Irrigation
- Crop Rotation/Tillage
- Fertilizer Application
- Grazing
- Edge of Field Buffers
- Timber Harvest
- Septic Inflow/Lawn Chemicals
- Urban Practices (street sweeping)
- Reservoirs

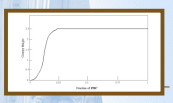


Manual Parameterization (ctd.)

- Crop Management Options
  - Planting (scheduled by date)
  - Harvest Operation (scheduled by date)
    - Removes biomass without killing plant
    - Harvest & kill option available
  - Crop Rotation/Tillage
  - Biological Mixing
  - Fertilizer Application

Manual Parameterization (ctd.)

- Potential/Actual Plant Growth
  - Biomass production *f*(radiation-use efficiency)
    - Simulated using potential heat units
      - Leaf Area Development
      - Plant Height Development
  - Rooting depth
    - Depends on plant type
  - Nutrient Uptake
  - Crop Yield
    (nutrients and plant material are lost from system)
  - Plant Stress (water, temperature, nutrient)

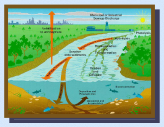


Manual Parameterization (ctd.)

- Water Management Options
  - Irrigation Withdrawl and Application
  - Water Transfer
  - Point Source Loadings
  - Reservoirs
  - Ponds & Potholes
- Urban Management
  - Buildup/Washoff
  - Street Cleaning

SWAT Channel Processes

- Flood Routing
- Evaporation
- Transmission
- Sediment Routing
- Nutrient Cycling
- Pesticide Dynamics
- Impoundments



Manual Parameterization (ctd.)

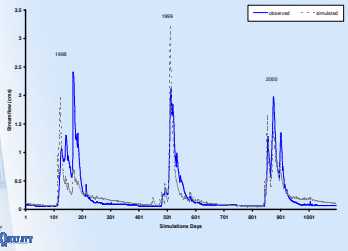
- Main Channel Processes
  - Hydrologic Routing
    - Muskingum
    - Variable Storage
  - Sediment Routing
    - HRU Load Transport
    - Bedload Transport
    - Channel Evolution
  - In-Stream Nutrients
    - QUAL2E Algorithms
      - Nutrient Dynamics
      - CBOD/Oxygen
      - Chlorophyll, Algal Growth

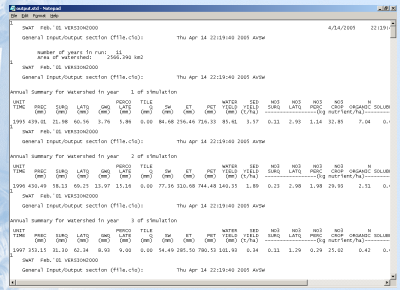
SWAT APPLICATION

SWAT - Little belt Mountain Landscape

- Tenderfoot Experimental Forest
  - SIMPPLLE Landcover Modeling
  - SWAT Hydrologic Modeling
- University of Montana
  - Watershed Modeling Lab
  - Dissertation Work – Rob Ahl

Preliminary SWAT Modeling Results





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   SWAT  Feb. 01 VERSION2000                                                    4/14/2005     22:19:4
   General Input/Output section (ffile.cio):          Thu Apr 14 22:19:40 2005 AVSW

        number of years in run:  11
        Area of watershed:     2366.240 km2
   SWAT  Feb. 01 VERSION2000
   General Input/Output section (ffile.cio):          Thu Apr 14 22:19:40 2005 AVSW

Annual Summary for watershed in year   1 of simulation
 UNIT              PERCO   TILE                 WATER   SED   NO3   NO3   NO3   NO3      N
 TIME   PREC   SURQ   LATQ   GWQ   LATE    Q    SW    ET    PET  YIELD  YIELD  SURQ   LATQ   PERC   CROP  ORGANIC SOLUBL
        (mm)   (mm)   (mm)  (mm)  (mm)  (mm)  (mm)  (mm)  (mm)  (mm) (t/ha)  ---------------(kg nutrient/ha)---------
 1995 439.01  21.98  60.56   3.76   5.84   0.00  84.68 236.46 716.33  85.61   3.57   0.11   2.93   1.14  32.85    7.04    0.
   SWAT  Feb. 01 VERSION2000
   General Input/Output section (ffile.cio):          Thu Apr 14 22:19:40 2005 AVSW

Annual Summary for watershed in year   2 of simulation
 UNIT              PERCO   TILE                 WATER   SED   NO3   NO3   NO3   NO3      N
 TIME   PREC   SURQ   LATQ   GWQ   LATE    Q    SW    ET    PET  YIELD  YIELD  SURQ   LATQ   PERC   CROP  ORGANIC SOLUBL
        (mm)   (mm)   (mm)  (mm)  (mm)  (mm)  (mm)  (mm)  (mm)  (mm) (t/ha)  ---------------(kg nutrient/ha)---------
 1996 430.49  58.13  69.25  15.97  15.16   0.00  77.36 310.08 744.49 141.15   1.89   0.23   2.98   1.98  29.93    2.51    0.
   SWAT  Feb. 01 VERSION2000
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Annual Summary for watershed in year   3 of simulation
 UNIT              PERCO   TILE                 WATER   SED   NO3   NO3   NO3   NO3      N
 TIME   PREC   SURQ   LATQ   GWQ   LATE    Q    SW    ET    PET  YIELD  YIELD  SURQ   LATQ   PERC   CROP  ORGANIC SOLUBL
        (mm)   (mm)   (mm)  (mm)  (mm)  (mm)  (mm)  (mm)  (mm)  (mm) (t/ha)  ---------------(kg nutrient/ha)---------
 1997 353.15  31.30  62.34   8.93   9.90   0.00  54.49 285.50 700.53 101.93   0.34   0.11   1.29   0.29  25.02    0.42    0.
   SWAT  Feb. 01 VERSION2000
   General Input/Output section (ffile.cio):          Thu Apr 14 22:19:40 2005 AVSW
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PROGRESS BREIFING

DEQ Task Order – 202105-05

- Task 1 – Data Compilation and Assessment
- Task 2 – SWAT Model Construction and Development
- Task 3 – Model Calibration and Verification
- Task 4 – Model Documentation
- Task 5 – Model Application and Scenario Management

Task 1: Data Compilation and Assessment

- Develop Modeling QAPP
- Compile Available Data
- Assess Data for Modeling
- Report

Task 1: Modeling QAPP

- Final
- Out for signatures
- Posted at QA web-site

http://www.deq.state.mt.us/wqinfo/QAprogram/WQPBQAP-06.pdf

Task 1: Data Compilation

- Surface Water
  - Montana DEQ/EPA - STORET
  - USGS
    - 14 sites, 8 w/ nutrients
  - Missoula County WQD/ U of M
    - 11 sites (1990-current)
- Ground Water
  - Missoula County WQD
    - 71 well samples (2001)
- MBMG
  - Ground Water Characterization
- USGS
  - 343 sites/wells

Task 1: Data Compilation (ctd.)

- USGS
  - National Land Cover Dataset
  - National Hydrography Dataset
  - National Elevation Dataset
  - Digital Ortho Quads
- NRCS
  - STATSGO soils
- DNRC
  - Reservoir Operation
- USFS
  - Fire Coverage
- Montana DEQ
  - Point Source Discharges

Task 1: Data Compilation (ctd.)

- Final report deliverable soon
- Will be available for TAC review/comment.
- Posted at project web-site

Task 1: Results – Identified Calibration Locations

- USGS Gages
  - Near Conner
  - Florence Bridge
  - Buckhouse Bridge
- DEQ Sites for validation
  - Ongoing Fieldwork

Task 2: SWAT Model Construction

- Watershed Delineation
- HRU Definition
- Management File Setup

Task 2: Watershed Discretization Objectives

Minimum number of subbasins for calibration while capturing as many 303(d) listed streams as possible.

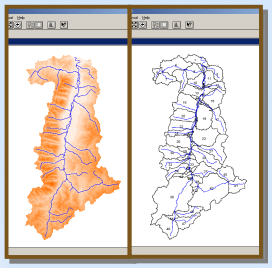
.

- Minimize PC computational time.
- Provide sufficient spatial resolution across watershed.

Task 2: Iterations

- First Generation
  - Very Coarse Resolution
    - Not adequate spatial refinement for project goals
  - Very Fine Resolution
    - Significant Processing Time
    - Potential Calibration Difficulties
- Final Subbasin Delineation
  - 49 Subbasins

Task 2: Final Subbasin Delineation



Task 2: Final Subbasin Delineation (ctd.)

- Density - 49 Subbasins

ID	Watershed	303(d) Listed Streams
1	Lower Bitterroot	Bitterroot River
2	Lolo to Miller	Bitterroot River
3	Miller Creek	Kirk
4	Middle Lolo	Lolo Creek
5	South Fork Lolo	South Fork Lolo Creek
6	North Upper Lolo	North Creek, Granite Creek
7	South Upper Lolo	West Fork Lolo Creek, Lee Creek, Lost Park Creek, East Fork Lolo Creek
8	Lower Lolo	Lolo Creek
9	Bitterroot	Bitterroot River
10	Chaffstra	Ketchum Creek
11	Marley	Bitterroot River
12	Eightmile	Kirk
13	Kenjour	Bitterroot River
14	Refuge	Bitterroot River
15	Threemile	Threemile Creek, Ambrose Creek
16	Stevensville	Bitterroot River
17	North Burnt	North Burnt Fork Creek
18	Kootenai	Kootenai Creek
19	Ball Crossing	Bitterroot River
20	Bear	Sweathouse Creek, Bear Creek
21	Victor	Bitterroot River
22	Mill	Mill Creek
23	Woodside	Bitterroot River
24	Blodgett	Blodgett Creek
25	Riverside	Bitterroot River

Task 2: Final Subbasin Delineation (ctd.)

- Density 49 Subbasins

ID	Watershed	303(d) Listed Streams
25	Riverside	Bitterroot River
26	Sawtooth	Bitterroot River
27	Skalkaho	Skalkaho Creek
28	Sleeping Child	Sleeping Child Creek
29	Ward	Bitterroot River
30	Lost Horse	Lost Horse Creek
31	Charlos Heights	Bitterroot River
32	Como	n/a
33	Rock	Bitterroot River
34	Tin Cup	Tin Cup Creek
35	N. Darby	Bitterroot River
36	Upper Bitterroot	Bitterroot River
37	Rye	Rye Creek, North Fork Rye Creek
38	Lower West Fork	West Fork Bitterroot River
39	Lower East Fork	n/a
40	Moose	Moose Creek
41	Upper East Fork	n/a
42	Middle East Fork	n/a
43	Laird	Laird Creek, Gilbert Creek
44	Middle West Fork	West Fork Bitterroot River
45	Overfelch	Overfelch Creek
46	Upper West Fork	West Fork Bitterroot River
47	Hughes	Hughes Creek
48	Florence	Bitterroot River
49	Darby	Bitterroot River

Task 2: Current Work

- Continue Task 2
  - Basin Parameterization
  - HRU Management File Setup

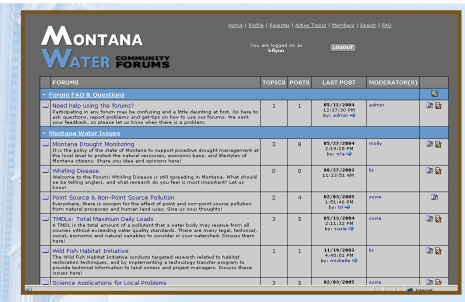
Upcoming Work

- Task 3: Model Calibration
  - Hydrologic Calibration
  - Sediment Calibration
  - Nutrient Calibration

ADVISORY GROUP FORMAT

Format

- Mainly Web-based
- Limited Meetings
- Telephone
- Email



http://water.montana.edu/forum/default.asp

Web-based Interaction

- Montana Water Forum
  - Once posted, moderator notified and emails group
  - Site is password protected
  - Need to sign in as user
  - Password: bitmodtac

Thanks to Montana Water Forum!

Ground Rules

- DEQ will moderate!
- Maintain professional courtesy!
- Unbiased Science!
- Work cooperatively!
- Constructive feedback!
- Be senatorial!

Bitterroot TAC – Thank you!

- Montana Bureau of Mines
- Montana DEQ
- Montana State University
- Missoula County WQ Dst.
- Plum Creek Timber
- Ravalli County Planning Dpt.
- Rocky Mountain Rsch. Station
- University of Montana
- USFS