Meeting Minutes
S-1063 Quantification of Best Management Practice Effectiveness for Water Quality Protection at the Watershed Scale

Annual Meeting May 13 & 14, 2015
Texas A&M AgriLife Research and Extension Center
17360 Coit Road, Dallas, TX 75252

List of attendees:

Brian Benham (V Tech), Prem Parajuli (MSS), François Birgand (NCSU), Indrajeet Chaubey (Purdue), Fouad Jaber (TAMU) , Dharmendra Saraswat (U Ark/Purdue), Aleksey Sheshukov (KSU), Bruce Wilson (UMN), Art Gold (URI), Soni Pradhanang (URI), Prasanta Kalita (UIUC), Sunday Tim (IaSU), Mike Hirschi (Waterborne Environmental), Sara McMillan (Purdue), Zhuping Sheng (TAMU), and David Sample (V Tech)

1. Introduction

Brian Benham welcomed the participants and provided brief overview of the project. We are in the first year of a 5 year project with an approved proposal and objectives. The primary goal of this meeting is to finalize the objectives with deliverables and expected outcomes.

Prem Parajuli led introductions of all participants who each provided brief background and goals for involvement with the project.

2. Hatch projects – background and goals

Brian led discussion with input from several more senior project participants on the history of Hatch projects and particularly how universities and federal agencies assess and engage faculty in regional, multi-state projects.

Art Gold provided information about NIFA's Water Directive (see attached file) with $100 million focused on water issues in rural, agricultural and urbanizing systems. It is anticipated that each state will have water quality coordinator and that Regional Centers will be established to coordinate competitive grants. It may be an opportunity for this project to submit proposals.

Art also suggested that project leaders visit with our program manager at USDA (Kitty Cardwell) to ensure that she is fully aware and engaged in our collaborative research project.

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3. S1063 Background

Brian Benham, with input from Bruce Wilson, Mike Hirschi and Tim Sunday, presented the regional projects that preceded the current project. This was quite helpful for many of the newer members of the project team and helped to set the stage for discussions of individual objectives.

Objective 1: BMP monitoring (Brian Benham)
This objective focuses on measuring the success of practices (structural and non-structural) for stormwater management. Some questions that were raised:

- Are practices implemented and functioning correctly?
- What happens to BMPs that are in the ground for a longer period of time?
- How do we assess performance? Could visual assessment sufficient?
- How are agricultural BMPs supported and included in cost-share funding?
    - Art suggested working with Farm Services Agency on this issue
- What is the role of proprietary BMPs?
    - Particularly relevant in the Chesapeake Bay where credits are tied to implementation of tested BMPs.
    - Independent verification of function of these systems is needed - industry trying to sell these but need to determine whether it is legitimate to TMDL programs

What are some potential project outcomes?

- Meta analysis of past data
- Get this group involved in relevant expert panels on specific technology (e.g., bioreactors, stream restoration) for Chesapeake Bay Program

Objective 2: BMP Modeling (Prem Parajuli)
Watershed-scale modeling has primarily focused on agricultural BMPs using SWAT. One specific effort was highlighted as an example outcome: modifications to SWAT to include better representation of overland flow/transport and enhance overall spatial representation.

Questions that the group would like to address under this outcome:

- Assessment of BMP function under climate change scenarios; how do changes to precipitation patterns (e.g., timing, amount and intensity), temperature, CO2 concentration get integrated into our models?
- What are the “best” models for quantifying and predicting BMP function at the watershed scale?
- Can we enhance model performance when targeting BMPs in combination (e.g., “stacked” BMPs)
- How do various models include non-structural practices?
- Can we include water reuse? Create storage in ponds (e.g., tailwater recovery ponds) to store water during wet periods and use it for irrigation later. - can this be included in the model?

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- How are Inline ponds/dams perceived in different regions and what are their effects on hydrology/water quality?
    - Efforts to remove these all over the country but what are the impacts on water quality (lost functions of sediment trapping/storage, denitrification)
- Many areas of the country need to include both groundwater and surface water.

The discussion wrapped up with the broader question, particularly from the modeling perceptive is that we are really talking about sources/sinks - we don't need to limit our focus to the traditional definition of BMPs.

Objective 3: Uncertainty (François Birgand)
There is an opportunity to make a big contribution in this area from the scientific perspective (both monitoring and modeling) and in outreach and communication with stakeholders.

Driving question: Can we set up a monitoring framework to get a decent picture of the uncertainty of the performance? This could be based on land use (LU) and size of watershed, type of pollutant, and sampling frequency with the goal of creating expected uncertainty bands.

Critical need to address misconceptions - "if we implement BMPs we will see WQ improvement"

- At what spatial/temporal scale should we expect to see some level of improvement?
- There is an assumption that BMPs should work better when used in combination but they don't always work synergistically
    - Important to know kinetics and controlling processes.
- Can have unintended consequences.
    - Sediment/erosion example of no-till without stream bank stabilization.
    - No-till = less sediment but more soluble P and NO3
- Monitoring programs focus on load reductions but concentration is regulatory stick
- Climate variation - what is the effect of BMP function in different regions
    - Eastern Oregon example: low rainfall and buildup of NO3 in GW
- What do we evaluate? Sensitivity coefficients themselves! need to move beyond matching observed vs modeled

4. Tour of BMPs at Texas A&M Agrilife (Fouad Jaber)

The group toured multiple types of BMPs that are constructed and monitored for water quality improvements including permeable pavement, green roofs, bioretention and a meandering wet pond.

5. Open discussion of Objective 1 (François Birgand)

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The discussion started with each participant sharing ongoing and future/planned research efforts related to BMP monitoring:

- Aleksey (KS) - Sediment sources at watershed scale; no BMP testing specifically but windshield surveys for BMPs (ag focused: terraces, no-till, grassed waterways) and land use (retrospective 2002 - present)
- Mike and others at Waterborne (IL) N/P, pesticides under tile drainage (Q, C) and at watershed outlets (1991-2005); BMPs would be nonstructural (precision ag, variable-rate fertilizer); CRP vs corn/beans; wetlands, bioreactors
- Bruce (MN) –
    - (Ag): two-stage ditch, saturated buffers, riparian vegetation - N/P, TSS
    - (Urban): rain gardens, infiltration swales (mostly volume)
- Ping (west TX) - salinity issues are important; Rio Grande
- Art/Soni (RI) - riparian buffers (N and GHG)
- David, Zach Easton, Brian (VA)
    - Urban: wet retention pond, bioretention, floating wetlands (coastal) - GW, seepage, N/P/TSS; denitrifying bioreactors, curtains, drains (N/P/GHG/C)
    - Ag: water management (irrigation rates)
    - Stream restoration - Stroubles Creek monitoring.
- Sara - (NC)
    - Urban: Charlotte - wet retention ponds, constructed wetlands, bioretention, stream restoration/reconnected floodplains (N/P/TSS/C/Temperature); partner with City of Charlotte on BMP monitoring through Pilot BMP Program (includes some proprietary BMPs)
    - Ag - stream restoration = instream & riparian (N/P/GHG/Q)
- François (NC)
    - Urban - N/P/C/GHG/TSS (permeable pavement, bioretention, green roof, rainwater harvesting, wetlands, stream restoration)
    - Ag - control drainage, bioreactors
- Prem - (MS) Ag - watershed scale, crop rotation, tillage, tailwater recovery ponds, filter strips
- Indrajeet, Sara, others - (IN)
    - Ag - bioreactor, 2-stage ditches (N retention; P release); Drainage water management (on-site storage and reuse)
- Fouad - (TX)
    - Urban - permeable pavement, bioretention, green roof, rainwater harvesting, wetlands - N/P/TSS/bacteria

Systems level analysis is needed that extends single site data and helps to understand the cumulative effects of BMPs. Treatment trains are quite common in both agricultural and urban watersheds but none of the models take into account the interaction effects. In series, we would predict that total reduction of X and Y in series << X + Y (where X and Y are data based on information/monitoring of a single BMP). This type of monitoring is needed and done infrequently (Art – field + riparian; Bruce – treatment train in MN). Review and “gap” article on this question could be an outcome of this objective.

Potential products/outcomes:

1. Meta-analysis of past datasets of BMPs a. Add data to Art's existing meta-analysis of bioreactors. - output is removal/time/volume, effect of T°C, design, hardwood/softwood, where they are functioning better/worse, b. do we include peer-reviewed journals or other non-public datasets?	Easily attainable ↓
2. Critique of monitoring: are we measuring the right thing? Are we considering the right factors for monitoring? a. Edict BMP monitoring guidelines b. Case studies are valid way of sharing results in other disciplines - is this an appropriate approach for a monitoring critique? c. High intensity sampling vs. low frequency: what are we really gaining by one or the other d. What can one do/obtain with EC, Q, pH, etc.?	↓ ↓ ↓
3. Editorial article on BMPs in series a. When used in series to BMPs function synergistically? b. Are there rules for BMP placement in watersheds?	↓
4. New proposal effort: What is the impact of climate change on BMP design guidelines and predicted success a. Governing agencies do not measure each BMP but assign % removal based on design. What are the effects of changing precipitation patterns on this removal efficiency? b. How resilient are BMPs? If not resilient, what are the consequences of failure? c. Updating return intervals continuously so question related to older BMPs using "old" return intervals	↓ Desirable But not easy

6. Open discussion of Objective 2 (Prem Parajuli)

The discussion started with each participant sharing ongoing and future/planned research efforts related to modeling BMPs at site and watershed scales. Listed as a "running total" of the models, approaches, parameters currently in use (i.e., if someone already stated that they were using a model, it would not be stated again unless additional functionality or novel applications were being done).

- Virginia (Brian & David)
  - Watershed scale: HSPF, SWAT, GWLF: PCBs, N/P, sediment, climate change. Pass through factors (e.g., pass through factors to model BMPs)
  - Single BMP, site, watershed scales: SWMM (climate change effects, N/P/TSS) - BMPs are "all of the above"

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- Darmendra (AR): SWAT - development of tools to facilitate depiction of LU change in SWAT and targeted BMP placement.
- François (NC): Ag – Drainmod
- Aleksey (KS):
    - Ag BMPs/conservation practices;
    - Models: WEPP, Annualized AGNPS, RUSLE2, CONCEPTS (instream water quality model using geomorphological data), APEX. Climate module WINDS
- Tim (IA) - pretty much all of the one that are on the board already but focused on interfaces, cloud-based computing
- Mike (IL) - PRZM - Pesticide root zone model for pesticide/herbicides; BMPs are export coefficient based.
- Bruce (MN) - BASIN, GRASSF, MIN FARM
- Ping (TX) - MODFLOW + RiverWay = Colorado River, Rio Grande; Salinity + Bacteria (E. Coli); Land use, climate conditions
- Soni (RI): REM + statistical model for riparian buffer; PNET-BGC – forest productivity
- Sara (NC)
    - NC - RHESSys for urban BMPs; developing process based modules for retention pond and constructed wetlands
    - IN - L-THIA-LID, STEPL to model BMPs in mixed urban/ag watersheds
- Prasanta (IL) - WEPP + SWAT
- Indrajeet (IN) –
    - CENTURY, DAYCENT - climate change impacts
    - Purdue is part of SWAT developing team (currently develop landscape routing algorithms - released June 2015). Adding BMPs - filter strips, two-stage (summer?), bioreactor (add this next), gullies
    - Stream water quality component complete redo - work on this in the Fall; currently QUAL2E
    - Optimization methods for BMPs at the watershed scale - maximize WQ, minimize cost
- Fouad (TX) - SWAT-LID module, HYDRUS2D, MIKE-SHE (raster based)

Water quality models have been calibrated and validated with composite sampling (perfectly calibrated to data collected during low flow conditions, perhaps). New high-resolution sensors (e.g., nitrate) would be key to validate.

Points of discussion included:

- Majority of models are empirically based with regard to pollutant and volume retention by BMPs. Many of the agricultural BMPs are simulated by modifying land cover (points to expertise of the modeler, not capabilities of the model itself).
- Real-time and archived datasets available? Associate these with metadata
- Make models easy to use by developing interfaces
- Make models accessible through cloud-based computing
- Scale up modeling results

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Potential products/outcomes:

1. Review paper – What current model does what BMP? Using what concept/simplification? Do current models sufficiently represent BMPs? (pick 10 models?) a. How does one modify design criteria in light of climate change? How robust are BMPs? What consequences of climate change on BMPs, and can they be modeled?	Easily attainable ↓
2. Produce new modules within existing models - use benchmark datasets to test these b. Most new modules created on modeling plateforms (e.g. SWAT) should be validated on benchmark datasets c. Generate a modeling QA/QC and accreditation d. Benchmark datasets require creating database for public access with citations	↓ ↓
3. BMPs in series/cumulative impacts– ties back to same issue raised during discussion of Objective 1. e. How do you modify design criteria in light of climate change? f. How are BMP spatial placement, cumulative vs. counteractive effects taken into account?	↓ ↓
4. Review of realtime datasets with new sensor data (see later discussion of this in Objective 3)	Desirable But not easy

7. Open discussion of Objective 3 (François Birgand)

- Darmendra (AR)
  - SWAT - Priority watersheds based on NPS pollution; uncertainty on inputs
  - Tool developed for SWAT (LULC uncertainty tool): Uncertainty in input LU data (classification uncertainty).
- Aleksey: KS, NE, MO, IA, IN
  - SWAT parameterization - set of watersheds with calibrated models
  - PRIZM: NEXRAD DATA uncertainty in climate datasets affect hydrology
- Mike/Prasanta: Waterborne/IN
  - Jorge Guzman - Uncertainty in input parameters propagating through model (Monte Carlo); PCA
  - SWAT, PRIZM

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    - Uncertainty in analysis holding times, preservation, freezing
    - SWAT/WEPP - climate change
- Bruce: MN
    - Uncertainty in Fish IBI, stochastic weather series with/without climate change; optimized monitoring to get maximize amount of data collected for each sampling point (Fisher info criteria/objective functions - hydro models to find optimal surface).
- Ping: west TX
    - Weather forecast/decision support system. sensitivity analysis & uncertainty
    - USDA (multiple models - uncertainty when linking models)
- Art: RI
    - How resolution changes understanding of watershed processes. High resolution sensors (temporal); high resolution remote sensing data (spatial). Example: landscapes with isolated wetlands with high resolution spatial data are actually connected.
- Soni: RI
    - REM/statistical - global sensitivity analysis, PCA
    - SWAT - Monte Carlo
- Sara: NC
    - RHESSys - long term climate uncertainty, scenario uncertainty (BMP placement); Monte Carlo (inputs)
- David: Chesapeake Bay (VA, PA, NY)
    - SWAT + SWMM = Monte Carlo (inputs), scenario testing
    - Uncertainty in LU spatial resolution of existing data
- Prem: MS
    - SWAT w/SUFI2 (model input parameters, BMPs) to improve model efficiency?
- Indrajeet: IN
    - Sources and impacts of uncertainty: how does uncertainty in measured data affect model outputs; how does this effect calibration approaches?
    - Projecting forward: uncertainty from land use compared to uncertainty in climate. Preliminary results suggest that uncertainty in LU dominates. Science: Stationarity is Dead article - talked about both impact of LU and Climate Change (CC) but many just focus on CC when referencing it.
    - Stochastic vs deterministic methods to quantify uncertainty
    - Lack of BMP data in model calibration - which BMPs have been applied within the time period of calibration (adjust parameters for lack of knowledge to calibrate the model).
    - Optimization method - Monte Carlo vs other heuristic approaches affect outputs
    - Wish list - structural uncertainty in model, potential for huge impact
- Fouad: TX: SWAT/SUFI2
- François: NC
    - Sample preservation/degradation in field collected samples: acidification, freezing, etc. - low hanging fruit! (Fouad offered to share

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QA/QC protocols from EPA that have this type of information but could still be valuable to test some of these things).

- Uncertainty on high frequency sensor data (optical sensors) - algorithm to convert absorbance to concentration so you can create own calibration with your own data. Works well with NO3, really complicated with DOC. Currently using Partial Least Squares Regression, which works well for highly auto-correlated data.
  - Turns out that this is site specific with no predictive power… how can this be used as prediction?
- Can we develop a water quality rating curve - what parameters can we predict and with what uncertainty, how many samples are needed? Huge demand for this particularly with DOC
- Uncertainty on loads (infrequent sampling, compositing methods)
- Uncertainty on number of storms to be sampled, particularly with regard to BMP sampling
- GSA of uncertainty in monitoring - apportioning uncertainty to things like Q, lab error, etc.
- How is model calibration impacted by high resolution water quality data. (wish list) - look at kinetics

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Potential products/outcomes:

1. Quality control methodology to reduce uncertainty in sampling collection and holding. a. Bruce suggested a standards/protocol: "ASABE engineering practice" b. EPA 319 QA/QC document designed for discrete sampling. needs to include sensors as well.	Easily attainable ↓
2. SW BMP sampling - composite vs discretized data	↓
3. Effect of sampling frequency on monitoring uncertainty and model output a. A lot of high temporal frequency sensor data within the group b. Run existing engines to quantify uncertainties and extract rules c. Outliers - do they cluster by region, seasonality, d. Run Global Sensitivity Analysis (GSA) to apportion the source of uncertainty for monitoring	↓ ↓
4. Model calibration - broad opinion paper: uncertainty bands in model input and output to see if they overlap. a. paper on calibration ignores uncertainty in input; next paper went a little further (basic guidelines) - issues of temporal/spatial scales, constituent specific.	↓
5. Land use / climate change projections, can use techniques such as GSA to apportion sources of error to LU and CC.	↓
6. Paper on protocol (scholarship of sharing data) - thought piece that lays this out. Many papers on this already, our contribution to this literature would be specific to the high resolution sensor data	Desirable But not easy

Discussion about two types of published data as outcome of this project.

1. Benchmark datasets for SWAT: Make 4-5 watersheds with good data available to SWAT community - need to test algorithms on multiple watersheds and publish these results.
2. High resolution senor data: Assign doi to the data so it can be cited to evaluate uncertainty. PURR libraries can help with this. Would be a significant contribution from this group. Start with NO3 as a test case.

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Questions/concerns that were raised:

- What about peer-review to ensure that these data are “good”, need documentation of meta data and independent assessment of QA/QC.
- Potential to write a paper about scholarship involved in sharing data, information; quantification of uncertainty is really important in this outcome
- What about misuse/mitigation of risk of “losing” your data to someone else who publishes with it? Suggestion was to start with older data sets (but are there many of these in the sensors?)
- Journals are publishing datasets as supplemental data (use of already published work).

8. Elections and housekeeping

Brian Benham requested to roll off of the leadership group. The following leadership positions for 2015-16 were elected:

Chair: François Birgand
Vice Chair: Prem Parajuli
Secretary: Sara McMillan

Social media presence would be a benefit to engaging researchers at our universities, USDA and other stakeholders. Sara will develop a Facebook page, and Linked-In group as a starting point. Bruce Wilson offered to host a webpage for the project.

9. Next meeting locations:

2016 - Illinois-Urbana/Champagne - May 18-19, 2016
2017 - Raleigh, NC
2018 - Minnesota

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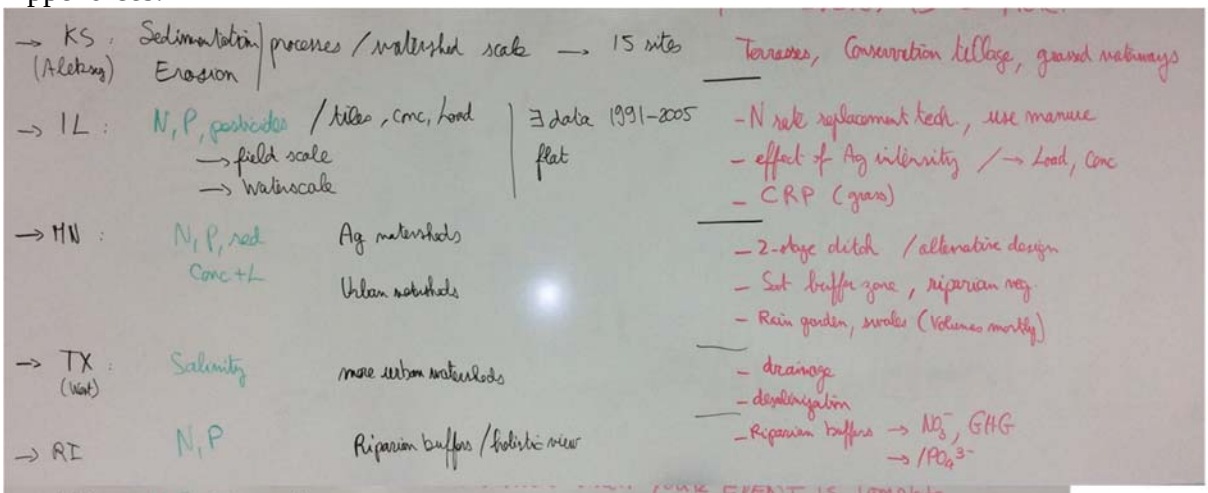
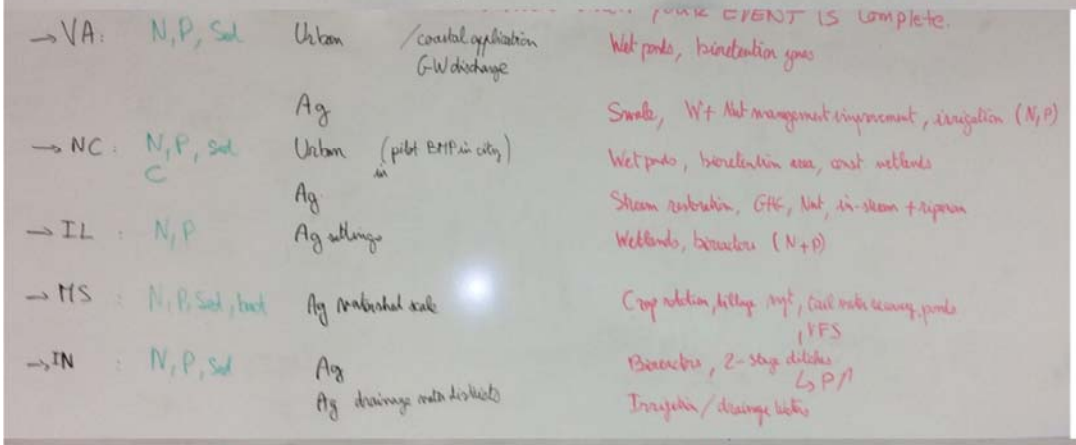
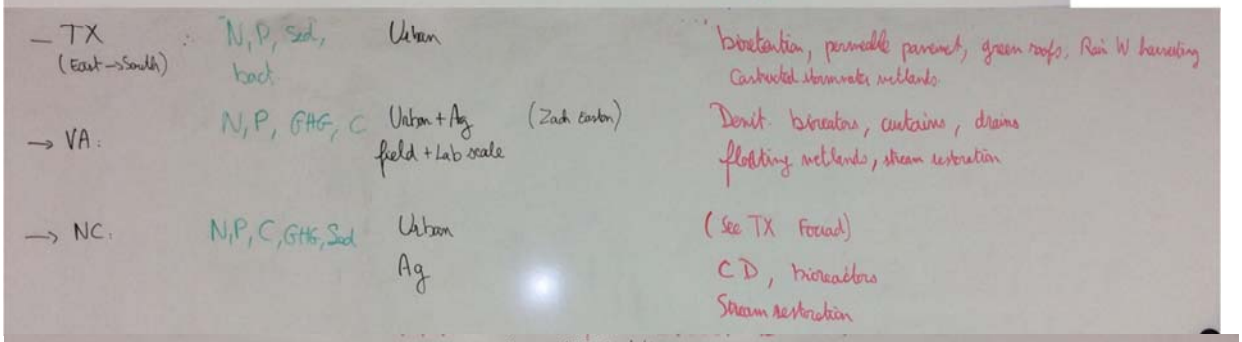
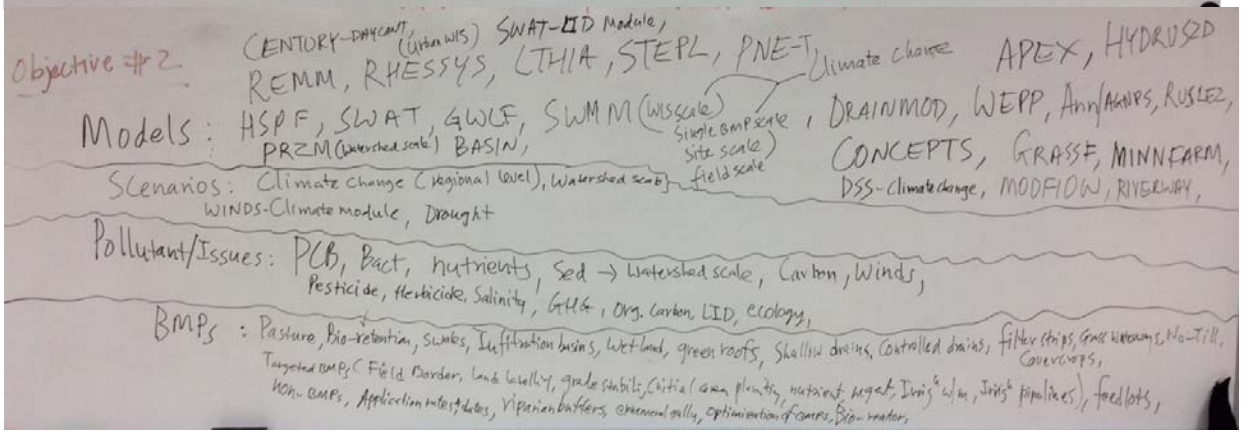
Appendices:


→ KS : Sedimentation / Erosion (Aletsay) processes / watershed scale → 15 sites
Terraces, Conservation tillage, grassed waterways
→ IL : N, P, pesticides / tiles, conc, load
→ field scale
→ watscale
∃ data 1991–2005
flat
- N rate replacement tech., use manure
- effect of Ag intensity / → Load, Conc
- CRP (grass)
→ MN : N, P, sed Conc + L
Ag watersheds
Urban watersheds
- 2-stage ditch / alternative design
- Sed buffer zone, riparian veg.
- Rain garden, swales (Volume mostly)
→ TX : (West) Salinity
more urban watersheds
- drainage
- desalinization
→ RI N, P
Riparian buffers / holistic view
- Riparian buffers → NO3-, GHG
→ PO4 3-


→ VA: N, P, Sed
Urban / coastal application GW discharge
Wet ponds, bioretention zones
Ag
Swale, W+ Nut management improvement, irrigation (N, P)
→ NC: N, P, Sed C
Urban (pilot BMP in city)
Wet ponds, bioretention area, const wetlands
Ag
Stream restoration, GHG, Nut, in-steam + riparian
→ IL : N, P
Ag settings
Wetlands, bioreactors (N+P)
→ MS : N, P, Sed, bact
Ag watershed scale
Crop rotation, tillage mgt, Soil water cleaning, ponds, FFS
→ IN : N, P, Sed
Ag
Ag drainage water districts
Bioreactors, 2-stage ditches → P?
Irrigation / drainage districts


- TX (East → South) : N, P, Sed, bact
Urban
bioretention, permeable pavement, green roofs, Rain W harvesting
Constructed stormwater wetlands
→ VA: N, P, GHG, C
Urban + Ag field + Lab scale
(Zach Easton)
Denit. bioreators, curtains, drains
floating wetlands, stream restoration
→ NC: N, P, C, GHG, Sed
Urban
Ag
(See TX Forcad)
CD, bioreactors
Stream restoration


Objective #2
Models: HSPF, SWAT, GWLF, SWMM (WS scale) (Single BMP scale Site scale) field scale, PRZM (Watershed scale) BASIN, CENTURY-DAYCENT, (Urban WS) SWAT-LID Module, REMM, RHESSYS, LTHIA, STEPL, PNET, Climate change APEX, HYDRUS2D, DRAINMOD, WEPP, AnnAGNPS, RUSLE2, CONCEPTS, GRASSE, MINNFARM, DSS-Climate change, MODFLOW, RIVERWAY,
Scenarios: Climate change (Regional level), Watershed scale, WINDS-Climate module, Drought
Pollutant/Issues: PCB, Bact, nutrients, Sed → Watershed scale, Carbon, Winds, Pesticide, Herbicide, Salinity, GHG, Org. Carbon, LID, ecology,
BMPs: Pasture, Bio-retention, Swales, Infiltration basins, Wetland, green roofs, Shallow drains, Controlled drains, filter strips, Grass Waterways, No-Till, Covercrops, Targeted BMPs, Field Border, Land leveling, grade stabilz, Critical area planting, nutrient mgmt, Irrig ditch, Irrig pipelines, feedlots, non-CAFOs, Application intensities, Riparian buffers, ephemeral gully, optimization of farms, Bioreactor,

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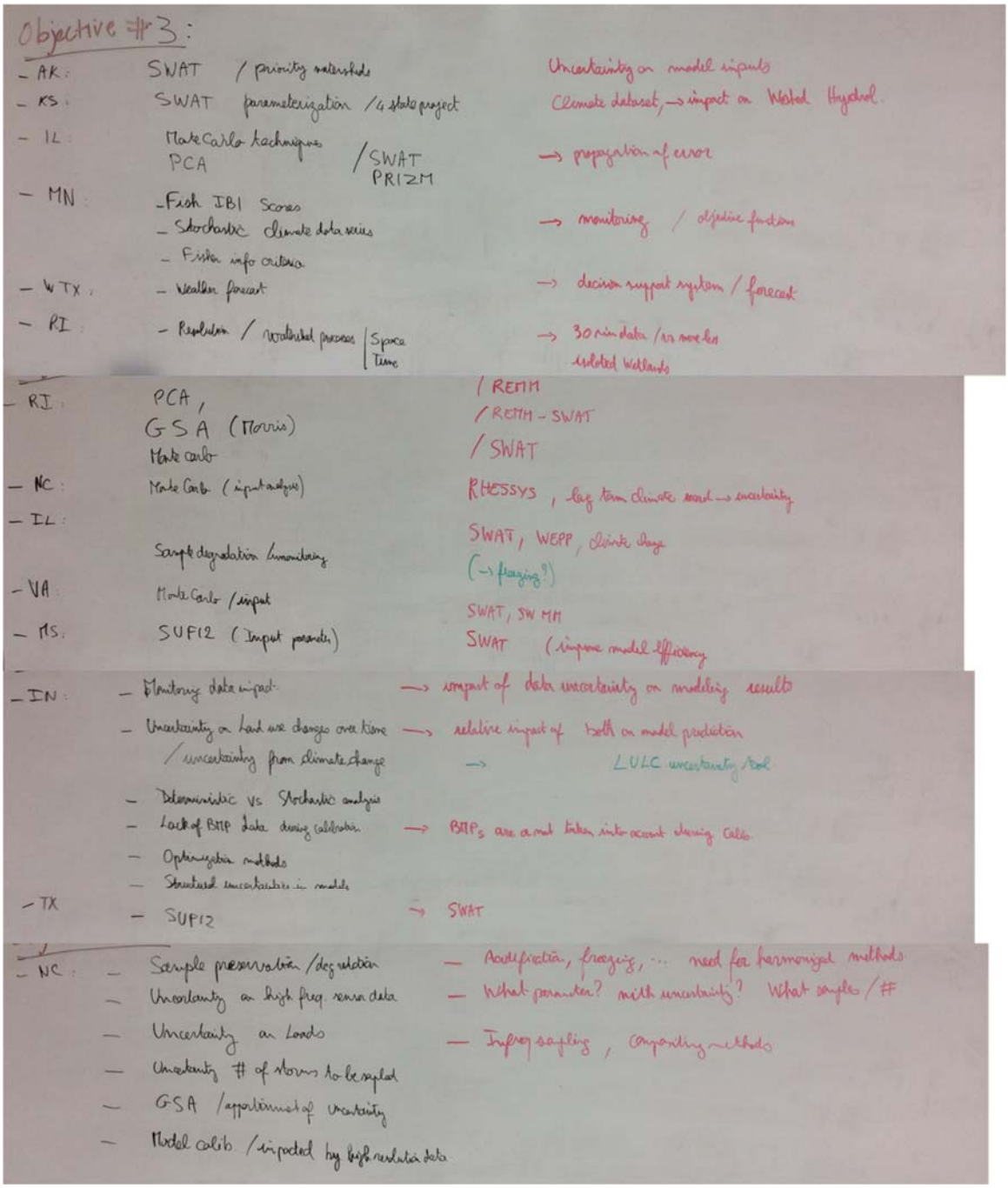
Objective #3:
- AK: SWAT / priority watersheds
Uncertainty on model inputs
- KS: SWAT parameterization / 4 state project
Climate dataset, → impact on Wetland Hydrol.
- IL: Mate Carlo techniques PCA / SWAT PRISM
→ propagation of error
- MN: - Fish IBI Scores - Stochastic climate data series - Fisher info criteria
→ monitoring / objective function
- WTX: - Weather forecast
→ decision support system / forecast
- RI: - Resolution / coupled process | Space Time
→ 30 min data / vs more les
isolated Wetlands
- RI: PCA, GSA (Morris) Mate carlo / REHM / REHM - SWAT / SWAT
- NC: Mate Carlo (input analysis) RHESSYS, long term climate scenario → uncertainty
- IL: Sample degradation / monitoring SWAT, WEPP, climate change (→ flooding?)
- VA: Monte Carlo / input SWAT, SW MM
- MS: SUFI2 (Input parameter) SWAT (improve model efficiency
- IN: - Monitoring data impact → impact of data uncertainty on modeling results
- Uncertainty on land use change over time / uncertainty from climate change → relative impact of both on model prediction → LULC uncertainty tool
- Deterministic vs Stochastic analysis
- Lack of BMP data during calibration → BMPs are not taken into account during Calib.
- Optimization methods
- Structural uncertainties in models
- TX - SUFI2 → SWAT
- NC: - Sample preservation / degradation — Acidification, freezing, ... need for harmonized methods
- Uncertainty on high freq. sensor data — What parameter? with uncertainty? What samples / #
- Uncertainty on Loads — Impact sampling, computing methods
- Uncertainty # of storms to be sampled
- GSA / apportionment of uncertainty
- Model calib. / impacted by high resolution data

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