Virginia Water Resources Research Center Annual Technical Report FY 2011

Introduction

The Virginia Water Resources Research Center (VWRRC) was established at Virginia Tech in 1965 as a federally authorized program. In 1982, the Virginia General Assembly authorized the VWRRC as a state agency under the Code of Virginia (§23-135.7:8).

MISSION

The VWRRC provides research and educational opportunities to future water scientists; promotes research on practical solutions to water resources problems; and facilitates timely transfer of water resources information to policy- and decision-makers and the general public.

MISSION ELEMENTS

Research

Assisting university researchers in securing research support funds from public and private sources.

Assisting university researchers in initiating and executing water resources research.

Education

Advancing educational opportunities for students in water-resources fields by

(1) Helping university researchers provide undergraduate and graduate research experiences in water resources.

(2) Coordinating an undergraduate minor and graduate certificate in water resources at Virginia Tech.

Outreach

Maintaining and making available via the VWRRC website a publication series that synthesizes and reports on water resources science, engineering, and policy.

Publishing *Virginia Water Central,* a newsletter featuring articles on water-related policy and law, summaries of water conditions in Virginia, and news briefs about water issues.

Producing Virginia Water Radio, a weekly radio show and podcast featuring unique perspectives on water sounds and news, and information involving Virginia's waters.

Securing academic advisors to work in an advisory capacity with public and private sectors as requested

Initiating and participating in the development and execution of conferences and symposia on Virginia, regional and national water issues.

Research Program Introduction

The research program of the VWRRC is supported through

(1) its annual appropriation from the Commonwealth of Virginia,

(2) external funding through grants and contracts, and

(3) a portion of overhead generated by external funding.

The VWRRC's 104B funds are not allocated to support research, but are used to support its outreach and information dissemination programs and to provide administrative support.

The VWRRC funded one new research project granted to the University of Virginia from the Center's state budget allocation. During this reporting period, funding for one facilitated USGS 104G grant to a researcher at George Mason University occurred. Five additional grants passed through USGS to the VWRRC and were administered by the Center. Basic information regarding these six grants and resulting products are described in the following section.

Award No. 08HQGR0153 Studies of U.S. Army Corps of Engineers Policies and Programs, Phase II - Part 2

Basic Information

Title:	Award No. 08HQGR0153 Studies of U.S. Army Corps of Engineers Policies and Programs, Phase II - Part 2
Project Number:	2008VA132S
Start Date:	9/9/2008
End Date:	8/31/2011
Funding Source:	Supplemental
Congressional District:	VA-9
Research Category:	Social Sciences
Focus Category:	Management and Planning, Law, Institutions, and Policy, None
Descriptors:	
Principal Investigators:	Stephen H. Schoenholtz

Publications

1. None
2. None
3. FY2010 None
4. None
5. FY2010 None

Modernizing USACE Policies and Programs – Phase II, Part 2

Dr. Woolley prepared 4 draft white papers:

1) A history of the legacy of Gilbert White
2) A case study of flood risk management programs of the Urban Drainage and Flood Control District – Denver
3) A case study of flood damages and flood control – Chesterfield MO
4) A case study of Broome County, NY flood experience

These drafts remain in editorial review. It is anticipated they will appear as background papers for an IWR policy study to be published in the fall of 2012.

Copies will be available at that time.

Denitrifying bacterial community structure and diversity, and denitrification potential as affected by hydrologic design and soil properties in wetlands created in Chesapeake Piedmont, USA

Basic Information

Title:	Denitrifying bacterial community structure and diversity, and denitrification potential as affected by hydrologic design and soil properties in wetlands created in Chesapeake Piedmont, USA
Project Number:	2010VA142G
Start Date:	9/1/2010
End Date:	8/31/2011
Funding Source:	104G
Congressional District:	VA-11
Research Category:	Water Quality
Focus Category:	Wetlands, Water Quality, Hydrogeochemistry
Descriptors:	None
Principal Investigators:	Changwoo Ahn

Publication

1. No publication available at this time.

Report on the progress of the project

May 23, 2012

Title of the project: *Denitrifying Bacterial Community Structure and Diversity, and Denitrification Potential as Affected by Hydrologic Design and Soil Properties in Wetlands*" (USGS Award # G10AP00139)

PI: Dr. Changwoo Ahn, Environmental Science and Policy, George Mason University

All the work proposed has been completed. Manuscripts are in progress. The attached is the first manuscript developed. The outcome of the research will also be presented soon in a conference as well early July 2012.

Changwoo Ahn, Ph.D

Denitrifying Bacterial Community Structure is Affected by Development of Soil Conditions in Created Mitigation Wetlands

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We investigated the abundance and genetic heterogeneity of bacterial nitrite reductase genes (*nir*) in relation to soil structural attributes in created and natural non-tidal freshwater wetlands in Virginia. Soil attributes included soil organic matter (SOM), total organic carbon (TOC), total nitrogen (TN), pH, gravimetric soil moisture (GSM), and bulk density (D_b). A subset of soil attributes were analyzed across the sites, using euclidean cluster analysis, resulting in three soil condition (SC) groups of increasing wetland soil development (i.e., SC1<SC2<SC3 less to more developed) as measured by accumulation of SOM, TOC, TN, the increase of GSM, and the decrease of D_b. *NirK* gene copies detected ranged between 1.1 x 10^2 and 2.3 x 10^3 ng^{-1} extracted DNA and were highest in the most developed soil, SC3, and lowest in SC2, which had a significantly higher pH than the other two SC groups ($F = 3.8$, $p = 0.02$), suggesting soil pH may have impacts on the community structure. Gene fragments were amplified and products were screened by terminal restriction fragment length polymorphism (T-RFLP) analysis. Among 146 different T-RFs identified, fourteen were dominant and together

made up more than 65% of all detected fragments. While SC groups did not relate to whole *nirK* communities, soil attributes The outcome of the study suggests that the use of SC groups be useful to track the functional development of created mitigation wetlands.

Keywords: denitrifying bacterial community, wetland soil development, T-RFLP, qPCR, wetland functions

Mitigation wetlands are created and/or restored as a result of the national policy of ‘no net loss,’ which mandates the amelioration of the loss of wetland services through creation, replacement or enhancement (34). The degree to which this policy has been effective is debatable, with many studies indicating a mixed record of successful functional replacement (2, 52). Wetland soils serve as sites of important biogeochemical reactions that contribute to the myriad ecosystem services for which wetlands are recognized (e.g. nutrient cycling, water quality improvements, and pollution control). The degree to which soil composition (i.e. soil organic matter, total organic carbon and total nitrogen contents) begins to resemble natural soils (e.g. soil development) in created wetlands may influence biogeochemical processes, thus affecting the ability for created wetlands to regain lost wetland functions.

Created and restored wetlands tend to show lower levels of organic C and N, higher bulk densities and lower productivity than their natural counterparts (8,14, 20). Still, in most cases of wetland mitigation, vegetation has been used as the sole measure of mitigation success (7, 42). Relying on vegetation alone leaves out the role of soil physicochemical (e.g. soil moisture, pH, C content) and biological (e.g. bacterial communities) attributes in the functional development of wetlands. Soil organic matter (SOM) and carbon in particular are considered the main drivers of biogeochemical processes in wetlands (50). SOM provides the energy source and nutrients necessary for bacterial growth that can directly limit or enhance the development of ecological functions (43, 50). The ability of wetlands to support diverse metabolic and catabolic processes depends on the ability to support anaerobic and aerobic environments (35), which are directly affected by SOM and the resulting water holding capacity (16, 50).

Denitrification is one of the key ecological functions of natural wetlands extensively studied (23, 26, 31). It is a dissimilatory metabolic process that integrates a series of reductions to convert nitrate (NO_3^-) to dinitrogen (N_2), resulting in a loss of fixed nitrogen from the system. The initial reduction from NO_3^- to NO_2^- is facilitated by the synthesis of nitrate reductase under anaerobic conditions and with the presence of NO_3^-. Subsequently, NO_2^- can be reduced to NO, then N_2O and finally to N_2. The last three products being gases, released to the atmosphere at rates dependent on the efficiency of the denitrification processes, are important to water quality functions and climate change implication of wetlands. The coupled biogeochemical reactions are carried out by different members of the microbial community. Denitrifying bacteria play a significant role in the denitrification function of wetlands (23). It is known that denitrifiers constitute a taxonomically diverse functional guild with members belonging to all three domains, including more than 60 genera of bacteria, and they can represent up to 5 % of the total soil microbial community (19). Numerous studies have investigated the factors controlling denitrification in an attempt to better understand the process, mostly focusing on the roles of NO_3^- availability, O_2, and pH (22, 45, 48). These are the key regulators of denitrification rates at any particular instance. Recently, the assumption that the composition of the denitrifying community is of minor importance in controlling denitirification has been challenged by Cavigelli and Robertson (11), and Holtan-Hartwig et al. (29), which suggested that denitrifier communities vary in their tolerances to environmental conditions and stresses. Therefore, denitrifying bacterial communities may act as a medium through which environmental controls on denitrification are realized. However, little is known about the structure of denitrifying bacterial community composition and abundance as affected by soil properties.

With increasing age and additional plant growing seasons, the soil properties of a created wetland should mature and develop. An excellent indicator of soil development and quality is SOM content (8, 30), as it is a major source of nutrients (especially N) (40). SOM provides both organic N, the substrate of mineralization, and organic carbon, which is a required energy source of both mineralizing and heterotrophic denitrifying microbes (4, 23, 26). Wallenstein and others (46), in a literature review of environmental controls over denitrification, noted that C availability, pH, moisture and temperature are key factors in determining denitrifying community structure. Specifically, it has been suggested that increased soil organic carbon can be associated with bacterial diversity and may control the enzymatic/metabolic rates of the bacterial communities responsible for N processing (1, 16).

We studied the effects of soil development on denitrifying bacteria structure in created and natural wetlands in the Piedmont region of Virginia. Specifically we hypothesized that soil conditions (i.e., development and/or maturation) in created wetlands would be related to the abundance and genetic heterogeneity of bacterial nitrite reducers, the first constituents of the denitrification process that produce a gaseous product, thus removing N from wetlands. The understanding generated by this study will be useful in enhancing the chance of success for ‘functional’ wetland mitigation for future efforts.

MATERIALS AND METHODS

Site descriptions. Five non-tidal freshwater wetlands located in the Piedmont physiographic region of northern Virginia were chosen for this study (mean annual precipitation 109 cm, mean temperature min 7 ºC/ max 18ºC). Three of the wetlands are mitigation wetlands created by Wetland Studies and Solutions Inc. (WSSI) on old farmland with a predominantly herbaceous cover. The other two are natural wetlands and include bottomland riparian forested wetlands and open herbaceous wetlands.

All created wetlands contain at least a 0.3 m low permeability subsoil layer covered with the original topsoil from the site that was supplemented with commercially available topsoil to a depth of 0.2 m. This design creates a perched, precipitation-driven water table close to the soil surface and limits groundwater exchange in the wetland. Loudoun County Mitigation Bank (LC) is a 12.9 ha wetland and upland buffer complex, constructed in the summer of 2006 in Loudoun County, Virginia (39º1′ N, 77º36′ W). LC receives surface water runoff from an upland housing development and forested buffer, as well as minor groundwater inputs from toe-slope intercept seepage. LC consists of two wetland basins (LCs 1 and 2). LCs 1 and 2 are two contiguous sites separated by a berm and connected by a drainage channel with LC1 approximately 0.4 m higher in elevation than LC2. This design causes LC1 to drain more quickly leaving it inundated for shorter periods after precipitation than LC2, while LC2 can remain under standing water (e.g., < ~12 cm) for longer periods. Bull Run Mitigation Bank (BR) is a 20.2 ha wetland and upland buffer complex, constructed in 2002 in Prince William County, Virginia (38º51′ N, 77º32′ W). The site may receive water from Bull Run from a culvert structure that routes water via a central ditch through the wetland, as well as overbank flow from Bull Run, which sharply bends around the corner of the site. The wetland receives limited surface water runoff from wetlands and negligible groundwater. North Fork Wetlands Bank (NF) is a 50.6 ha wetland, constructed in 1999 in Prince William County, Virginia (38°49 ′ N, 77°40 ′ W). With the exception of minor contributions from toe-slope intercept seepage, the site is disconnected from the groundwater by an underlying clay liner. Study plots were located in two created hydrologic regimes: main pod area-fed by upland surface water runoff and a tributary of the North Fork of Broad Run that is controlled by an artificial dam; and vernal pool area - located in the south west quadrant of the wetland and fed solely by precipitation. All Vegetation in LC1, LC2 and BR is mostly herbaceous, interspersed with young tree saplings and shrubs in projected forested areas. NF vegetation includes diverse wetland herbs, shrubs, trees and submerged and floating vegetation supported by the varied hydrology. The tree communities are established and in some instances include communities extant at time of wetland creation.

Manassas National Battlefield Park (BP), is a 2,000 ha site with areas of natural wetland coverage located in Prince William County, Virginia (38º49′ N, 77º30′ W). Study plots were located in an area of herbaceous wetland within a matrix of forested floodplain. The site is connected to Bull Run by a culvert on its eastern end and also receives groundwater and upland surface water runoff. Vegetation is mostly herbaceous with a few mature trees interspersed throughout. Banshee Reeks Nature Preserve (BN) is a 290 ha site with areas of seep and riparian wetlands located in Loudoun County, Virginia (39º1′ N, 77º35′ W). These floodplain riparian wetlands receive water from groundwater springs, surface water runoff, and occasional overbank flooding from Goose

Creek. Vegetation is a mixture of herbaceous plants dominated with mature wet bottomland forest.

Soil sampling. Soil samples were collected on four dates: October and December 2010 and April and June 2011. A total of 16 study plots in the created wetlands (e.g., LC, BR and NF) and 4 plots in the natural wetlands (e.g., BN and BP) were selected. Each plot was 100 m^2 (e.g. 10 m x 10 m) and was divided into four (e.g. 5 x 5 m) quadrants. Within each quadrant, three soil samples were taken at the depth of 5-10 cm from the top by use of an auger (1 1/4" diameter) at random and combined in a polyethylene bag. All samples were kept in a cooler with ice packs to slow bacterial activity until further processing in the laboratory. At the laboratory, each bag was homogenized manually to mix all three samples for each quadrant. Any visible root or plant material was manually removed prior to homogenization.

Soil physicochemical analyses. Sub-samples taken for SOM, total organic carbon (TOC), total nitrogen (TN) and pH were air dried. Once air dried, soils were macerated using a mortar and pestle and any large constituents (e.g. rocks and large organic debris) were removed. A Perkin-Elmer 2400 Series II CHNS/O Analyzer (Perkin-Elmer Corporation, Norwalk, CT, USA) was used to analyze percent TOC (~TC) and percent TN. Sub-samples (2-3 grams of air dried soil) were separated for SOM, loss on ignition (LOI) method, and oven dried at 105 ◦C for 24 hours, weighed and placed in 405 ◦C for 16 hours. SOM was calculated as the difference between the dry soil mass and the mass of the soil after oxidation of organic matter [(dry mass – ovened at 405 ◦C mass)/(dry mass) x 100] (5). For gravimetric soil moisture (GSM), field-wet mass was measured and samples dried at 105 ◦C for 48 hours. GSM was calculated by: [(wet mass – dry mass)/(dry mass) x 100] (41). For pH determination, 10 g air dried soil samples were combined with 10 mL of deionized water, swirled and left to stabilize for 10 minutes prior to measurement (44). Bulk density (D_b) was measured once during the study period in November 2010. D_b was determined by collecting 5 cm by 10.2 cm cores, weighing the entire field-moist core, converting to dry weight based on GSM percentage, and dividing by the total volume of the soil in the core (200.2 cm^3)

Microbial Community Analyses

Extraction of DNA. DNA was extracted from approximately 0.5-1 g of soil per sample using the UltraClean® Soil DNA Isolation Kit (MoBio Laboratories, Solana Beach, CA, USA) and following manufacturer's instructions. Extractions were quantified using the NanoDrop 1000 Spectrophotometer (Thermo Fisher Scientific, Willmington, DE, USA).

PCR amplification of *nir* fragments. Bacterial *nirK* gene fragments were amplified using primer pairs F1aCu - R3Cu (approximately 470 bp) developed by Hallin and Lindgren (24). The forward primers (F1aCu) were 5'-end FAM labeled (Operon Inc.). PCR amplification was done with 50-uL reaction mixtures in 0.5 mL Eppendorf tubes. Each reaction contained 1 uL of extracted DNA, 1.25 U of GoTaq® polymerase (Promega, Madison, WI, USA), manufacturer's reaction buffer containing 25 mM MgCl2, 2.5 mM of each deoxynucleotide triphosphate, 1.2 ug/uL non-acetylated BSA, and 20 uM of each primer. The PCR was run in a Mastercycler® gradient cycler (Eppendorf, Hamburg, Germany) with an initial denaturing step of 4 min at 94C; 35 cycles of denaturation at 94C for 30 s, primer annealing at 59C for 1 min, and extension at 72C for

1 min; then a final extension at 72C for 7 min. Products were confirmed by electrophoreses of 5uL of each reaction on 1% agarose gel.

Amplification of *nirS* gene fragments was attempted by PCR using primer pairs F1acd-R4cd (24), and also primer pairs nirS11f-nirS6R developed by Braker et al. (6). These amplifications yielded strong products for the positive control (*Pseudomonas stutzeri*), but faint if any amplification products in environmental samples. Since *nirS* gene abundances were below our detection limit, we focused on *nirK* gene amplification products for the study.

Terminal Restriction Fragment Length Polymorphism Analysis. Screening of the nitrite reducing bacterial communities was done by terminal restriction fragment length polymorphism analysis (TRFLP). Amplified *nirK* fragments were digested with *HaeIII* (New England BioLabs, Beverly, Mass., USA) restriction endonuclease enzyme for at least 4 hours at 37C. Aliquots (2-4 uL) of each digest were mixed with 12 uL deionized formamide and 0.5 uL of GeneScan-ROX500 (Applied Biosystems Instruments, Foster City, CA, USA) size standard. Mixtures were denatured for 3-5 min at 93C in and snap cooled on ice for 2 minutes. Fragment lengths were determined by using an automated DNA sequencer, model ABI 310 (Applied Biosystems Instruments, Foster City, CA, USA). The fluorescently labeled fragments were detected and analyzed by the GeneMapper® v4.1 (Applied Biosystems Instruments, Foster City, CA, USA) software. Terminal restriction fragment (T-RF) peaks from all samples were aligned using the interactive binner script (38) for R statistical software environment. T-RFs were only considered if sized between 50-400 bp with relative abundances greater than 1%. Most samples yielded detectable amounts of *nirK* gene fragments, except for samples collected in June 2010 for LC1 and BP.

Quantification of nirK gene copies. Quantitative PCR (qPCR) assays were used to quantify the abundance of *nirK* gene copies within soil bacterial communities. QuantiTect® SYBR® green PCR kits were used in 25 uL reactions containg 0.6uM of each primer, quantitect SYBR green PCR master mix, and 1 uL of DNA template in a Stratagene MX3000P thermal cycler (Agilent Technologies, La Jolla, CA, USA). Run conditions included an initial denaturing step of 15 min at 95C; 45 cycles of denaturation at 95C for 30 s, primer annealing at 55C for 30 s, and extension at 72C for 1 min; then a final cycle of 95C for 30 s, 55C for 30 s and 95C for 30 s. Standard curves were obtained with serial plasmid dilutions of a known amount of plasmid DNA containing a fragment of the *nirK* gene. Inhibitory effects of coextracted substances were tested by spiking one of three replicates with the 1e2 plasmid serial dilution to confirm amplification of correct abundances.

Data analyses. Soil condition (SC) groups were determined by cluster analysis at 70% similarity of soil physicochemical parameters that included pH, GSM, Db, TOC and TN. Statistical significance of the SC groups was verified by applying a similarity profile test (SIMPROF) which performs permutation tests at each node of the cluster analysis dendogram. SIMPROF thus determines whether each cluster set has significant evidence of a multivariate pattern different from the rest (13). We compared physicochemical and nitrite reducer community assemblages using multivariate analysis of similarities (ANOSIM) (1, 13). Additionally, principal component analysis (PCA) was used to visualize ‘best fit’ of plots along soil physicochemical properties and temperature gradients. All test described thus far were performed using PRIMER 6, version 6.1.5 (Primer-E Ltd., Plymouth, United Kingdom). PCA-generated principal coordinates were used for further analysis in bivariate regressions. Shannon–Weiner's diversity index (H') was calculated based on the observed fragments generated by T-RFLPs of the wetland soils. Where H' is equal to ∑[pi (ln pi)] and pi is the peak area (i.e., relative abundance of a particular T-RF) in the ith observed taxonomic unit (OTU) (e.g. base pair length at which T-RF is detected).

Analysis of variance (ANOVA) was used to compare soil physicochemical variables, T-RF diversity and *nirK* gene copies abundance between soil condition groups. Dunnett's posthoc tests for uneven variances were carried out for each ANOVA to determine between-group differences. Bivariate regressions of soil properties and *nirK* abundances were performed to confirm significant relationships between factors. ANOVAs and regressions were conducted using SYSTAT 12 (Cranes Software International Ltd).

Redundancy analysis was performed on denitrifying bacteria community composition based on *nirK* gene T-RFLP. Soil physico-chemical attributes used for redundancy analysis (RDA) included pH, SOM, TOC, TN, GSM and temperature (C). RDAs were carried out using CANOCO, version 4.5. (Biometrics-Plant Research International, Wageningen, Netherlands). The significance of the relationships between the soil physicochemical variables and the T-RFs were calculated by use of Monte Carlo permutations and $p<0.05$ were considered non random.

RESULTS AND DISCUSSION

Development of soil properties. Soil properties were found not to be solely defined by the age of the wetland or even necessarily homogeneous within each site (Table 1). SOM and TN were significantly higher in the forested natural wetland (BN), the oldest created wetland (NF) and one of the youngest created wetlands (LC1) with SOM contents of 4.1% up to 5.6% and TN from 0.24% to 0.48%. The same trend was found for TOC and GSM content, with the exception of NF which showed a non-significant higher content than BR, BP and LC1. Soil pH values ranged from 4.2 to 6.5 with NF containing the highest and BP the lowest values.

Soil properties develop through the accumulation of SOM which is closely associated to age related factors such as seasonal plant senescence (2). However, age based soil development trajectories have been found to be highly variable and not predictive of plant community development (18). SOM accumulation can vary due to variables that may facilitate or impede autochthonous (e.g. seasonal plant senescence) and allochthonous or allogenic (e.g. sediment brought by flooding or runoff) sources of organic matter. The construction process itself can compact soils increasing Db and decreasing microtopography leading to a loss in water holding capacity and loss of SOM (33). Therefore comparison of soil development within and between wetland sites may be better achieved by identifying soil attributes that contribute to soil development. Accumulation of SOM, TOC, and TN along with the resulting lower Db and increased GSM have been identified as structural attributes correlated with increased plant (18) and biogeochemical productivity (50).

We compared plots from four created and two natural wetlands by grouping them along a soil condition gradient. SC groups were identified by cluster analysis of all plots discriminated by five easily measured soil physicochemical properties; pH, GSM, Db, TOC and TN. SC groups effectively discriminated plots according to progressive soil development/maturation (e.g., SC1 < SC2 < SC3), irrespective of site (Table 1). SOM ranged on average from 3.2% in SC1 to 5.0% in SC3 and was significantly different for each group ($p<0.01$). While TOC and TN are closely related to SOM, there was no difference in TOC and TN contents between SC1 and SC2 ($p>0.05$). TOC and TN were highest in SC3 ($p<0.05$) which on average had contents of 2.0% and 0.2% respectively (Table 1). Db and GSM followed a similar pattern indicating that SC1 was the least mature group having higher Db ($p<0.01$) and lower GSM ($p<0.01$; Table 1). These values indicate mineral soils and are comparable to young (e.g., < 20 years old) created wetlands in Virginia (TOC 0.3-4.0%) (33), North Carolina (SOM 0.6-4.03, Db 0.99-1.64 $g^{-1}cm^{3}$) (8), and New York (SOM 6.2%, Db 1.1 $g^{-1}cm^{3}$) (2). Natural wetlands were also included in the SC groups and while SOM and TOC contents are lower than reported in Pennsylvania (SOM mean 11.5%) (10) and Maryland (TOC mean 5.7%) (28) they were comparable to other Virginia natural sites (0.7-7.7%) (33).

Seasonal variability was observed in SOM with October and December having a significantly higher content than April and June (Table 2). TOC followed a similar trend with the exception of October not being significantly higher than April and June. TN contents were highest in June and lowest in April with no significant difference between October and December (Table 1). GSM measurements ranged from 29% to 40% with December and April significantly wetter than October and June (Table 2). However, all the differences observed in the variables seemed within the ranges of natural variation, based on several studies conducted on the same wetlands as investigated in this study (see 1, 18, 33, 50). Temperatures ranged on average from 1.3 C in December to 20.5 C in June.

Abundance of nitrite reducers among SC groups. Denitrifying bacterial community abundances were assessed by quantifying the number of *nirK* functional gene copies per sample. *NirK* gene copies ranged between 3.6 x 10^4 and 3.4 x 10^7 copies g^{-1} soil. To account for any differences in biomass between samples, we also calculated the abundance of copies normalized to the amount of extracted DNA. The gene copy numbers ranged from 1.2 x 10^2 to 4.4 x 10^3 copies ng^{-1} extracted DNA. It is difficult to find comparable studies in wetland soils quantifying *nirK* genes, however our gene copy abundances were lower than those published for a paddy field in Taoyuan, China (2.0 x 10^8 to 2.4 x 10^8 copies g^{-1}) (12) and riparian soils in Thomas Brook watershed, Canada (2.2 x 10^9 copies g^{-1}) (15). Other more comparable values were found in studies looking at *nir*K gene copy abundances in various soils (9.7×10^4 to 3.9×10^6 copies g^{-1}) (25) and organic humus in south Bohemia (2.7 x 10^4 to 1.2 x 10^6 copies g^{-1}; 3).

Abundances of *nir*K gene copies, whether calculated per gram soil or per ng of DNA, were greater in the plots with greater SOM, TOC, TC, GSM and lower D_b when comparing soils of similar pH (Table 1). SC3 plots had the highest abundance (*p=0.02*) followed by SC1. Denitrification is a facultative process that requires anaerobic conditions, such as those observed in inundated soils. The more developed SC plots have higher levels of SOM which not only provide an energy source but also can contribute to lower Db. The lower Db in turn increases pore space that allows for greater water retention and may lead to higher GSM. The resulting soil matrix is better able to maintain anoxic conditions, that may be able to give an advantage to those bacteria that are able to use an alternate (i.e. NO^{-}_{2}) terminal electron acceptor than O_2.

When pH was considered, the lowest *nirK* gene abundances occurred in soils with higher pH; SC2 contained an order of magnitude less gene copies than either SC1 or SC3 (Table 1). SC2 SOM and GSM contents were higher on average than SC1, yet this group contained the lowest number of *nirK* gene copies (Table 1 ; $p<0.01$). However, the relationship between higher pH and low copy numbers was not limited to SC2 plots, a bivariate regression of pH and *nirK* abundances supports that our soils have a negative relationship with increased pH ($R=0.27, p=0.03$). pH has been extensively researched as an environmental factor affecting bacterial communities (21, 32). Among the few studies that have specifically linked *nirK* communities to pH, Barta and others (2010) found that *nirK* gene abundances had a positive relationship with pH. Furthermore, they found that in Bohemian Forest soils the lower threshold was a pH of 5. Our data show that this relationship may not apply consistently observed to all soil types and may point to adaptations to the lower pH by soil denitrifying communities (46). In fact, the effect of pH is not necessarily a direct one on the denitrification processes, and may be more related to other environmental and biological factors (39). For instance, the availability of organic carbon and other nutrients can be diminished in acidic environments, leading to lower energy source and reducing the activity of the heterotrophic microbial community as a whole and the denitrifying community in particular (39). Finally, we have to consider a significant limitation of this study, where we focus on bacterial nitrite reducers, which constitute one group that perform one intermediary step in the whole denitrification processes. Studies have linked lower pH levels to a higher ratio of N2O:

N_2 when measuring denitrification yields (9, 17). Therefore, the low abundance of *nirK* genes in NF may indicate a higher community composition of denitrifiers that convert N_2O to N_2.

To further link the relationship between nitrite reducers and soil condition groups we looked at the PCA of physicochemical attributes (Fig. 1) which clearly demonstrated SC groupings. Forty seven percent of all the variation between plots was explained by PC1, which was negatively related with SOM, TOC, TN and GSM (Fig. 1). PC1 was also negatively correlated with *nirK* abundances (*adjusted* $R=0.318$, $p<0.01$), indicating that as SOM, TOC, TN and GSM values increased so did the nitrite reducing community. PC2 was negatively correlated with pH and temperature and was not significantly correlated to *nirK* gene abundances (*adjusted* $R=0$, $p=0.63$). The effect of temperature can be appreciated by looking at changes in the abundances of the *nirK* gene copies over the four different sampling periods (Table 2). April has the lowest abundances ($p<0.01$), but by June these are higher yet still not significantly different from those in October and December. A cyclical pattern may exist where growth is maximized at the end of the growing season, after a period of higher temperatures. That is, there could be a time lag in response of *nirK* bearing community to temperature changes, whereby the effect of higher temperature causing increased abundance is not observed until June (rather than in April), and similarly, the effect of lower temperature causing decreased abundance is not observed until December (rather than October) and lowest in April (Table 2). Since gene copy numbers do not measure activity and denitrification is a facultative process, the abundance of nitrite reducers is not in and of itself indicative of functional development. However, the abundance of a functional gene (e.g. *nir*) in a community may be used as a baseline for comparing potentials for functional development. Relating the abundances with SC attributes further can indicate a link between the soil structural controls and their effect on functional development. Nitrogen flux rates for example can increase with soil structural measures equivalent to SC (50). The increased nutrient availability and energy source in soils with higher SOM content, along with moisture retention that enable lower redox potentials, do affect potential denitrification rates (50). Our results show that nitrite reducers are responsive to soil development, (e.g. increased SOM, TOC, TN and GSM and lower Db) and their abundance may serve as good surrogates for functional development in terms of N cycling in created wetlands.

Denitrifying community diversity and structure among SC groups. The denitrifying bacterial communities from plots classified by one of the three SC groups were evaluated by T-RFLP analysis of the amplified *nir*K gene fragments. We detected a total of 146 different T-RFs in all of the samples. The average numbers of fragments observed in each group were 131, 99 and 110 for SC1, SC2 and SC3, respectively. Nitrite reducer community structures were not explained by SC groupings (ANOSIM *Global* $R=0.046$, $p=0.1$). In contrast, differences were detected by sampling period (ANOSIM *Global* $R=0.23$, $p=0.01$). Eighty-seven T-RFs were detected in October, 93 in December, 129 in April and 56 in June. Of these only 34 T-RFs were detected in all sampling periods. The greatest differences were between April and June (*ANOSIM* $R=0.39$, $p=0.01$). Comparable temporal variations in *nirK* community structures have been identified in arable soils (51) and a wetland mitigation bank in Illinois (36). The temporal variability indicates greater sensitivity of the *nirK* communities to seasonal factors such as soil temperature, soil moisture and nutrient inputs that may vary seasonally.

Diversity values ranged from 2.7 to 3.2, no significant difference was found by SC (Table 1). These values are lower than a comparable study using T-RFLPs to assess *nirK* gene diversity in marsh (H' = 3.6) and upland (H' = 4.4) soils in Michigan (37). Admittedly the comparison is somewhat limited due to the range of primers and methods used to study denitrifying bacteria communities. While no significant differences were found between SC groups, the average values were higher in SC3 than the other two groups (Table 1), indicating mature soil structure might support higher diversity of denitrifying bacterial community. Temporal variations in diversity were observed in April and June, which both the highest and lowest H' values, respectively (Table 2). The lower diversity in June was also affected by the exclusion of LC1 and BP as these soils did not produce PCR products (e.g. *nirK* gene fragments). April diversity values were affected by an increased number of fragments that had very low relative abundances (data not shown). H' is considered a useful diversity index that takes into account richness and evenness; however it is known to be more sensitive to the variability in abundance of rare groups (27). Therefore, although the April diversity values are significantly higher than other sampling periods, we have to be cautious of the extent to which the rare groups may contribute to overall structure.

Considering the effect of rarer species on diversity values we identified fourteen T-RFs, from the 146 detected, which together made up more than 65% of all detected T-RFs. Dominant T-RFs did correspond to four main factors; 1) pH, 2) TN, 3) temperature and 4) GSM, SOM and TOC (Fig. 2). Specifically we found three fragments (e.g., T-RFs-311, 277 and 141) were positively correlated with TN and negatively with pH. While two (e.g., T-RFs 281 and 313) increased in relative abundance with decreasing pH and lower TN. Four fragments (e.g., T-RFs 131, 173, 243 and 337) increased in abundance with increased GSM, SOM and TOC. Four others (e.g.,T-RFs 135, 141, 209 and 275) were positively correlated with temperature (Fig. 2). The importance of dominant T-RFs in *nirK* soil communities was explored by Wertz and others (2009) in Canadian agricultural soils. The study compared whole and active (using mRNA transcripts from entire community) *nirK* community composition, concluding that the active portion was relatively stable and more abundant in all sampled soils (49). This kind of variations in *nirK* community structures have also been observed in stream sediments along an urbanization gradient (47). Another study revealed *nir*K (and *nos*Z) community shifts in stream sediments along a disturbance gradient created by urbanization (e.g. percent impervious cover and water quality indicators), as measured by TRFLP community analysis (47). This can be seen as somewhat analogous to results here. Some of the same physicochemical constituents important to the dominant TRFs in our study, and which may be different in constructed versus natural wetlands, and differing soil conditions, such as TN, TOC, and pH, are also those that changed with urbanization. All of these studies show that *nirK* bearing denitrifiers respond to physicochemical changes in the environment, making *nirK* community structure assessment a useful tool.

Relative abundance shifts of the dominant T-RFs were apparent by SC groups and sampling period (Fig. 3). Two dominant fragments (e.g., T-RFs, 277 and 275) had higher relative abundances in SC1, while two others (e.g., T-RFs 209 and 173) had lowest abundances in this group. SC2 plots collectively had lower abundance of four dominant fragments (e.g., T-RFs 135, 275, 279 and 281) and highest of fragment 119. SC3 had the most evenly distributed abundance profile and had the highest abundance of T-RF-135

(Fig. 3). Sampling period also played somewhat a role in dominant T-RFs composition. Two, 119 and 281 bp, were relatively higher in April. Eight dominant T-RFs (131, 135, 173, 209, 243, 275, 313 and 337) had higher relative abundances in October and December (Fig. 3). These results highlight the relationship between soil development and the structural characteristics of a biological component of the denitrification process. Denitrifier communities in the wetlands studied seem to be dominated by a few members that respond to soil physicochemical attributes.

CONCLUSIONS

We investigated a subset of soil denitrifying communities (e.g., nitrite reducers) and soil properties in created and natural non-tidal freshwater wetland soils in Virginia. Soil condition groups classified study plots according to increased soil development using five easily measured physicochemical attributes; TOC, TN, Db, pH and GSM. SC groups in turn had significant relationships with nitrite reducers in terms of abundance with its greater abundance associated with mature soil properties. While SC groups did not relate to whole *nirK* communities, soil attributes that identified SC groups did significantly correlate to dominant members of the community. Furthermore, this study highlights the need for further study of the relationship between the different constituents of denitrification and soil pH. The outcome of the study suggests that soil properties and their maturation are to be used in post-construction monitoring to better assess functional development of created mitigation wetlands.

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USGS Award # G11AP20207 Modernizing U.S. Army Corps of Engineers Planning and Regulatory Policies and Programs Phase IV

Basic Information

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Principal Investigators:	Stephen H. Schoenholtz, Leonard Shabman

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There are no publications.

Modernizing USACE Planning and Regulatory Policies and Programs – Phase IV

Dr. Shabman participated in the design of an educational workshop on the permitting of water supply projects under Section 404 of the Clean Water Act, held in Atlanta GA in February 2012. He made two presentations at the workshop and prepared one background paper.

The paper might be available as a part of the IWR published workshop report in fall 2012.

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February 2012

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A Conceptual Framework for U.S. Army Corps of Engineers Water and Related Land Resources Implementation Studies

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Visiting Scholar Program

Throughout its history, the Institute for Water Resources (IWR) has invited preeminent water resources academicians and practitioners to take up residence at the Institute to foster scholarly exchange. At any given time, IWR frequently has faculty from universities spending time in residence at the Institute. Both IWR and the Corps benefit from such faculty engaging in ongoing water resources studies and research on a reimbursable basis. Visiting scholars are expected to help infuse new energy and ideas to the IWR program, while the practical work environment at IWR and/or the Hydrologic Engineering Center (HEC) provides a stimulating context for mutual exploration of potential advances in hydrologic engineering and planning analysis. Such experiences have proven to be intellectually invigorating for both the Institute staff and the visitors themselves.

American Association for the Advancement of Science
Science and Technology Policy Fellows Program
Through the American Association for the Advancement of Science (AAAS) Science and Technology Policy Fellows Program, IWR sponsors post-doctoral and senior fellows to work on water resource policy issues such as analyzing the linkages between water resources development and water resources problems (e.g. drought, floods) and the economies of developing nations. Individuals with a systems engineering, economics, public participation or water resources background are especially encouraged to apply. This highly selective fellowship program gives scientists and engineers a real-world introduction to how science interacts with policy in Washington.

Leo R. Beard Visiting Scholar Program
For many years, the Hydrologic Engineering Center (HEC) has invited prominent hydrologic and hydraulic professionals to take up residence at HEC in Davis, CA to foster scholarly exchange. Faculty from a number of universities have spent some of their sabbatical with HEC and on occasion HEC has also had prominent engineers from other agencies join the Center in the same capacity. The experience and the exchange of ideas that these scholars bring to HEC have proven to be intellectually satisfying and productive for both HEC staff and the visitors themselves. Such scholars in residence are known as "Leo R. Beard Visiting Scholars."

Maass-White Visiting Scholar Fellowship
The Maass-White Visiting Scholar Fellowship is designed to ensure that today's water resources challenges benefit from innovative thinking of the nation's top academics, and to promote a deeper understanding of real-world water resource problems by those in academia. The fellowship honors the late Arthur Maass and Gilbert F. White–two scholars who had a revolutionary impact on the practice of water resources planning and management.

National Research Council Research Associateship Program
Through the National Research Council (NRC) Research Associateship Program, IWR sponsors postdoctoral and senior research awards to conduct relevant research for one to two years at one of IWR's locations. Fellowships are given for the purpose of conducting research (chosen by the doctoral level scientists and engineers) to apply their special knowledge and research talents to areas that are of interest to them and to the host laboratories and centers.

UCOWR Water Resources Fellowship
The Universities Council on Water Resources (UCOWR) and IWR developed a visiting scholar program in 2003. The program invites academicians to the Institute to focus on emerging water resource issues of relevance to the civil works mission. While on sabbatical these scholars are expected to perform applied, policy-relevant research to extend the Corps of Engineers knowledge of and thinking about emerging water resources needs and issues. UCOWR Fellows, chosen via a UCOWR/Corps panel, are university professors who have substantial applied experience in water resources planning and management, as well as strong teaching credentials.

Lieutenant General Frederick J. Clarke Fellowship
Lieutenant General Clarke (Chief of Engineers 1969-1973) was instrumental in securing expert, independent advice on environmental issues facing the Corps by founding the Environmental Advisory Board (EAB). The Corps plays an increasingly important role in many of the most profound environmental issues faced by our nation's water resources. The Clarke Fellowship recognizes that USACE will need the advice of our nation's brightest scholars to ensure that these environmental issues are tackled with the utmost skill and understanding. The fellowship provides scholars with the opportunity to engage with and advise USACE leaders on important policy issues related to their environmental mission. Clarke Fellowships are awarded to researchers who have demonstrated scholarship in the areas of environmental quality and policy analysis in water resources planning.

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2012-VSP-01

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This report does not reflect policy development by the U.S. Army Corps of Engineers, and its publication does not represent any official position or policy of the Executive Branch, Department of the Army, U.S. Army Corps of Engineers, or IWR, nor does it imply any endorsement of the report contents by those entities. The report reflects the views of the authors alone and is written in the form and structure of current Corps planning guidance in order to help readers to identify how and where IWRM principles could be woven as an integrated process into the Corps planning framework.

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Forward

Motivation and Purpose

The U.S. Army Corps of Engineers (Corps) has long been required to demonstrate that its proposed water resource development projects provide net benefits to the nation as a condition for Congressional authorization and funding. The Corps was instructed by the Rivers & Harbors Act of 1902 to show in project planning studies that recommended water resources investments produced benefits that exceeded costs. This general principle was famously reiterated by the Flood Control Act of 1936, which stated:

> "It is hereby recognized that destructive floods upon the rivers of the United States, upsetting orderly processes and causing loss of life and property, including the erosion of lands and impairing and obstructing navigation, highways, railroads, and other channels of commerce between the States, constitute a menace to national welfare; that it is the sense of Congress that flood control on navigable waters or their tributaries is a proper activity of the Federal Government in cooperation with States, their political sub-divisions and localities thereof that investigations and improvements of rivers and other waterways, including watersheds thereof that for flood-control purposes are in the interests of the general welfare; that the Federal Government should improve or participate in the improvement of navigable waters or their tributaries including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected."

Since that time there have been multiple efforts to interpret the Congressional intent within Corps guidance for project planning studies. Perhaps the greatest challenge has been to reflect the concept of multiple objectives (as alluded to in the quotation above) in plan formulation and evaluation. This was a major focus of the Harvard Water Program in the 1960s, and its ideas for multi-objective planning were manifested in Corps planning guidance in the early 1970s under the so-called *Principles and standards for planning water and related land resources*. However, subsequent federal water planning guidance set out in the 1983 *Economic and environmental principles and guidelines for water and related land resources* (P&G) moved away from a multiple objective focus by defining a single federal objective based on national economic development, subject to an environmental protection constraint.

Since publication of the 1983 P&G planning framework, the Corps' role in water resources planning and management has continued to evolve in response to changing public values and program budget levels and priorities, and the cost sharing reforms of 1986. The Corps has made significant changes to modernize its internal plan formulation and evaluation procedures and analytical methods. Perhaps most significant was the creation of planning and analysis procedures to implement a new ecosystem restoration mission, to accompany the Corps' historic responsibilities for enhancing waterborne commercial transportation and flood and coastal storm damage reduction.

Today, the concept of "Integrated Water Resources Management" (IWRM) is being advocated as a better way to approach the challenges of 21st century water management, and many observers have noted that current Corps planning guidance falls short of that ideal. The so-called Section 216 reports from the National Research Council noted the need to re-focus attention in planning studies to multiple objectives and tradeoffs, better account for uncertainty, and accommodate the concepts of adaptive management, stakeholder collaboration, and systems analysis for watershed scale planning and evaluation. Recent literature on “ecosystem services” provided by the natural environment has been offered as yet another concept to be considered in Corps planning. These planning concepts and more are encompassed by the principles of IWRM.

To facilitate movement toward an IWRM focus in Corps planning studies, a conceptual framework is needed that will allow the Corps to review, and as needed modify and extend, its current practices and then organize those practices according to IWRM principles That framework must also accommodate the reality that the Corps remains bound by the particular ways its studies and projects are authorized and funded, which not only circumscribe the missions of the agency, but also affects the ways in which modern planning concepts can be accommodated in plan development and implementation. This framework is offered in order to stimulate discussion and further dialogue on how contemporary concepts of IWRM might be integrated into Corps planning.

The framework contained in this report is written in the form and structure of current Corps planning guidance in order to help readers to identify how and where IWRM principles could be woven as an integrated process into the current Corps planning framework. The conceptual framework was prepared by Leonard Shabman, Resident Scholar at Resources for the Future and Visiting Scholar at the Corps’ Institute for Water Resources (IWR), and Paul Scodari, IWR Senior Economist.

Some Reflections on the Framework

Among the most important challenges faced in revising Corps planning and analysis guidance to reflect contemporary concepts of IWRM are the following:

1. The need for the planning framework to recognize and accommodate the authorized Corps missions and policies (e.g., cost sharing requirements of non-federal project sponsors) that would remain unaffected by any changes to the planning process.

2. The need to better acknowledge and communicate the uncertainties inherent in the analyses that support water resources investment decisions, including possible recognition of multiple possible future “without project conditions.”

3. The need to clearly define the Corps’ role in ecosystem restoration relative to that of other federal and non-federal agencies.

4. The need to clarify the Corps' role in flood risk management relative to that of other federal and non-federal agencies.

5. The need to recognize that multiple decision criteria measured in non-commensurate terms (monetary units, non-monetary quantitative units, and qualitative descriptions) and shared decision-making means that plan selection cannot be determined by applying an analytical algorithm that, through computation, identifies the “best” plan.

6. The enhancement of collaborative planning and shared decision-making will be realized by a) incorporating different agency responsibilities in plan formulation, b) increasing the transparency of the logic and computations in the analysis, and c) assuring that multi-criteria evaluation and

analytical tools (such as monetization of project effects) contribute to reconciliation of disparate views and lead to more expeditious decision-making.

Of particular note is that all of the challenges are treated within the framework as an integrated process as opposed to being addressed as isolated subjects. In fact, the imperative was to have a framework that incorporated the many individual planning concepts central to IWRM, not as a list of considerations, but rather as part of an integrated whole that recognizes interdependencies and has a consistency of definitions. As one example, the framework relates the definition of adaptive management, and where that concept applies in plan formulation, to the ways that uncertainty is addressed in the planning process.

Incorporating IWRM concepts, especially for complex water resources problems, would add to the requirements of a planning study at the same time that there are demands on the Corps for shorter-duration and less-costly studies. Any further development of the conceptual framework must accommodate the need to reconcile the level of detail required by the framework with study time and resource constraints.

Finally, new imperatives for collaborative planning will highlight, not mask, differences among decision participants in the identification of planning problems, opportunities, and preferred solutions. This in turn will highlight differences of view about the meaning of the federal interest and how multi-objective plan formulation and multi-criteria evaluation can be used in federal budgeting decisions and financing responsibilities for the different actions included in a preferred alternative. At the same time, the collaborative planning requirements may demand a new set of skills and new decision processes throughout the Corps hierarchy.

Request for Comments

The conceptual framework is being published as part of IWR's Visiting Scholar Program in order to stimulate thoughtful dialogue and to facilitate the exchange of ideas relevant to integrating contemporary concepts of IWRM into civil works planning guidance and practice. Corps staff, other federal agency and non-federal agency staff, and the general public are asked to share their observations and insights on any part or the entirety of the framework. Submitted comments can relate to the clarity, substance, or workability of the framework or parts thereof. Comments should be submitted electronically to Paul Scodari (paul.f.scodari@usace.army.mil).

In doing so, please note that the publication of this report by IWR does not represent any official policy, position, or endorsement of the report contents by the Executive Branch, Department of the Army, Army Corps Engineers, or IWR.

In reviewing the framework and in consideration of this request for comments, the following additional factors should be kept in mind. First, there is more conceptual thinking behind many sections of the framework than can be fully elaborated on within the framework. Some of that thinking is partially reflected or at least alluded to in the explanatory endnotes as well as in the two issue papers included in the appendices. Therefore, readers are encouraged to consult the framework endnotes and appendices when reviewing the document.

Second, the framework is intentionally Corps-centered, and it is recognized that some have argued that Corps planning need not be constrained by authorized Corps missions and administration budget priorities. Whatever the conceptual merits of this argument, the authorized Corps mission areas need to be highlighted, and the limits of Congressional authorization and the reality of cost sharing with non-federal project sponsors need to be accommodated.

Third, the framework focuses on project level planning, but within a watershed context. The Water Resources Planning Act of 1965, which created the authority for the existing P&G, draws a distinction between Level C (project) and Level B (basin scale) planning. Level C planning is what is addressed by the framework. Programmatic authorizations are more like Level B studies in that they establish the broad guidelines for the Level C planning and project implementation; the programmatic regulations of the Comprehensive Everglades Restoration Plan are an example of how that relationship might work. The possible contribution of this framework to programmatic planning and implementation (a blend of level B and C) has not been addressed here, but could be as logical future actions.

Finally, trends in the relative share of the Corps budget dedicated to construction-general versus operations and maintenance, combined with aging Corps-managed infrastructure and increasing attention to project re-operation and modifications to address emerging problems and opportunities (e.g. sustainable rivers program, water supply reallocation), mean that Corps planning guidance will increasingly be applied to modifications of existing projects as well as to project operations and management. This will increase the need for attention to collaborative planning, because recommended changes will need to take into account and secure agreement from the stakeholders served by the current project operations as well as the beneficiaries of the outcomes associated with potential changes in project operations.

This report should be cited as follows:

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Towards Integrated Water Resources Management: A Conceptual Framework for U.S. Army Corps of Engineers Water and Related Land Resources Implementation Studies

Section 1. Introduction

a. Purpose. This framework is for use by the U.S. Army Corps of Engineers (Corps) in formulating, evaluating, displaying, comparing, and recommending alternative plans in water and related land resources implementation studies. It is to be applied to project-level study authorities for the purpose of determining the federal interest in new and modified water resources investments and operations.

b. Planning resources. This framework requires the practical application of contemporary planning and analytical procedures in hydrology, engineering, economics, planning, the biological sciences, and other natural and social sciences for plan formulation, evaluation, and comparison within the civil works missions and authorities of the Corps.

c. Planning guidance. For purposes of conducting implementation studies, the Secretary of the Army will issue Corps-specific guidance on analytical procedures that that will implement this framework in consideration of:

- Available study times and resources,
- The level of detail in the study reports required for informed decision-making at all levels of the decision hierarchy, and;
- The need to assure the transparency of the analysis to non-federal sponsors and other agencies and stakeholders, and assure their engagement in the planning process at appropriate junctures.

Section 2. Federal Interest Evaluation Criteria

2.1 Primary Evaluation Criteria

The following effects of alternative plans shall be evaluated and used as primary federal evaluation criteria in plan display, comparison, and decision-making:[1]

a. National environmental quality (NEQ) effects. NEQ effects represent the positive and negative changes in the physical, chemical, and biological conditions of the nation's water and related land resources at the watershed scale, as measured in non-monetary units. [2]

b. National economic efficiency (NEE) effects. [3] NEE effects represent the positive and negative changes in the economic value of water and related land resources[4] or the economic value of the national output of goods and services produced using these resources, as measured in monetary units.

2.2 Additional Evaluation Criteria

The following effects of alternative plans will be evaluated and reported as additional federal evaluation criteria in plan display and comparison. The District Engineer may determine that one or more of these additional evaluation criteria are neither applicable nor material for decision-making, but must provide a statement in the report justifying that determination.

a. Public safety effects. These effects represent the effects of flood and coastal storm damage reduction plans, as well as other types of plans when warranted, on the reduction of and remaining risks to human life and safety, as measured in non-monetary units and/or qualitative descriptions.

b. Other environmental quality effects. These effects include effects on significant cultural and aesthetic resources, as well as sub-watershed-scale ecological resources, as measured in non-monetary units and/or qualitative descriptions.[5]

c. Effects on low-income, tribal and minority communities. These effects include the incidence of national economic efficiency effects, national environmental quality effects, public safety effects, and other environmental quality effects—as measured in the units for these evaluation criteria outlined above— on low-income, tribal, and minority communities. These effects also include any employment and income effects on these population groups, as measured in monetary and non-monetary units.[6]

Section 3. Overview of Planning Process

3.1 Introduction

The planning process consists of a series of iterative elements to identify problems and opportunities, to formulate and evaluate alternatives as combinations of water and related land resource management measures that are reasonably expected to address the problems and opportunities, and to display and compare the results of the evaluations of alternative plans. The product of the planning process is analysis and communication of the significant effects of each alternative plan with clarity and transparency sufficient for decision participants and decision-makers to be fully aware of the assumptions employed, the data and information included in the analysis, and the reasons and rationales for their use in analysis.

a. Planning elements. The planning process includes the following analytical elements in support of decision-making:

(1) Specification of the water and related land resources problems and opportunities relevant to the planning setting.

(2) Inventory, forecast, and analysis of current and expected future water and related land resource conditions (that are relevant to the identified problems and opportunities) within the planning area if no Corps civil works action is taken (the future, without-project condition).

(3) Formulation of alternative plans to alleviate problems and realize opportunities.

(4) Evaluation of the effects of the alternative plans on the problems and opportunities and on the federal evaluation criteria, as compared with the without-project condition.

(5) Display and comparison of significant effects of alternative plans to facilitate the selection of a preferred plan.

(6) Recommendation and reporting of a preferred plan

b. Iterative Process. Planning is a dynamic process requiring iteration among the five planning elements that engages all the technical specialists and analysts, those responsible for decision-making, and other relevant agencies and stakeholders. This iterative process may sharpen the planning focus or change its emphasis as new data are obtained or as the specification of problems or opportunities change or become more clearly defined. Consideration of each element in the process may require previous elements to be revisited.

c. Planning results. The study report that recommends a plan that would require Corps budgetary support or changes to existing project operations must a) justify the plan using the analysis of the plan according to the federal evaluation criteria, and b) provide assurances that any measures in the plan that are to be implemented by non-Corps entities (public or private) will be undertaken by those.

3.2 Scoping

There needs to be an early and open "scoping" process as soon as practical after a decision is made to begin planning. This process is complementary with the scoping process described in the CEQ NEPA regulations (40 CFR Parts 1500-1508).

The purpose of scoping is to obtain the perspectives of other agencies and stakeholders and to consider those perspectives in preparing a study plan that identifies a clearly understood and broadly supported focus and scope of analyses to be undertaken in support of decision-making, and ensure that all significant decision-making factors are addressed while avoiding unneeded and extraneous studies. (Section 3.2.1.e. describes the engagement of non-Corps parties in the planning process.)

3.2.1 Major Scoping Factors

Major factors to be addressed in scoping include: planning purpose, planning area, analytical focus and level of detail, accommodation of uncertainty, and engagement with other agencies and stakeholders in planning.[7]

a. Planning purpose. Planning purpose refers to the water resources management problems and opportunities to be addressed in a planning study. The starting point for identifying the planning purpose(s) is the study’s authorizing document, which normally identifies in general terms the area-specific problems and opportunities for study. While there may be a wide range of potential water-related problems and opportunities in any planning area, the Corps must necessarily focus its planning around those problems and opportunities that are consistent with Corps authorities and priority missions.

b. Planning area. The planning area refers to the specific geographic area where alternative plans to address problems and opportunities are formulated and evaluated. The planning area should include the geographic scope necessary for analyzing the nature and extent of problems and opportunities, as well as potential locations of alternative management plans to alleviate problems and realize opportunities (often called “project areas”) as well as the locations of resources and existing projects that would be directly, indirectly, or cumulatively affected by, or that could affect, the alternative plans (often called the “affected area”).

   A systems perspective should be taken to define the planning area.[8] The planning area should be of sufficient size to permit the assessment and evaluation of the hydrologic interactions of a project with other water resources projects and programs. The 8-digit Hydrologic Unit Code should be initially used as the appropriate watershed scale,[9] but planners should assure that the planning area includes potential significant hydrologic interactions of plans with existing civil works projects in other watersheds.

   In some cases, considerations other than hydrologic interaction may contribute to defining the planning area. For example, the planning area associated with inland navigation waterways and related harbors are likely to include the regional transportation sector, including alternate and complementary modes of transportation as well as directly related harbors. As another example, if a wildlife species of interest is identified for management, the relevant eco-region that defines the species habitat throughout its life cycle may not coincide with watershed boundaries.

c. Analytical focus and level of detail. In general, the focus, methods, and level of detail and complexity of planning analyses should be commensurate with the scale, scope, and magnitude of problems and opportunities and expected management effects, budget costs, analytical uncertainties, and levels of stakeholder conflict that might be expected to attend a potential decision. At the same time, the level of detail and complexity in planning analyses must necessarily be scaled to match the available study resources.

d. Addressing uncertainty. An important part of scoping is an initial determination (subject to later revision) of how uncertainty will be addressed in planning.

Uncertainty is the result of imperfect knowledge concerning the present or future state of a system. The concern with uncertainty in civil works planning relates to the "cost" of decision error—that is, while a decision today will be made with the expectation of positive future outcomes, there is the possibility that the decision may prove to have unacceptable future adverse consequences. Adverse consequences are often thought to include, although not limited to, undesired ecosystem changes, loss of human lives, property damages and income losses. In a broader context, adverse consequences also include the commitment of current resources that may not achieve intended results (e.g., navigation investments undertaken today may not realize the projected transportation cost savings because the anticipated increased future navigation traffic never materializes; or actions taken to modify the future structure and functions of an ecosystem may not yield the intended biological outcomes). Therefore, it is not uncertainty itself that is the concern; rather, the concern is about the magnitude of possible future adverse consequences (i.e., costs) from a decision. Two basic sources of uncertainty are:

(1) Knowledge uncertainty. Knowledge uncertainty refers to the confidence in an analytical prediction of a future state of some system. Knowledge uncertainty arises from incomplete understanding of a relevant system as well as modeling and data limitations. Some knowledge uncertainty is reducible in principle with more data and the development of more complete models for data analysis and prediction. However, reducing knowledge uncertainty may require greater costs and time than is available to the study.

(2) Natural variability**.** There is inherent variability in the physical world and this "randomness" is irreducible. In the water resources context, uncertainties related to natural variability include phenomena such as stream flow, assumed to be a random process in time, or soil properties, assumed to be random in space. Natural variability cannot be altered by obtaining more information, although its characterization might improve with additional knowledge. Natural variability is sometimes dealt with by statistical or probabilistic methods. [10]

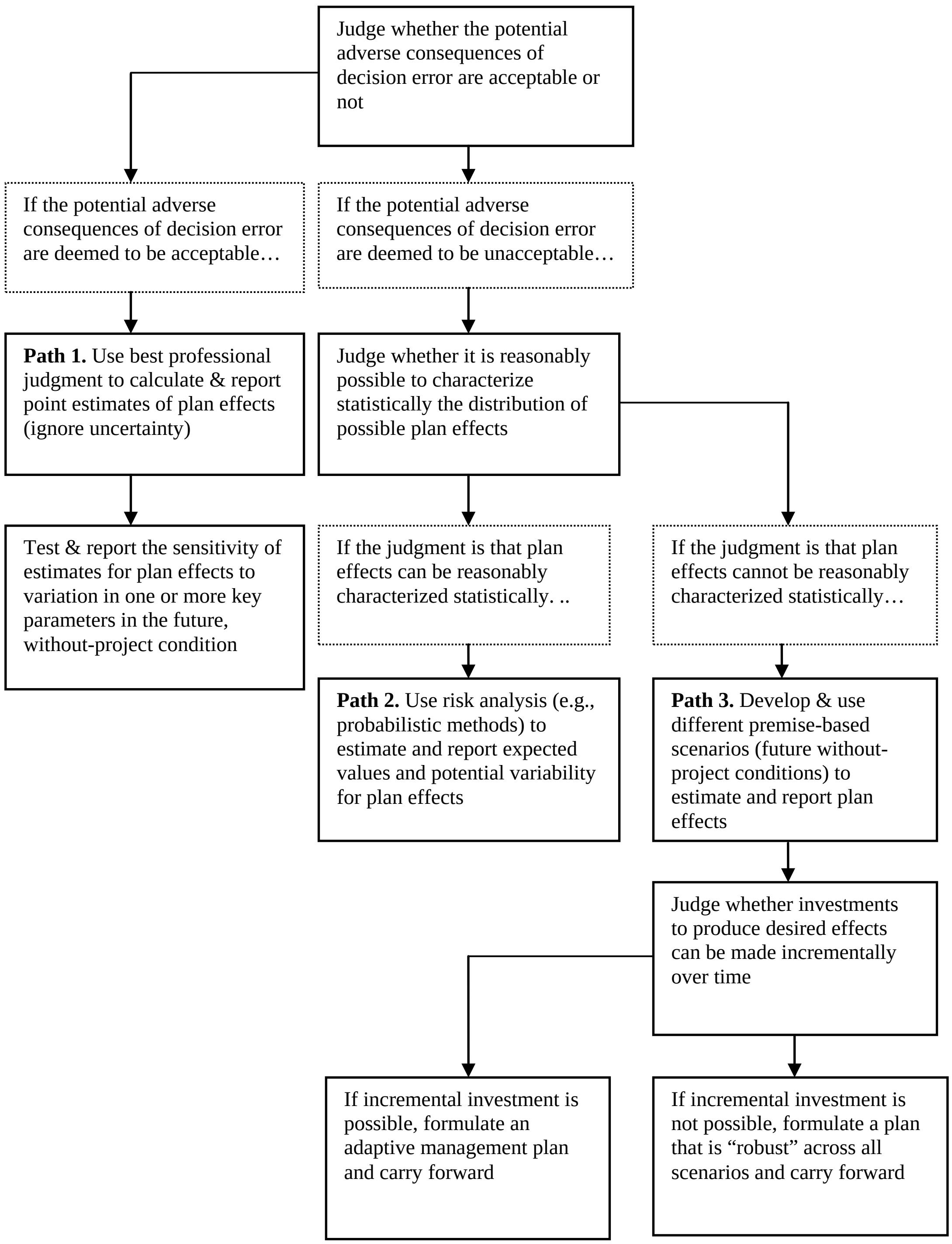
Figure 3-1 illustrates three different paths for addressing uncertainty in planning, and at the scoping stage one path will be selected. As part of the scoping process, and as one basis for choosing a path, an inventory will evaluate the quantity and quality of models and data required for specification of identified problems and opportunities, for forecasting with- and without-project conditions, for identifying potential alternatives for addressing the problems and opportunities, and for evaluating alternative plans. While an initial scoping decision will select one path (in consideration of the necessary level of analysis detail, available resources, and available data and models), at any point in the iterative planning process a decision may be made to shift from the initially chosen path for addressing uncertainty to another path. The District Engineer (DE) in the final report must provide a statement justifying the path chosen.

Path 1: When there is little uncertainty or when the potential future adverse consequences of making a wrong decision are judged to be acceptable, then each planning element will be executed using **best professional judgment** for making point estimates of without-project conditions and with-project plan effects on problems, opportunities, and the federal evaluation criteria.[11] This could be augmented by using sensitivity analysis to identify how estimates of plan outcomes would change with variation in one or more key parameters relating to the estimated future, without-project condition.

Path 2: If the potential adverse consequences of decision error are judged to be unacceptable, but the distribution of possible plan outcomes can be reasonably characterized statistically with available study resources, planning should employ a **risk analysis** framework. Risk analysis will assign probabilities to possible future conditions and outcomes using expert elicitation or statistical data analysis, and report the range of possible outcomes and their likelihoods for the without-project conditions and with-project plan effects on problems, opportunities, and the federal evaluation criteria.

Path 3: If the potential adverse consequences of decision error are judged to be unacceptable, and the level of uncertainty makes it impossible to credibly characterize the statistical distribution of possible plan outcomes, planning should build **premise-based scenarios** for reporting without-project conditions and with-project plan effects on problems, opportunities, and the federal evaluation criteria. [12] A decision to employ scenario analysis to address uncertainty might be made during the scoping phase, or might come later in the planning process when it becomes apparent that uncertainty has important implications for plan formulation, evaluation, and decision-making. Under such conditions of uncertainty, if there are opportunities to formulate a plan that approaches problems and opportunities with incremental implementation, then adaptive management measures can be included in one formulated alternative. Conversely, if there is no opportunity for incremental implementation, the analysis should report how different alternatives address problems and opportunities and contribute to the federal evaluation criteria under different scenarios. [13]

Figure 3-1: Scoping for Addressing Uncertainty in Planning



e. Engagement with other agencies and stakeholders. As part of the iterative process, other agencies and stakeholders may be engaged to help inform the specification of problems and opportunities, engage in joint fact-finding, suggest alternative plans, and participate in the formulation, evaluation, comparison, and recommendation of alternatives. The Corps will engage with other agencies and stakeholders in different ways depending on project circumstances. The degree of engagement varies from holding public meetings to full integration of stakeholder involvement into each step of the planning process.[14]

(1) Parties to engage

a) Cost share partners. Those non-federal agencies or other legal entities that are legally obligated to participate in plan development or provide funds or in-kind support for plan development or project implementation must be engaged in the planning process.

b) Other federal and non-federal government agencies. Civil works projects and their operations have limited capacity to alleviate problems and realize opportunities on their own. Whether in the area of flood damage reduction and risk management, reliable water supply, or ecosystem restoration, the authorities of the Corps are either limited (as in the areas of water quality improvement, urban river restoration, and floodplain regulation) or there are other agency programs that can bring expertise and funding to the development of alternatives (e.g., FEMA). The completeness criterion (which is addressed later in this framework) demands attention to including other agency program measures in plan formulation. However, there are often differences in program missions and the analytical approaches and decision criteria used among the Corps and other agencies. Engagement with other agencies (both federal and non-federal) that are not cost share partners in the scoping process will increase the understanding of their respective programs and allow for consideration of those programs in plan formulation.

In addition, interagency engagement will allow agencies with different missions and responsibilities than those of the Corps to participate (see options for engagement) in plan formulation. Such participation will recognize a broad range of interests with the potential to formulate and recommend a plan that will minimize opposition to plan implementation.

c) Other stakeholders. Agencies of government, non-governmental organizations, as well as individuals can represent those who will obtain benefits from alleviating problems and realizing opportunities, or who will bear the financial costs or other adverse consequences of any alternative plan. In addition, there may be organizations that are created specifically to include diverse stakeholder interests (e.g., Missouri River Recovery Implementation Committee).

(2) Options for engagement.[15] The following terms describe different levels and forms of agency and stakeholder engagement, including but not limited to engagement with the non-federal project sponsor. Whatever the level and form of engagement, some commitment to effective communication enhances the chance that the preferred alternative (plan) will earn support from those most directly affected by a recommended plan. Many formats for agency and stakeholder communication exist and these can be tailored for each of these levels and forms of engagement.[16]

a) Inform. Communication generally is from the Corps to stakeholders in open public meetings, and the burden is often on the stakeholders to attend the meetings, review information, and provide comments. It is helpful to ask stakeholders during scoping what they perceive to be problems, opportunities, and possible alternatives, and how they wish to be informed as planning proceeds. At each point in the planning process there should be information provided on the progress of the planning process, including what problems and opportunities are the focus and what alternatives are being formulated and evaluated.

b) Consult. The Corps project manager identifies particular organizations, agencies and individuals who are to be consulted with throughout the planning process, seeking their input, considering their concerns and suggestions, and reporting back on what advice was taken, what was not, and why. Engagement of this level and form will almost always be the minimum necessary with the non-federal project sponsors. Whether consultation of this form should be extended to others will be based on a situation assessment [see (3) below].

c) Involve. The Corps project manager identifies particular organizations, agencies, and individuals who will be engaged in a dialogue dedicated to reaching agreement to the extent possible on any matter related to planning, but without an explicit commitment to make reaching agreement a condition for moving forward in the planning process. Engagement of this level and form generally is expected by the non-federal project sponsor.

d) Collaborate. The Corps project manager will identify particular organizations, agencies, and individuals who will participate on the planning team in a shared planning process, with a commitment to seek mutual agreement on analyses related to any step in the planning process. At this level of collaboration, the Corps project manager should consider adoption and implementation of a “Shared Vision Planning” (SVP) or similar process as a possible format for collaborative analysis and planning.

e) Shared decision-making. The Corps project manager identifies those organizations, agencies, and individuals who will have recognized authority or ability to affect the choice of a recommended alternative and/or to implement measures that are part of that alternative. With shared decision-making, the expectation is that there will be a requirement for agreement on all elements of the planning process before a preferred alternative can be recommended and implemented. At this level of engagement, the use of a SVP process, or elements therein, should be fully considered and employed as study resources permit.

(3) Choosing among engagement options. No single engagement approach is appropriate for all situations or for all relevant stakeholders and agencies. In addition, the options for engagement are subject to situation-specific state and federal laws regarding such matters as “government in the sunshine” and the structure of advisory committees. Also, the form and level of engagement may vary at different stages of the planning process. During scoping, the Corps project manager should inventory possible agencies and stakeholders and consult with them about the level, form, and timing of their engagement. In particularly controversial situations, it may be useful to ask an independent and impartial professional to conduct the assessment. This situation assessment then provides the basis for the choice of how to engage with each possible agency or stakeholder group.

a) Situation assessment. A situation assessment may be informal or formal, depending on the scale of the project. The larger or more controversial the project, the more benefit there is in preparing a written assessment document as a basis for gaining a shared understanding of the rationales and expectations for the engagement approach taken with each agency or stakeholder group. Assessments can include initial individual conversations, public meetings, and/or other tools to fully understand and identify the parties that may be affected, the problems and opportunities that are most relevant to these parties, their degree of interest in participating (see levels and forms discussion above), and to identify opportunities for and obstacles to their participation, including time and resource constraints. Information associated with the choice factors below also should be obtained. Educating stakeholders about options for engagement can help them to make an informed decision about how they wish to participate.

b) Choice factors. Factors to consider when making choices on the level and form of agency and stakeholder engagement for each planning element include: the public significance of the project, amount of investment, scientific or technical complexity of the issues and/or degree of uncertainty, degree of controversy and/or relationships among parties (including numbers of parties, cultural diversity, balance or imbalance of power, types of expertise, and resources), time available for consultation within project deadlines, agency staff and budget resources to engage in collaboration, and the preferences of cost share partners and other agencies and stakeholders.[17]

c) Agreement on engagement. A situation assessment will lead to agreement with agencies and stakeholders on the following.

    i. The objectives for engagement, what products are anticipated, and how outputs will be used and by whom in the final decision?

    ii. Who will participate and in what roles (e.g., as representatives of an interest group, as individuals, as experts, etc).

    iii. What processes would be effective and preferred by those participating and what specific procedures and ground rules for engagement will be utilized.

    iv. How analytical results will be reviewed and used in the planning elements and what mechanisms will be used for determining the credibility and usefulness of analyses.

    v. Timing and locations of engagement, under whose auspices meetings are held, and other logistics of involvement.

Section 4. Analytical Elements of Planning [18]

4.1 Specification of Problems and Opportunities

a. Basis. Initially, statements of problems and opportunities will reflect the specific instructions in the study authority, in other instructions by the Congress or the Executive Branch, and with consideration of the expectations of the non-federal project sponsor. The problems to be alleviated and opportunities to be realized should be specified for the planning area as defined in the scoping process. In the process of describing problems and opportunities, the planning area may be adjusted to accommodate new understandings of physical, biological, and economic relationships.

b. Focus and scope. Corps planning will be directed to addressing problems and opportunities (i.e., planning objectives) consistent with Corps statutory authorities and priority missions.

(1) Corps authorities and priority missions include the following general categories of planning objectives:

   a) Protect and restore the life support services of nationally significant ecological resources, in cooperation with other federal and non-federal programs and activities, through the management of watershed hydrology and/or geomorphology.

   b) Enhance flood and coastal storm damage reduction and risk management, in cooperation with other federal and non-federal programs and activities.

   c) Increase the efficiency and reliability of the national transportation system through investment in and operation and management of inland waterways and harbors.

(2) Additional problems and opportunities can be considered in implementation studies if directed by the study authorization, or if they serve agency and stakeholder concerns as long as these problems and opportunities do not conflict with the purposes of the study authority. Possible examples include: a) contribute to reliable water supply for municipal, industrial, and agricultural uses, and b) contribute to renewable energy supply by the production of hydro-electric power. In some cases, stakeholder-defined problems and opportunities may be outside the federal interest (e.g., waterfront renewal), but measures to address the stakeholders' desires can synergistically be made part of the plan, and the costs properly allocated to those purposes.

c. Level of problem alleviation and opportunities attainment. There is no presumption that any specific level of problem alleviation or opportunity attainment must be met. The statements of problems and opportunities describe a desired direction of change from the current and expected future without-project conditions, but do not prejudge how much, if any, of that change may be warranted. [19] Whether and to what level change is secured by some plan is determined by an evaluation of plan monetary and non-monetary benefits in relation to plan monetary and non-monetary costs.

d. Descriptions of problems and opportunities. In specifying problems and opportunities, the following apply:

(1) The problems and opportunities should be described as desired outcomes (e.g., reduce and then manage residual flood risk in River City), and not as an alternative plan(s) that might be presumed to secure those outcomes (e.g., build a levee in River City, or remove structures from the floodplain in River City).

(2) The statement of problems and opportunities should specify metrics for measuring changes in the level and direction of change.

(3) The problems and opportunities should be described for current conditions as well as future conditions that are expected to prevail in the absence of civil works intervention (i.e., the without-project condition).

e. Modifications. Initial expressions of problems and opportunities may be modified during the iterative planning process.

4.2 Inventory Current and Forecast Future Without-Project Water & Related Land Resources Conditions

a. Without-project condition. The forecast of the future level of problems and opportunities that would be expected in the absence of civil works action is the baseline for analysis of the effects of formulated alternative plans on alleviating problems and realizing opportunities. For example, if the problem is reducing and then managing residual flood risk in River City, then the current flood risk as well as the future flood risk, in consideration of socioeconomic change, hydrologic alteration, public policy and other factors, must be taken into account in predictions of future flood risk.

b. Forecast uncertainty. Planners must determine how uncertainty in the future, without-project condition will be addressed in the forecasting of future resource conditions. The uncertainties may be in the water and related land environment (e.g., non-stationarity of the hydrograph, land subsidence), in human activity (e.g., land settlement and population growth) or in limited understanding of hydrologic, geomorphic, or ecological processes (e.g., the fate and transport of sediments, or the response of a wildlife species to changes in the structure and functions of the water and related land ecosystem). Section 3.2.1 (scoping) and Figure 3-1 outlined different approaches for determining when and how to address uncertainty in planning.

4.3 Formulation of Alternative Plans

Alternative plans (or plans) are to be formulated in a systematic manner to ensure that a full set of plans are developed that can reasonably be expected to alter the without-project level of the specified problems and opportunities. Formulated plans need not be limited to include only measures that the Corps could implement directly under existing authorities, and can include measures that can be implemented under the authorities and missions of other federal and non-federal agencies. The scoping process will have established the collaborative relationships to make such cooperation possible in plan formulation. The following considerations will apply to plan formulation.

4.3.1 General Considerations in Plan Formulation

a. Formulation criteria. All alternative plans will be formulated in consideration of three criteria: completeness, effectiveness, and acceptability. [20] In assessing the extent to which a plan meets the criteria, the uncertainty of achieving each criterion should be recognized and reported.

(1) Completeness. Completeness is the extent to which an alternative plan includes all necessary investments or other actions required to ensure the realization of the predicted effects on problem alleviation or achievement of opportunities. This may require relating the actions in the plan to other public or private actions if these other actions are required for alleviating problems or realizing opportunities. Formulated plans should include and report on actions that will be implemented under the authorities of other federal agencies, state and local entities, as well as possible contributions by non-governmental organizations.

(2) Effectiveness. Effectiveness is the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities.

(3) Acceptability. Acceptability is the extent to which an alternative plan is in compliance with applicable laws and associated regulations, including but not limited to federal and state laws and regulations relating to endangered and threatened species, water quality, cultural and historic resources, and compensatory environmental mitigation under Section 906(d) of the Water Resources Development Act of 1986 as amended (33 U.S.C. 2283(d)). [21] Acceptability also depends on the workability and viability of the alternative plan from the perspectives of relevant state and local entities and the affected public. When institutional barriers related to acceptability would prevent attainment of these criteria, or if compliance with the criteria limits the ability to alleviate a problem or realize an opportunity, plans may be formulated to include recommendations for changes that involve removal of those barriers.

b. Management measures. Plans will be formulated using management measures that in combination address the planning problems and opportunities. “Structural” management measures are defined as those that intentionally modify existing hydrologic and geomorphic structure and processes. Structural measures typically involve implementing, altering, or removing engineered structures. For example, building a new levee and increasing the height of an existing levee are examples of structural measures, as is removal of a levee to allow for hydrologic reconnection of a river to its historic floodplain. “Nonstructural” measures are defined as management measures that avoid and minimize changes to the existing hydrologic and geomorphic structure and processes of water and related land resources. Nonstructural measures include enhanced management of the use of existing infrastructure (e.g., congestion pricing on the inland navigation system) and measures that manage human activity and development (e.g., permanent removal of buildings located in the floodplain). Nonstructural measures can include modifications in public policy, management practice, regulatory policy, and pricing policy.

c. Conceptual compensatory environmental mitigation measures. For each alternative plan expected to have adverse effects on watershed-scale hydrology and geomorphology as well as significant ecological resources at the sub-watershed scale, conceptual compensatory mitigation measures will be formulated. These conceptual measures will be refined once the NEQ effects of plans are fully evaluated. This form of compensatory environmental mitigation is required by law and often may be essential to securing agreement on a preferred plan in a collaborative planning environment.

d. Conceptual compensatory economic mitigation measures. Conceptual compensatory economic compensatory mitigation measures may also be formulated for adverse plan effects on current watershed uses (e.g., current recreation uses), as deemed necessary and appropriate. These may take the form of financial payments or additional measures in the plan (e.g., a new location for a boat ramp, or assured access to an alternative water supply). This form of compensatory mitigation may or may not be required by law (e.g., possible legal requirement to maintain existing benefits of authorized purposes), but even when not, is often essential to securing agreement on a plan in a collaborative planning environment.

4.3.2 Full Array of Formulated Plans

a. Multiple plans. A number of alternative plans should be formulated early in the planning process and then a subset of those plans should be further refined and carried forward for evaluation. Multiple plans should be formulated that reflect possible tradeoffs among the problems and opportunities to be addressed, in recognition of the federal interest evaluation criteria and other relevant state and local considerations.

b. Required plans. The array of formulated plans should include the following required plans that will be carried through to plan evaluation and then to plan display, comparison, and recommendation.

(1) Protection and restoration plan. Except in the case of planning where ecosystem restoration is the only specified problem and opportunity, one alternative plan will be formulated that addresses the specified problems and opportunities by relying principally on management measures that protect (avoid and minimize adverse effects on) or restore watershed scale hydrology and geomorphology, when possible, in support of significant area-specific biological resources. This plan will be identified as the Protection and Restoration Plan and will be carried through the balance of the planning process and used as outlined below.[22]

There are two reasons to require formulation of a Protection and Restoration Plan. One is to assure that at least one plan that makes a contribution to alleviating problems and realizing opportunities while avoiding adverse impacts on watershed hydrology and geomorphology, and restoring these same features if possible, is fully developed and carried forward to evaluation, comparison, and consideration for recommendation as the preferred plan. It is recognized that in some planning contexts such a plan may not meet all of the formulation criteria outlined in Section 4.3.1 (completeness, effectiveness, acceptability), and thus may not have realistic prospects for recommendation as the preferred plan. However, even when the Protection and Restoration Plan is unlikely to be identified as the preferred plan, it will be used as a point of reference when displaying the tradeoffs among it and all other plans that have been formulated to address problems and opportunities in plan comparison. The use of the Protection and Restoration Plan for this purpose is outlined in Section 4.5.[23]

(2) Adaptive management plan. If deemed advisable and practical after consideration of the consequences of uncertainty on path 3 [see Section 3.2.1d.(2) and Figure 3-1], at least one formulated plan will include adaptive implementation elements designed to reduce knowledge uncertainties attributable to analytical limitations in order to increase confidence that the

intended outcomes of the plan will be realized over time. If the formulation process does not identify a viable adaptive management plan, the study will document efforts to identify such an alternative and explain why it could not be formulated. [24]

4.4 Evaluation of Alternative Plans

Each formulated plan will be evaluated for its contribution to national economic efficiency (NEE) and national environmental quality (NEQ), as measured against the without-project condition. Plans will also be evaluated for their effects on the additional federal interest evaluation criteria as deemed necessary for informed decision-making in a particular planning context, including public safety effects, other environmental quality effects, and other social effects.

4.4.1 Prediction of Plan Effects

Predictions of the effects of alternative plans made using metrics for representing the level of problem alleviation and opportunities attainment, as measured against the without-project condition, should be made for selected years over the period of analysis. The predictions made should draw upon official or otherwise recognized and accepted sources for matters such as, but not limited to, national and regional projections of income, employment, output, and prices for specific goods, services and commodities, population, exports, and environmental conditions. Depending on the treatment of uncertainty chosen during scoping, uncertainty in predictions should be characterized quantitatively or qualitatively, and the effects on evaluation metrics for the evaluation criteria described.

4.4.2 Primary Evaluation Metrics

NEE and NEQ measures will be the primary measures reported to facilitate evaluation and comparison of alternative formulated plans for alleviating problems and realizing opportunities.

a. National Economic Efficiency (NEE) metrics. NEE effects will be measured as the positive and negative effects of plans on the economic value of water and related lands, or the economic value of the national output of goods and services produced using these resources, as expressed in monetary units. [25]

Economic benefits will be measured as increases in monetary units reflecting beneficiaries' willingness to pay (WTP) for increases in the economic productivity of affected water and related land resources, or increases in the national output of goods and services produced using these resources. Economic costs will be measured in monetary units reflecting plan implementation and associated costs, as well as the opportunity costs to affected individuals resulting from any decrease in economic productivity of water and related land resources, or decrease in the national output of goods and services produced using those resources.

b. National Environmental Quality (NEQ) metrics. NEQ effects of plans will be measured as the positive and negative changes in the physical, chemical and biological conditions of the nation's significant water and related land resources at the watershed scale, as expressed in non-monetary units.

The NEQ effects of alternative plans will be evaluated using metrics that are biologically-meaningful. The chosen metrics may include readily measured and predicted changes in hydrologic and geomorphic structure and processes in rivers and coastal systems. Examples include area of floodplain reconnected to a river (surrogate for enhanced native fish spawning and refuge as well as nutrient trapping), increases in area of emergent sand bars (surrogate for bird population increases) or changes in the shape of the hydrograph (surrogate for fish productivity, riparian habitat creation, and invasive species control). Alternatively, metrics might be developed and used that are more directly related to the desired biological outcomes, such as changes in habitat suitability indices for one or a community of species. In all cases the effect of an action on the chosen metric should be predictable with an acceptable degree of uncertainty, as judged by decision participants.

The direction of NEQ effects can be either positive of negative. In order to determine the direction of change when the biological outcome is not measured directly, it may necessary to describe a reference condition. Consider a metric where life support for a specific fish species is the biological outcome and the shape of the hydrograph best suited to fish spawning is the metric. In this case the past hydrograph or the hydrograph on a river with a viable fish population might be the reference condition.

Negative NEQ effects may occur in two ways and the response in plan formulation is different. First movement away from the desired biological outcome or reference condition, under the future without-project condition, is a negative change in NEQ that has no relation to the proposed action (plan), but is the basis for measuring positive NEQ effects when plans are formulated to add to NEQ. This is termed “restoration.” [26]

Second, a negative NEQ effect may occur as the result of a proposed action (plan), when measured against current resource conditions and not the reference condition. Supplemental plan features or changes made to a plan with the purpose to maintain NEQ or minimize the negative NEQ effects of plans in relation to the current resource conditions are not restoration, but rather are termed compensatory environmental mitigation. The same metrics may be used to measure both restoration benefits and to establish a level of compensatory environmental mitigation.[27]

4.4.3 Additional Evaluation Metrics

Plan effects on public safety, other environmental quality effects, and other social effects may be measured and reported, as required to satisfy the information requirements of all parties engaged in decision-making, or to meet other reporting expectations.

a. Public safety (PS) metrics. PS effects of alternative plans will be measured as the changes in risks to human life and safety from flood and coastal storm hazards, and other potential hazards as warranted, and risks that remain after plan implementation (residual risks), as expressed in various quantitative units or qualitative descriptions. An accounting of residual risks to human life and safety is required when flood and coastal storm threats are identified as problems and opportunities to be addressed in a planning study. PS effects will be measured in non-monetary units or qualitative descriptions relating to one or more of the following determinants of flood and coastal storm risk:

(1) Hazard (e.g., frequency and intensity of possible floods and storms that exceed the design level of any hazard reduction measures included in plans).

(2) Exposure (e.g., the number of people potentially exposed to residual flood and storm hazards).

(3) Vulnerability (e.g., the ability and means of potentially exposed populations to evacuate or otherwise avoid or mitigate injury and death from residual flood and storm hazards).

b. Other environmental quality (OEQ) effects metrics. OEQ effects will be measured as the effects of alternative plans on significant cultural, aesthetic, and sub-watershed-scale ecological resources, as measured using appropriate non-monetary indicators. An appropriate indicator is a characteristic of a relevant resource that serves as a direct or indirect means of measuring or otherwise describing changes in the quantity and/or quality of resource attributes.

c. Other Social Effects (OSE) Metrics. OSE will be measured as the effects of alternative plans on low-income, tribal, and minority communities, [28] as expressed in monetary units, non-monetary units, or qualitative descriptions relating to one or more of the following:

(1) Changes in employment, wages, and other measures of economic activity within the community.

(2) Incidence of NEE and NEQ effects on groups within the community.

(3) Incidence of PS and OEQ effects on groups within the community.

4.4.4 General Considerations in Plan Evaluation

a. Measurement of national economic efficiency effects. Measurement of economic benefits and opportunity costs (foregone benefits) in monetary units will generally be made for affected goods and services that are marketed, as well as those that are not marketed but that have a substitute good or service that is marketed.[29] However, any plan effect may be assessed in monetary units if the following conditions hold: (1) the assessment can be accomplished using the available study resources in consideration of all study requirements; (2) the assessment is deemed by the District Engineer to be important for informed decision-making, and; (3) the assessment is broadly viewed as valid and acceptable by the project stakeholders that are engaged in decision-making.

b. Accounting for an effect in multiple ways. Any plan effect can be measured and shown in different ways across multiple effects categories to allow decision-makers to consider that effect from alternative perspectives. As one example, the flood damage reduction effects of plans can be measured and shown as monetary NEE metrics (property damages avoided), as hydrologic PS metrics (the level of residual hazard), and as OSE metrics reflecting the incidence of these measured effects on low-income, tribal, and minority communities.

c. Compensatory environmental mitigation costs. For each alternative plan that has adverse watershed-level and/or sub-watershed-level effects on significant ecological resources as measured by NEQ and OEQ metrics, respectively, conceptual compensatory environmental mitigation measures will be developed and the costs of these measures will be assessed and recorded as part of the NEE evaluation.

d. Compensatory economic mitigation costs. As deemed necessary and appropriate, conceptual compensatory economic mitigation measures may be developed for adverse plan impacts on current watershed uses (e.g., current recreational uses) and the costs of these measures (e.g., replacement of recreational access, payments to purchase water rights or replacement power supply, relocation assistance payments) assessed and recorded as part of the NEE evaluation.

e. Life cycle analysis.

(1) Period of Analysis. The period of analysis is to be the same for each alternative plan. The period of analysis is to be the time over which any alternative plan would have significant beneficial or adverse effects on the federal interest evaluation criteria.

(2) Time pattern of effects. Positive and negative NEE and NEQ effects may not occur uniformly over the period of analysis.

  a) Some alternatives that rely on hydrologic and geomorphic restoration through the mimicking of natural processes may cause NEQ improvements to come about slowly, but then become self-maintaining (i.e., not require occasional interventions) and self-designing at some point in time. That time pattern of effects should be recognized and reported.

  b) Future NEE benefits may not occur in the same year for all plans and some plans may have different levels and frequency of costs. For all plans, the years that different levels of benefits are realized and the years that different levels of costs are incurred for operations and maintenance and for significant repair and replacement should be reported.

(3) Discounting. Discounting will be used to convert all future NEE (monetary) effects to present values using the discount rate established annually for civil works planning. Discounting may be applied to NEQ effects, for present value comparison with NEE effects, as long as the time patterns of NEQ benefits and costs to realize those benefits over the project life are also reported. [30] Non-monetary effects with respect to the other evaluation criteria (PS, OEQ and OSE effects) would not normally be discounted for plan display and evaluation.

f. Prices of goods, services, and factors of production. The prices of goods, services, and factors of production (i.e., input costs) should reflect real exchange values expected to prevail over the period of analysis. To the extent practical, direct government subsidies or other programs that affect observed exchange values should be recognized and adjustments made to those prices to reflect real exchange values. If adjustments cannot be made, the subsidies that distort real exchange values should be identified and described. [31]

4.5 Plan Display and Comparison

a. General considerations in plan display and comparison.

(1) To assure transparency and full recognition by decision participants of the different plan effects and the different parties that may realize them, all predicted effects for each plan, even if expressed in commensurate metrics (e.g., monetary units) should be left disaggregated (i.e., not summed or otherwise combined) for the purpose of plan display and comparison. For example, estimated monetary benefits from addressing a specific problem or opportunity (e.g., flood risk management) should be shown separately from the estimated financial costs of plan implementation, as well as separately from the estimated monetary value of any incidental plan benefits or foregone benefits associated with other affected goods and services (e.g., recreation). For purposes of recommending a plan, however, aggregation may be applied, as outlined in Section 4.6.

(2) The one exception to the requirement for disaggregation of plan effects involves a measure of total financial costs for plan implementation, which can be shown as the total discounted present value sum of all financial component costs for implementing a plan (e.g., initial capital costs, annual O&M costs, costs associated with future repair or other necessary interventions). Even in this case, however, each individual component of plan financial costs should be shown separately along with the sum and time pattern of plan financial costs for plan display and comparison.

(3) To assure transparency in the characterization of conceptual environmental and economic compensatory mitigation proposals, the adverse effects, a description of the conceptual compensation plan, and preliminary estimates of the financial costs of implementing the compensation for each formulated plan should be shown separately in the plan display and comparison. [32]

b. Phase 1 plan display and comparison. There are two phases in plan display and comparison. Phase 1 will display and compare the evaluated effects of plans using the primary evaluation criteria (NEE and NEQ). The set of plans included in Phase 1 display will include the Protection and Restoration Plan as well as all evaluated plans that meet the formulation criteria outlined in Section 4.3.1. The purpose of the Phase 1 display and comparison is to narrow the set of plans that will be carried forward for Phase 2 plan display and comparison (another purpose is to identify plans that might be improved by reformulation and then considered further through the iterative process).

(1) A Phase 1 display will be developed to report the effects of plans in terms of each evaluated NEE and NEQ effect as well as any conceptual compensatory mitigation plans and associated costs. Specifically, the following effects should be included and shown separately in the display matrix:

- NEE monetary benefits for each good or service for which plans have been formulated to produce (i.e., evaluated economic benefits for addressing specified problems and opportunities).
- NEQ non-monetary effects, both positive and negative, as measured using one or more NEQ metrics.
- NEE monetary benefits and costs associated with other affected goods and services. These effects can include incidental benefits for each positively affected good or service, as well as the opportunity costs (benefits foregone) for each negatively affected good or service.

- NEE financial costs for plan implementation, including the following component and total costs shown separately: a) initial capital outlays, b) annual operation and maintenance costs, c) costs for future repair and any other necessary interventions, and d) total financial costs for plan implementation (discounted present value sum of cost items a-c).
- A description of the conceptual compensatory environmental mitigation proposal for adverse NEQ effects and adverse OEQ effects, and the financial costs of implementing the proposal.
- A description of the conceptual economic compensatory mitigation proposal for adverse effects on existing watershed uses, and the financial costs of implementing the proposal.

(2) The display should refer to the places in the report where the analysis supporting the results reported in the display can be found.

(3) The Phase 1 display will be used to compare the effects of alternative plans in order to judge whether some plans are "inferior" to one or more other plans. NEE benefits and costs for incidental goods and services, as well as conceptual compensatory mitigation plans and associated costs, can be used as supplemental information for judging whether certain plans are inferior to one or more other plans. Any of various methods and associated graphical displays and plots for multi-criteria comparisons of plan effects may be employed to facilitate plan comparison. The result of the comparison should be a narrowing of the set of plans to be carried forward for the Phase 2 plan display and comparison. (Another possible result is a decision to reformulate and reevaluate one or more plans that have been judged to be inferior).

c. Phase 2 plan display and comparison. Phase 2 will focus on the display and comparison of the evaluated effects of non-dominated plans relating to all evaluation criteria, both primary and additional. The set of plans included in this phase will include the Protection and Restoration Plan as well as the subset of plans that have been carried forward from the Phase 1 plan display and comparison. The purpose of this second round of display and comparison is to identify a subset of plans that will be considered for possible recommendation as the preferred plan.

(1) The Phase 2 display will be developed to report the effects of plans that have been carried forward in terms of all evaluation criteria, including the primary criteria (NEE and NEQ), the additional criteria (PS, OEQ and OSE), as well as conceptual compensatory mitigation plans and associated costs. As in the Phase 1 display, each evaluated effect should be displayed separately.

(2) The Phase 2 display will be used to identify plans that may be considered unacceptable based on their effects on the additional evaluation criteria (e.g., unacceptable public safety effects), and should be screened from further consideration (or reformulated).

(3) The Phase 2 display will be used to identify and consider the incremental NEE and NEQ effects of plans as measured against those of the Protection and Restoration Plan. Any of various types of methods for implementing incremental analysis may be employed for illustrating the incremental NEE and NEQ gains and losses from moving from the Protection and Restoration Plan to each of the other plans. The result of this incremental analysis should be the selection of a subset of plans to be considered for possible recommendation as the preferred plan. [33]

(4) If the Protection and Restoration Plan meets the formulation criteria set out in Section 4.3.1, it should be included in the set of plans carried forward for possible recommendation.[34]

4.6 Plan recommendation

a. The responsibility of the planning process is to provide useable information for those with decision-making authority. The responsibility of those with decision-making authority is to use the information provided to conclude whether one or more alternative plans for a specific place are in the federal interest and can be considered for selection, and then recommend one of those plans as the preferred alternative.

b. Decision-making responsibility [35]

(1) Within the Corps, the District Engineer (DE) has the initial responsibility for making a federal interest determination and recommending a preferred plan. While the Corps decision begins with the DE, the recommendation for a preferred plan is ultimately the responsibility of the Corps organization and the Assistant Secretary of the Army for Civil Works [ASA (CW)]. Because of the in-progress review process of the Corps, the DE recommendation should be that of the agency as a whole.

(2) Project cost share partners make a financial commitment to developing the plan and will have financial obligations for plan implementation. The DE will share the display and comparison information and engage with cost share partners in selecting a preferred plan.

(3) Other federal agencies and non-federal government agencies may have projects and programs that are part of any formulated plan in the final array of plans, or may have responsibility to approve any plan before it may be implemented. The DE will be expected to share the display and comparison information and engage with other agencies of government in selecting a preferred plan.

(4) The Executive Branch, through the Office of Management and Budget and the Council on Environmental Quality, as well as the Congress has responsibility for reviewing the Corps recommendation, and through the legislative process, making the final determination on authorization and appropriations. Therefore, the Corps may, through the Office of the ASA (CW), share the display and comparison information and engage these entities before recommending a preferred plan.

c. Plan recommendation and reporting responsibilities

(1) The DE will provide a summary of all technical review comments from the technical review processes in place and a response to the comments indicating how they were addressed, and if rejected, the basis for that rejection. These will be part of the information made available for agency and public comment.

(2) The DE will publish the display and comparison information for all plans for a concurrent 90 day public and agency comment period, and will provide a summary of public comments as well as a response to the comments indicating how they were addressed.

(3) The DE will prepare a written statement indicating the basis for the following determinations (specifically referring to the results in the Phase 1 and Phase 2 display and comparison, to the technical review comments, to public and other agency comments, and to the preferences of the cost share partners):

- Which plans displayed in Phase 1 were not carried into Phase 2.
- Which plans in Phase 2 did not meet a federal interest determination and were not further considered for the preferred plan.
- If the Protection and Restoration Plan is not recommended, the reasons for that decision.
- The reasons for selection of the preferred plan.
- If the DE determines that no plan is in the federal interest, then a no federal action alternative will be recommended as the preferred plan.

In preparing the written statement in support of the preferred plan, the DE may choose to aggregate the effects that were disaggregated in the plan display and comparison phases in ways that the DE believes can help clarify the basis for the decision made. The choice to aggregate the measures of NEE, NEQ, and other effects, and how that aggregation is executed, is at the DE's discretion. [36]

(4) The DE will ask the cost share partners and other agencies who have agreed to implement elements of the preferred plan to prepare a statement to accompany the DE recommendation supporting the recommendation and providing evidence for their commitment and capacity to implement their elements within the plan. The partners will comment on the logic used by the DE and may provide additional reasons for supporting the recommendation.

Appendix A: Formulation and Evaluation of Alternatives Affecting Floodplains, Flood Risk Management, and Public Safety

Background

Current Corps guidance says that planning studies for flood and coastal storm damage reduction (F&CSDR) projects should generally recommend project plans that maximize net national economic benefits subject to an environmental protection constraint. Benefits are measured as expected property damages avoided by a plan, and the analysis of plans is to report an estimate of the residual expected annual property damages that would occur with the alternative in place. Planning guidance does not require that benefits from reduced risks to human life and safety as well as the residual risks to life and safety with the plan in place be quantified and discussed in F&CSDR studies (though in recent years the Corps has increased attention to residual risks to human life and safety in planning studies).

Current Corps policy does not specify any minimum level of project performance that must be provided, but net economic benefits must be positive for whatever plan is recommended. However, a non-federal sponsor may desire a plan that provides a different level of performance than that provided by the plan that maximizes net economic benefits. This might be a desire to have no properties exposed to the 1% annual chance flood event that affects community requirements under the National Flood Insurance Program. If a non-federal sponsor prefers a plan that eliminates exposure to the 1% annual chance flood event (but not to floods of higher magnitudes and lower likelihoods of occurrence), and that plan has net economic benefits, Corps policy allows it to be recommended without formulating and considering other plans. Alternatively, a non-federal sponsor might prefer a plan that eliminates exposure to higher magnitude and less frequent flood events (i.e. that provides a higher level of performance) than that associated with the plan that maximizes net economic benefits, and be willing to adjust the cost share to secure that plan.

Corps policy also directs planners to formulate and consider a primarily “nonstructural” (NS) plan in F&CSDR studies, which has been generally understood to incorporate measures designed to reduce determinants of flood risk other than the flood hazard (that is, these risk reduction measures do not focus on reducing flood surface water elevations in the floodplain). The use of such management measures is promoted by environmental advocacy groups and others as a means to achieve flood damage reduction while avoiding and minimizing changes to existing watershed hydrology and geomorphology, thus limiting negative impacts on the “natural and beneficial functions” of floodplains and wetlands.

NS measures for flood damage reduction include the removal/relocation (buyouts) of structures in the floodplain that can reduce the potential for people and assets to come into direct contact with floodwaters by changing use of the floodplain (that is, measures that reduce “exposure”). They also include measures such as flood warning and preparedness systems and flood-proofing of buildings that can reduce the negative consequences that occur when people and assets are exposed to flood hazard by accommodating existing floodplain uses to that hazard (that is, measures that reduce “vulnerability”). Measures to reduce exposure and vulnerability are typically considered together in the formulation of the NS plan, but usually with limited or no measures to reduce flood hazard. The NS plan is often found by the Corps to fail the net economic benefits test and/or is deemed unacceptable by non-federal project sponsors, however.

Nevertheless, some management measures to reduce exposure or vulnerability are usually included in F&CSDR plans that are recommended for implementation. For example, limited buyouts are sometimes used to reduce the costs for levee alignments, or to contribute to community amenities such as river access that are often important for local acceptability of project plans. Further, project partnership agreements require non-federal sponsors to implement floodplain management plans and comply with NFIP requirements. Moreover, in recent years Corps policy and guidance have allowed for the formulation of "combined" plans that can jointly protect and restore floodplain and upstream wetlands while also reducing flood risk. This has allowed planning to formulate and consider plans that include what might be termed "natural infrastructure hazard reduction" measures, such as levee setbacks for local floodplain restoration and upstream watershed restoration.

In addition to having positive net economic benefits, a recommended plan must be consistent with "protection of the Nation's environment." In practice, that environmental protection constraint is deemed satisfied by making compensatory environmental mitigation measures part of the plan, and factoring the mitigation costs in the net benefits calculation for the plan. Corps guidance expects that the environmental quality effects of any plan to be evaluated in non-monetary terms and used to determine any necessary environmental mitigation for that plan. But there is no expectation that Corps planners should consider and balance tradeoffs among the evaluated environmental quality effects and economic effects of plans in plan comparison and selection.

Motivations for Change

Critics of the Corps planning processes for F&CSDR note several areas of concern. Among the criticisms is that past Corps F&CSDR studies have:

1. Focused too much on formulating plans that rely on "hard" hazard reduction measures such as upstream reservoirs, levees, and channel modifications to the exclusion of plans that include natural infrastructure hazard reduction measures (as defined above) in combination with measures that can reduce community exposure and vulnerability to flooding.

2. Failed to measure and use information on the negative and positive effects of plans on floodplain and wetlands functions in plan formulation, evaluation, comparison, and selection.

3. Failed to measure and use information on plan effects for reducing risks to human life and safety, as well as the residual risks to human life and safety that would remain following plan implementation, in plan formulation, evaluation, comparison, and selection.

Options for Modernizing Corps Guidance

The desire that combinations of natural infrastructure and exposure and vulnerability reduction measures be given more serious attention and consideration in F&CSDR studies could be addressed by requiring one plan to be formulated by starting with and then adding successive increments of such management measures. The intent of this plan would be to address problems and opportunities while also avoiding and minimizing adverse impacts on (and restoring, when possible) floodplains and related wetlands functions; the framework presented here calls such a plan the "Protection and Restoration Plan."

The effect of requiring formulation of a Protection and Restoration Plan would be to address one of the criticisms of current practice. The requirement would assure that at least one plan that makes a contribution to flood damage reduction while avoiding and minimizing adverse impacts on watershed hydrology and geomorphology (and restoring these same features, when possible) is fully developed and carried forward to evaluation, comparison, and consideration for recommendation as the preferred plan. It is recognized that in some planning contexts the Protection and Restoration Plan might involve unacceptably high residual flood risks, and thus may not have realistic prospects for recommendation as the preferred plan. Other plans could be formulated that build on the Protection and Restoration Plan by adding traditional hazard reduction measures (e.g., levees and channel modifications) as next added increments to the plan. In addition, plans that have hard infrastructure as the first increment, and add natural infrastructure and nonstructural measures as next added increments, might also be developed.

The Protection and Restoration Plan would also make a contribution to plan evaluation and to informing selection of a preferred plan by serving as a point of reference when comparing the NEE, NEQ, and other effects of other plans. That is, the Protection and Restoration Plan would serve as a point of reference when displaying the tradeoffs among it and all other plans that have been formulated, evaluated, and carried forward for possible recommendation. The analysis would document the NEE, NEQ, and other (e.g., public safety) effects of the Protection and Restoration Plan for reducing and managing flood risks. The analysis would then systematically report the incremental changes in NEE benefits and costs and NEQ and other effects that would be realized if other plans were selected instead of the Protection and Restoration Plan.

Similarly, the desire that the public safety (PS) effects of alternative plans be considered in planning could be made operational by requiring the evaluation and comparison of plan effects on risks to human life and safety as well as risks that would remain after plan implementation (residual risks). PS effects could be measured in non-monetary units or qualitative descriptions relating to one or more of the following determinants of flood and coastal storm risk: 1) Hazard (e.g., frequency and intensity of possible floods and storms that exceed the design level of any hazard reduction measures included in plans); 2) Exposure (e.g., the number of people potentially exposed to residual flood and storm hazards), and 3) Vulnerability (e.g., the ability and means of potentially exposed populations to evacuate or otherwise avoid or mitigate injury and death from residual flood and storm hazards).

Commentary

In recent years the Corps has begun to reinterpret its F&CSDR missions within the broader concept of flood risk management, which recognizes that responsibility for reducing flood risk and managing residual risk must be shared among the Corps, local governments, and affected citizens. Shared responsibility implies that the localities that the Corps assists through F&CSDR projects are expected to play a role in “buying down” flood risks, and then assume primary responsibility for managing residual risks. As one example, all Corps F&CSDR projects might be expected to incorporate flood warning and preparedness systems, where these project features would be operated and maintained by local authorities. Similarly, while current Corps policy makes federal participation in a project contingent upon local implementation of floodplain management regulations, policy adjustments may be needed to ensure local compliance.

Shared responsibility also implies shared decision-making in which the desires of non-federal project sponsors must be taken into account. Thus, decisions must be made in consideration of the level of residual risk that non-federal sponsors deem acceptable, as well as the tradeoffs that they are willing to make among flood risk reduction using natural infrastructure hazard reduction and measures to reduce exposure and vulnerability, as opposed to traditional hazard reduction alternatives. In the end, shared responsibility for choosing a preferred plan must be accompanied by a shared commitment to implementing all elements of the plan and to continuous monitoring of that implementation over time.

The concerns that motivate criticisms of how floodplains are considered in plan formulation, evaluation, comparison, and selection are already addressed, however imperfectly, in current Corps planning guidance. In fact, there has been increased inclusion of natural infrastructure as well as exposure and vulnerability reduction measures in plans being proposed for authorization. Changes to guidance can be made to require greater consideration of natural infrastructure in plan formulation and evaluation by requiring formulation of a Protection and Restoration Plan and by using that plan as a point of reference for comparing the NEE, NEQ, and other effects of all other formulated plans.

However, considering a Protection and Restoration Plan for recommendation would necessarily depend on the available opportunities for such alternatives and their acceptability to non-federal sponsors. Many non-federal sponsors for Corps studies represent heavily populated areas where opportunities for natural infrastructure hazard reduction as well as exposure and vulnerability reduction may be limited. Therefore, while guidance changes may address the concern that the current practice of F&CSDR study execution does not give balanced consideration to plans that emphasize exposure and vulnerability reduction and natural infrastructure hazard reduction, in the end such changes in guidance cannot ensure that such plans would be deemed acceptable to non-federal sponsors.

Appendix B: Objectives and Evaluation in Civil Works Planning Studies

Background

This Appendix uses the concept of "ecosystem services" to explore issues relating to the evaluation of plan effects in a planning study. While numerous references provide somewhat varying definitions for the ecosystem services concept, most argue that ecosystem services are "natural" services provided by the environment that make a direct or indirect contribution to the well-being of people.

In the next section we re-interpret the meaning and implications of ecosystem services in ways necessary to make the concept operational within the authorities of the Corps and within the context of a watershed as opposed to ecosystem focus for Corps planning. The result is to derive the idea of "watershed services" from the concept of ecosystem services.

That is followed by a review of the Corps' current approach to the evaluation of changes in watershed services for civil works planning. Motivations for change to the current approach are then outlined, followed by a discussion of options for change. Particular attention is paid to the possibilities for, and limitations of, placing monetary values on all watershed services that may be affected by project alternatives.

Watershed Services

The structure and processes of river and coastal watersheds constitute "natural infrastructure" that in turn supports or directly provides natural services that are valued by people. Of course, this natural infrastructure exists alongside human infrastructure, and may have been altered by human interventions and uses over time, often by Corps projects. Below, we refer to this combination of natural and human infrastructure as "watershed structure and processes."

Watershed structure refers to the geophysical features and characteristics of a watershed at a point in time, such as topography and land cover, including the kinds and locations of wetlands, land uses, as well as the existing water control structures that affect the hydrologic and geomorphic regime of rivers, lakes, and related estuaries. Watershed processes refer to geophysical processes such as gravity and solar and wind energy that contribute to the hydrologic cycle and the movement of water and sediments through the geophysical structure, as affected by ecological functions, such as biomass production and nutrient cycling, that are present given some watershed structure.

Examples (not an exhaustive list) of four types of watershed services that are especially relevant to civil works are presented in the box below. The *Millennium Ecosystem Assessment* and other sources provide different, but generally consistent, categorization frameworks. We use this particular framework because it is readily interpreted in terms of the combined effects of natural and human-made infrastructure on the types and levels of watershed services that are most affected by the Corps civil works program.

Examples of Watershed Services Relevant to Civil Works

Input in Production of Marketed Goods & Services

- Waterway transportation
- Flood storage & conveyance
- Hydropower generation
- Water input and land productivity for agriculture and commercial & industrial production

Direct Use

- Municipal & home water supply
- Recreation & aesthetics

Waste Assimilation

- Processor or sink for human waste products
- Trap for eroded soil

Life Support

- Biodiversity
- Populations of one or more wildlife species

Watershed services that are valued as production inputs for marketed goods and services most closely align with the types of services that have been the objective for formulation of alternatives in traditional Corps water development projects. In most cases, those services were expected to be captured or enhanced by the construction of water control works.

The waste assimilation services may be used by intention, but often they are simply the inevitable result of human activity in the watershed. Management of the use of these services is the responsibility of the USEPA and state water quality agencies. However, if Corps projects or their operations affect the flow patterns and geomorphologic processes in rivers, then waste assimilation services may be enhanced or reduced. Other civil works actions have also been associated with waste assimilation service provision; for example, the restoration of wetlands areas may increase sediment trapping.

Most references to ecosystem services characterize life support services (as well as waste assimilation services) as “ecological” services that are most closely associated with natural infrastructure where, in the case of watersheds, “natural” is defined with reference to some pre-disturbance watershed hydrologic and geomorphic structure and processes. That is, it is presumed that life support services were provided at their maximum levels in that pre-disturbance state. These services are valued by people directly as well as indirectly through the support they provide for other services, such as recreation.

At the federal level, management of life support services is the responsibility of resource agencies such as NOAA and USFWS, and is also addressed by the Corps regulatory program under Section 404 of the CWA. With respect to Corps civil works missions and authorities, life support services may be diminished or may be enhanced by interventions in watershed structure and processes. However, the specific effects on life support services that would result from civil works interventions in watershed structure and processes may be difficult to separate from other factors, such as harvest pressure or nutrient levels in a river.

The specific types and levels of watershed services realized in any specific watershed are affected by water development projects and other human-made alterations to watershed structure and processes. Indeed, the intent of human interventions has been to increase the supply of one or more watershed services, since in many cases the service contribution to the well-being of people largely depends on such interventions. For example, rainfall, runoff, and water storage in rivers and lakes make a contribution to the municipal water supply service, but capital investment for the capture, treatment, and distribution of the water is required for this service to add to the well-being of people.

Current Evaluation Practice

Federal budget priorities, Congressional authorization language, interpretations of Corps legal authorities, and preferences of local cost sharing sponsors direct most Corps planning studies to formulate alternatives to enhance production inputs for marketed goods and services. These planning processes focus on waterborne commercial transportation and flood and coastal storm damage reduction, which the current Corps planning guidance refers to as “National Economic Development” (NED) outputs. More generally, these planning processes emphasize reducing the adverse consequences to people from extreme high-water and low-water conditions in the flow of the river at a location (the hydrograph), or that offset those effects by flood hazard reduction infrastructure (to address floods) and temporal and spatial water transfers (to address drought). These engineering works include dams and reservoirs, channel straightening and deepening, pipelines, and levee systems. With respect to coastal harbor development, the approach has been to accommodate deeper ship drafts and wider ships through channel deepening and port widening. In some studies, “nonstructural measures” (actions that do not alter the existing hydrology or geomorphology) are considered when formulating alternatives.

The evaluation of the effects of formulated plans on these kinds of NED outputs is based on the objective of national economic efficiency. The economic efficiency benefits are understood as the willingness to pay (WTP) of project beneficiaries for a change in services and are expressed in monetary terms, typically using WTP proxies. Once estimated, the benefits are compared with estimated costs (financial outlays and opportunity costs) to recommend the plan that maximizes net economic benefits. The WTP benefits may be limited to a specific type of benefit resulting from the change in a service (e.g., flood damage reduction benefits have been monetized primarily with reference to property damages avoided). In addition, other non-monetary evaluation metrics are often reported (e.g., level of protection in a flood damage reduction project).

Corps guidance also expects non-monetary estimation of the environmental quality (EQ) effects of plans formulated to serve NED outputs. The federal objective statement in current Corps guidance directs selection of the plan that maximizes net NED (monetary) benefits, but subject to a constraint that the plan must comply with applicable environmental laws and regulations. As a practical matter, this requirement demands an evaluation of environmental effects and recognition of such effects as they may constrain how plans are formulated, and consideration of such effects for determining any required environmental compensatory mitigation for a selected plan. Estimated costs in the net benefits analysis include expenses for any required compensation.

In recent years, the Corps has had the authority and budget to plan for and implement a category of projects that focus on "National Ecosystems Restoration" (NER) outputs (what the framework presented here labels as NEQ effects) as well as combined NED/NER outputs. In these planning efforts, plans are formulated to enhance life support services (the outputs) through the "restoration" of hydrologic and geomorphic structure and processes of rivers and associated wetlands and floodplains. Specific types of interventions in watershed structure and processes to enhance life support services include replicating historic high and low flows on the hydrograph, creating wetlands and riparian floodplain acres, restoring the original hydro-period of remnant wetlands, and reconnecting rivers to floodplains. This category of planning studies often considers the construction of new engineering works, but may also consider the re-operation, removal, or relocation of existing works. High-profile examples include the Kissimmee River restoration and the Comprehensive Everglades Restoration Plan (CERP) that are being implemented in cooperation with the South Florida Water Management District. (There are numerous examples of other, less well-publicized NER projects that are smaller in scale.)

Formulation of alternative plans for NER usually begins with attention to place-specific, biological goals (life support services). The mix of actions considered and their specific designs are guided by an implied or explicit "conceptual ecological model" that relates the actions that the Corps might take to the life support needs of desired target species or communities of species in the watershed where the plan is being executed. For example, formulation of plans to change reservoir operations for temperature modification might be conceptualized in terms of the needs of a specific cold-water fish species indigenous to that river system. As another example, levee setbacks with the construction of side channel habitats in the land reconnected to the floodplain may allow for improved spawning and nursery opportunities for a particular fish species.

It follows that the evaluation of these plans will use metrics that correspond to the place-specific biological objectives. Measures of NER benefits might focus on changes in existing watershed structure and processes that support place-specific biological objectives. These may include evaluation metrics reflecting acres of reconnected floodplain or the shape of the hydrograph at some point in the spawning season for the relevant fish species. Alternatively, evaluation metrics might be changes in a habitat suitability index (and area) for a target species or an ecological community. Whatever non-monetary evaluation metric is used for evaluation, it is related to the costs for each plan through a cost-effectiveness analysis and incremental cost analysis in order to identify cost-effective alternatives and then a "best buy" alternative. A determination of the "significance" of the affected resources and expected changes in life support services also plays a role justifying a selected NER plan. By Corps policy, the WTP (monetary) metric is not employed for representing NER outputs.

A NER plan may also indirectly increase or decrease any of the other watershed services; however, changes in those other services may not be evaluated in monetary or non-monetary terms, although there is no prohibition against such evaluation. For example, a floodplain reconnection to a river to increase spawning habitat for a particular species may also reduce downstream flood peaks, but any associated flood damage reduction benefits are typically not evaluated and considered in selection of a preferred plan.

Of note here is the concept of "incidental benefits" as defined by Corps policy and planning guidance. For example, plans that are formulated to provide flood damage reduction may also increase the quality of existing recreation services, and Corps guidance encourages the estimation of monetary benefits for such effects when practical. However, depending on the type of service, Corps policy may limit the extent to which such benefits can be included in net economic benefit calculations (in the case of planning for NED outputs) and cost-effectiveness and incremental cost analyses (in the case of planning for NER and combined NED/NER outputs), and thus play a role in plan selection. This limitation is what makes the benefits “incidental.” In certain cases, Corps policy does allow for the use of incidental benefits for justifying a plan. One example involves the permanent removal of structures in the floodplain (i.e., buyouts) in flood and coastal storm damage reduction planning. In that case, all the services of the new land uses created by removing structure are allowed to be measured and used as benefits towards justifying the costs of removal.

Motivations for Change

The often expressed criticism of civil works planning is that planning studies fail to recognize that the full array of watershed services, and life support services in particular, might be enhanced or diminished by civil works interventions in watersheds; the result is that the effects of plans on some services are not adequately evaluated and considered in plan comparison and selection. There appears to be a concern that the first category of projects described above (NED) continue to be formulated to enhance services that are inputs in production (waterway transportation and flood storage and conveyance), but the evaluation processes do not adequately evaluate and use the estimated effects of plans on life support services in plan comparison and selection (or in setting mitigation requirements for the selected plan). Similarly, the second category of projects described above (NER) continue to be formulated to enhance life support services, but the evaluation processes do not adequately evaluate and use the estimated effects of plans on other watershed services in plan comparison and selection.

Actions for Modernizing Evaluation Practices

Corps planning policy and guidance could address the concerns that appear to motivate the Corps’ critics by: a) acknowledging that plan effects on life support services have standing in plan comparison and selection for all planning studies, and; b) requiring the use of appropriate monetary and non-monetary metrics to evaluate all watershed services that are significantly affected by plans. More specifically, policy and guidance would accommodate the following points:

1. For all services categorized above as inputs in production and direct use services that are significantly affected by plans, require evaluation of all positive and negative effects from changes in service levels using monetary proxies for users’ willingness to pay (WTP) for those changes. Methods and procedures for evaluating such economic benefits are already included in Corps planning guidance, though updates to that guidance will be needed to reflect contemporary circumstances (e.g., deregulation of electricity markets) and economic evaluation technology (e.g., advances made by the Corps’ “Navigation Economics Technology” program).

2. For measuring the effects of plans on life support services, develop and apply appropriate place-based, non-monetary metrics for use in plan formulation, evaluation, and selection, with consideration also given to monetary (WTP) metrics when certain criteria are met.

With regard to point 2, there is much interest in evaluating the effects of plans on as many watershed services as possible using WTP metrics. Some people argue that changes in all watershed services, including life support and associated waste assimilation services, can and should be evaluated in monetary terms in civil works planning, so the that monetary benefits of intervention are directly comparable to the costs. A related argument is that if the effects of intervention on life support services are not evaluated in monetary terms, then these effects will receive less consideration in the decision-making process.

There are several factors that should be considered when deciding when monetary versus non-monetary metrics are appropriate for representing plan effects on some watershed service in a particular planning study. First, the chosen metrics should be capable of being predicted, with an acceptable degree of uncertainty, using the available planning models within study time and budget constraints. This criterion might be termed "predictability." Second, the metrics chosen should be decision-relevant for the area and central problems of concern where planning takes place, which requires that they be understood by and acceptable to non-federal sponsors and other study participants (who may include more than just representatives of the federal agencies involved in planning). This second criterion might be termed "credibility." Credibility is not completely independent of predictability, since an estimated performance metric that is characterized by high uncertainty may affect the extent to which that metric is viewed as credible by study participants and decision-makers. However, credibility also addresses other factors, such as whether the metric is intuitively meaningful to study participants (e.g., what is a habitat unit?), which can affect the extent to which different participants may view a metric as decision-relevant and acceptable.

The table below considers four different types of metrics for measuring the effects of plans on life support services, and includes judgments on how they compare against these criteria. (See discussion on watershed services for the logic behind the rows in the table). Of course, the specific judgments made in any planning case would necessarily consider place- and situation-specific circumstances. Note that completing evaluation at the level of rows 2-4 in the table requires drawing upon the result of analysis completed for the rows above it.

Options for Representing Plan Effects on Life Support Services

Basis for Evaluation	**Example Performance Metrics**	**Time & Cost of Analysis**	**Uncertainty in Estimates**	**Credibility of Estimates**
Hydrologic and Geomorphic Structure & Processes	Change in area of connected floodplain & acres of wetlands; shape of hydrograph	Low	Low	High
Ecological Function	Index of Biotic Integrity; Habitat Suitability Indices for one or a community of species; Direct measure of some stage in the life cycle of a species of interest	Low to Moderate	Low to Moderate	Moderate to High
Service Levels	Direct measures of changes in biodiversity or populations of one or more target species	Moderate to High	High	Moderate to High
Economic Value (WTP)	Alternative cost; Net income; Revealed and stated preferences for use (recreation) and non-use of services	Moderate to High	High	Low to High

To more fully appreciate the implications of the table for plan evaluation, consider as an illustration a planning objective (i.e., problem and opportunity to be addressed by planning) that is focused on a specific species, such as the endangered pallid sturgeon in the Missouri River. In that case, the planning objective might be described as "Increase the population of pallid sturgeon in the Missouri River for 30 river miles above and below Gavins Point Dam." Plan formulation for Corps actions that might contribute to this objective would require the development of a conceptual ecological model to describe how the relative effect of changes to the river's hydrologic and geomorphic structure & processes (row 1 of the table) would contribute to the defined planning objective. The development of the conceptual ecological model would be informed by reference to pallid sturgeon population dynamics in other watersheds that have viable populations and by analysis of past populations of pallid sturgeon in the river segment of interest. Of course, the desire would be to secure that end state in the most cost-effective manner, and the actions to meet that end state may extend beyond those within the authority of the Corps to implement. The conceptual ecological model for the Pallid sturgeon would help to identify the full range of actions required.

One could imagine a series of empirical models, based on the conceptual ecological model outlined above, corresponding to each row in the table, which could be used for evaluating and representing the effects of civil works interventions. For example, one possible intervention might be a series of structures (this could involve setting back a levee) at various locations along the river that reconnect the river to the floodplain with side channels that have certain flow velocities, depths, and other characteristics in order to create spawning areas for pallid sturgeon. The modeling in the first row would predict whether the structures would create such reconnections, and provide estimates of the acres of reconnected floodplain with the specified characteristics. This measure of reconnected floodplain acres might then serve as the metric for representing plan effects on the defined planning objective.

Instead of stopping the evaluation process at row 1 of the table, another model could be employed that uses the estimates of reconnected floodplain acres as one of many inputs to predict change in the quality and quantity of spawning areas for pallid sturgeon. The measure of effect might take the form of an index of habitat suitability for pallid sturgeon spawning. Alternatively, there might be a prediction of how many adults will enter the newly created areas, or spawning success once they enter the areas, or number of young pallid sturgeon that can enter into the river. These metrics relate to evaluation corresponding to row 2 in the table, and could serve as the metrics for representing plan effects on the defined planning objective.

Again, the evaluation process could continue on to modeling corresponding to row 3 and seek to predict growth and survival of the young pallid sturgeon in the river itself. This estimate of increased pallid sturgeon population is most closely related to the specified planning objective, and thus could serve as the metric for representing the effects of intervention.

Finally, evaluation of plan effects could continue further on to the last row and use an economic model that predicts the WTP value of the increase in the pallid sturgeon population resulting from the intervention. For example, the hypothesized value might relate to so called "non-use" preferences representing peoples' WTP to preserve the endangered pallid sturgeon in the Missouri River. In principle, such non-use values could be estimated using hypothetical choice (stated preferences) techniques such as "contingent valuation" that essentially involve structured public surveys that are designed in a way to elicit the choices that survey respondents would make if they had to pay for alternative states of nature. However, there is considerable disagreement over whether individuals' non-use preferences (as well as use preferences) for changes in life support services can be reliably estimated using stated preferences valuation techniques. Many objections to this approach have been articulated outside as well as within the economics profession.

In the specific example used here, which involves an endangered species, the significance of the species as a matter of federal interest is obvious and the nexus between the status of the population and Corps projects on the river is well-established. Therefore the need to monetize its value in order to justify plan formulation and investment by the Corps might be questioned (and is proscribed by current Corps policy). But even if planning in this case were focused on a wildlife species that is not endangered, calculations that trace through how interventions would affect human uses and preference satisfaction would be fraught with uncertainty, and the resulting WTP estimates might not be viewed as credible by at least some stakeholders.

To further illustrate that credibility challenge, consider how the general evaluation options described above might be applied to the choice of metrics for representing plan effects on ecological services (life support and waste assimilation services) when specified problems and opportunities focus on other watershed services. For example, consider a case in which the planning objective is specified as "reduce flood damages in community X," and where formulated plans might also affect ecological services in the watershed. Recall that in such contexts the conceptual framework for Corps planning (in section 4.3.2) calls for the formulation of a "protection and restoration plan" that makes a positive contribution to the defined planning objective while leaving current watershed hydrology unchanged (or restoring past hydrologic and geomorphic processes, when possible). Such a plan formulated to reduce flood damages might involve the restoration of an area of previously drained wetlands located along the river above the community. The extent to which restoration of previously drained wetlands along the river reduces flood peaks in the downstream community (a watershed service) would be estimated, and then the economic value (property damages avoided) calculated using well-accepted Corps procedures.

But how could the effects of plans on ecological services in this case be evaluated and represented? The restored wetlands might also trap nutrients that would otherwise enter the river. The reduced nutrient levels might have a positive effect on oxygen levels in the river, and then on populations of fish species that are prized by sport fishermen. Accordingly, the evaluation of these effects might seek to calculate nutrient reduction in the river (row 2) and then proceed to calculate the effect of nutrient reduction on the recreational fish population (row 3), and then recreational angler use and satisfaction and hence recreational anglers' willingness to pay for the nutrient reduction (row 4). However, that calculation would be characterized by increasing uncertainty with each evaluation step, and the resulting WTP estimate may not be viewed as credible by some stakeholders.

As an alternative to estimating and using complex bio-economic production functions to trace through the effects of plans on human uses and preference satisfaction, the increase in nutrient retention provided by the restored wetlands might be monetized in terms of the avoided costs associated with building a waste treatment facility that could provide the same level of nutrient reduction. However, professional economists and others have long criticized such "alternative cost" measures, since they are viewed as credible proxies for WTP only under highly restrictive conditions that rarely are in evidence.

In the end, different groups of people would make different judgments relating to the credibility of WTP estimates for representing the effects of plans on life support (and waste assimilation) services calculated using the valuation approaches outlined above. This is why the last cell of the table characterizes the credibility of WTP metrics for representing changes in ecological services as ranging anywhere from low to high, where credibility is judged by study participants and decision-makers.

As a general matter, judgments must be made about the preferred metrics for representing plan effects on life support services. Metrics that are based on hydrologic and geomorphic structure and processes, and to a lesser extent metrics based on ecological structure and function, rate best against choice criteria relating to predictability (time and costs of analysis as well as uncertainty) and credibility of estimates. These two evaluation bases have been used most frequently for the choice of metrics for representing plan effects on life support services in NER planning studies. For such metrics to be decision-relevant, however, they must be ecologically-meaningful in the sense that they can be conceptually linked to provision of the relevant life support services in any particular planning case.

As noted earlier, the choice of performance metrics for representing changes in life support services in any particular planning study would necessarily be place-specific and based on the central problems of concern. While metrics based on hydrologic and geomorphic structure and processes or ecological structure and function do not provide a direct representation of life support services, they can be useful for formulation and evaluation since they align with the types of watershed features that give rise to those services, and are generally more predictable and credible than metrics produced by the evaluation steps corresponding to rows 3 and 4 in the table.

That said, Corps policy might be revised to allow for use of any of the evaluation metrics included in the table, including WTP estimates, if the predictability and credibility criteria were met to the satisfaction of study participants and decision-makers. Whatever metric is chosen to represent changes in life support services in any planning case, that metric should be used to measure both positive and negative effects of alternatives on life support services, and to guide the determination of any necessary environmental compensatory mitigation.

Commentary

The need is to select and use evaluation metrics that are decision-relevant for the environments where planning takes place, and acceptable to and understood by non-federal sponsors and other study participants, such as federal resource agencies. Selection of metrics for the full array of affected watershed services is as much a bottom-up process for plan development as it is a top-down process that is directed by national policy and guidance.

Furthermore, given study budget constraints, performance must be measurable and predictable with some confidence using the types of models employed in planning. Of particular note here is that life support services, among all watershed services, has been the most difficult to define uniformly in a metric that is meaningful at a national scale. Further, changes in life support services are the most difficult to predict for a given change made to watershed structure and processes.

An alternative approach that would avoid these problems begins with the recognition that since life support services are closely aligned with natural watershed hydrology and geomorphology, proxy metrics for the effects of alternatives on life support services can be based on predicted hydrologic and geomorphic changes. Changes in these watershed attributes are most directly linked to civil works actions, and thus can be more readily and accurately predicted with an acceptable degree of uncertainty within study budget and time constraints. Such metrics have been successfully used in past NER planning. Metrics based on hydrologic and geomorphic outcomes must be ecologically-meaningful, however, and thus would necessarily be place-specific and based on the central problems of concern.

This approach to evaluating changes in life support services for civil works planning is recommended by the framework, and it would not be a radical departure from past practice. Proxy metrics for life support services based on ecologically-meaningful hydrologic and geomorphic metrics provide decision-relevant planning information in the same way that hydrologic metrics of flood damage reduction (level of protection) or water supply (safe yield) have assisted planning for many years. When such non-monetary metrics are employed, reference conditions for the relevant life support services can serve as a benchmark for comparing plans and deciding when one or more plans are “justified” (see box below).

As for the question of monetization of effects, the framework recommends that for all planning studies, including those that focus on ecosystem restoration, use of monetary metrics for evaluating all significant service changes that can be readily and credibly reported in monetary terms, and for which there is a tradition of employing monetary metrics for evaluation. For example, the monetary benefits of flood damage reduction for some community achieved by wetlands restoration in the watershed would be evaluated and reported in monetary terms in the same way that the flood damage reduction benefits for a levee would be evaluated and reported. On the other hand, for life support and waste assimilation services, the challenges to monetization described above need to be recognized. For this reason the framework leaves the decision on the extent of monetization of service changes, beyond the services that traditionally have been measured in monetary terms, to the participants in the planning collaboration; they can determine for themselves the credibility and hence the decision support utility of such measures.

Reference Conditions for Comparing and Justifying Alternative Plans

The decision-making challenge is to decide how much life support output is justified in consideration of financial and opportunity costs. Current Corps policy eschews monetization to justify a level of life support output. Instead, the District Engineer makes a recommendation on the justified level of output, as informed by cost-effectiveness and incremental cost (CE-IC) analysis. In a simple graphical display, one non-monetary metric of life support output would be displayed on the horizontal axis and net costs on the vertical axis. If the cost curve turns sharply upwards at some point, that inflection point helps to determine when additional units of the life support output may not be warranted by the cost required to achieve it.

However, the CE-IC framework does not define an end point that identifies where a higher level of investment cost to achieve a higher level of life support output is unwarranted. In the case of planning for recovery of an endangered species, such an end point would be a “viable” population that would make de-listing of the species possible. Outside the special case of planning for an endangered species, a possible end point for some life support output might be achieving some watershed reference condition.

Suppose the planning objective is to increase the population of a specific fish species in a river. The reference condition might consider a time in the past when the hydrologic conditions in the river supported what the planning stakeholders agree was a preferred level of the fish species. Based on that reference, a model of the hydrograph for that time could be developed and used to determine hydrologic indicators for representing plan effects on life support services, as well as for defining a target hydrograph corresponding to the preferred level of life support output. However, it does not follow that the recommended plan must meet the target hydrograph (indeed, it may be the case that none of the formulated plans could reach the target). The EC-IC analysis would be done and a judgment would need to be made on whether the incremental costs of plans that provide higher levels of life support output are justified.

End Notes

[1] The evaluation and comparison of alternatives will be against various choice criteria in order to support recommendation of a preferred alternative by multiple decision-makers (non-federal sponsor, District Engineer, Chief of Engineers, Office of Management and Budget, and the Congress). There can be no single bright-line computation that identifies the "best" alternative when there are multiple, non-commensurate choice criteria and multiple decision-makers. Therefore the intent of this framework is to produce a complete and useable display of the multiple and incommensurate measured effects of alternatives in order to best inform those who have the responsibility for choosing a preferred plan and recommending a federal funding contribution for implementing that plan.

[2] NEQ effects are expected to be realized over time and at the watershed scale as a result of plan implementation.

[3] Current Corps planning guidance uses the term "national economic development" effects to represent the economic efficiency implications of plans that lead to a reallocation of natural and human capital in the larger economy. In common understanding, however, that term refers to "economic growth" associated with the productivity of natural and human capital as reflected in changes in employment, wages, rents, and profits. In this framework, this category of effects relates to economic efficiency (rather than economic growth) and is labeled as national economic efficiency effects to avoid potential confusion. Beneficiaries' "Willingness to Pay" (WTP) for project outputs is a measure of economic benefits for economic efficiency evaluation. If infrastructure investments were to be evaluated for their potential to increase economic growth, this would require measures of economic performance that are different than WTP measures. If deemed necessary, further development of the framework could address measures for evaluating the implications of plans for economic growth, recognizing that such growth effects are most likely to be associated with inland navigation and port development planning contexts.

[4] Negative changes are foregone existing benefits (opportunity costs) of the current service flows from the water and related land resources system, including the benefits that currently are realized from the engineering works now in place.

[5] This corresponds to the Environmental Quality "account" in current Corps planning guidance, except that environmental effects at the watershed scale have been separated out for isolation in the new NEQ effects category.

[6] Evaluation of the employment and income effects of alternatives on low income, minority, and tribal communities is the only place in this framework where the evaluation of what current Corps planning guidance calls "regional economic development" (RED) effects are deemed relevant. Other than for this subset of the affected population, RED effects are not relevant as a federal evaluation criterion because such impacts have long been recognized as representing transfers of economic activity rather than national economic efficiency effects.

[7] Scoping in this framework is given added importance relative to how it is addressed in current Corps planning guidance.

[8] An alternative term to describe the need to define the systems of interest would be "planning scope" to emphasize both the geographic and non-geographic elements of the relevant systems.

[9] This is the same watershed scale used when considering the effects of wetlands dredge and fill permitting and compensatory mitigation offsets (e.g., mitigation banking) within the Corps regulatory program.

[10] Consider the analogy of a throw of perfectly balanced dice. In this case there is no knowledge uncertainty because we know that the possible outcomes must be between 2 and 12. However, for any given throw we can only assign a probability to the outcome. Continuing with this analogy, if we were handed the dice and knew little about them we would have knowledge uncertainty (the dice might not be balanced). We could invest in testing the balance of the dice and in so doing reduce knowledge uncertainty. The dice example can be misleading, however. The throw of a dice is a “closed” system, meaning that we may not know the outcome for any throw, but we can place bounds on and assign probabilities to the range of possible outcomes if the dice are balanced. If the system were instead “open,” that would mean that there were many unknown and unknowable external factors that could cause the future outcome to fall outside the range we might expect. Many argue that environmental and economic systems are open systems and so uncertainty due to knowledge uncertainty as well as unbounded natural variability may exist. Some would use this argument to advocate for a precautionary principle decision rule. However, the precautionary principle implicitly favors the status quo, and change may be desired. Beyond the precautionary principle, plan formulation could include redundancy and feedback elements, and a “robustness” criterion might be one decision factor. If incremental implementation were possible and committed to, then adaptive management strategies might be favored.

[11] The reasons path 1 was followed, including but not limited to limited study resources, should be justified. The qualifications of the professionals and experts whose judgments were used to assign values to key parameters and variables should be described.

[12] When forecasting future, without-project conditions when the level of uncertainty in future resource conditions makes it impossible to reasonably bound the range of possible plan outcomes, then scenarios representing different potential future resource conditions should be employed for plan formulation, evaluation, and display. Subsequent evaluations of plan effects would then be made under the different scenarios. When there is evidence that evaluations of plan effects are sensitive to the different scenarios, analysts should report on that uncertainty and provide a written characterization of the premises underlying each alternative scenario that identify what would need to happen for the scenario to be realized (the concept of “premise sets” can be used to achieve this result).

[13] A compelling application of premise-based scenario planning can be found in: U.S. Army Corps of Engineers, Portland District. 1985. Decision Document – Mt. St. Helens, Washington. In-House Document 99-135, December 10, 1985. Communication from the Assistant Secretary of Army (Civil Works). Washington, DC: Government Printing Office.

[14] Gail Bingham, President Emeritus of RESOLVE, contributed to the development of the conceptual logic in this section. Ms. Bingham served as a Senior Fellow at IWR during 2009, has mediated water policy and other natural resources issues for over 30 years, and is the author of numerous publications including, *When the Sparks Fly: Building Consensus When the Science is Contested*.

[15] The concept of "Circles of Influence" can be applied to organize the different options for engagement. http://www.computeraideddisputeresolution.us/bestpractices/circlesofinfluence.cfm

[16] This list is adapted (with significant changes) from: http://www.fermilabcommunity.org/pdfs/spectrum.pdf

[17] A consideration in choosing a level of engagement is the constraints imposed by the Corps' internal review process and the Federal Advisory Committee Act (FACA). If the levels of engagement deemed warranted by IWRM are to be realized, the Corps should review its current internal review polices and interpretations of FACA to maximize the possibility for engagement, and then issue clarifying guidance to its field offices.

[18] This section of the framework is written with only limited attention to the implications of uncertainty and the level and form of agency and stakeholder engagement. Any further development of this framework would need to address how the description of standard planning elements might need to be altered to better incorporate options for addressing uncertainty and agency and stakeholder engagement. For example, if a full "Shared Vision Planning" process for engagement were to be employed, the planning elements and the sequence in which they are addressed might be changed. See: http://www.iwr.usace.army.mil/docs/iwrreports/10-R-5.pdf

[19] This wording is meant to distinguish "objective-based planning" from "target-based planning," although targets based on statements and goals may become constraints on planning (e.g., meeting a water quality standard or securing some minimum level of residual risk) or a focus of planning (ESA requirements). The recognition of such constraints is addressed in plan formulation and can be accommodated in plan evaluation. See: Deason, J.P., Dickey, G.E., Kinnell, J.C. and Shabman, L.A. "An Integrated Planning Framework for Urban River Rehabilitation," Journal of Water Resources Planning and Management, November/December 2010.

[20] Note that in current Corps planning guidance, the list of formulation criteria includes "efficiency" as a fourth formulation criterion. It states, "Efficiency is the extent to which an alternative plan is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities." In effect, efficiency is a way to remove "dominated" (clearly inferior) plans from further consideration. However, the concept of a dominated plan is difficult to apply as an operational matter in the multi-criteria decision setting, at least at this planning stage. See the Phase 1 display discussion (later in framework) where the concept of removing dominated plans from final consideration is addressed.

[21] This formulation criterion will consider preliminary and conceptual determinations of the types and extent of compensatory mitigation that would be needed to offset the adverse environmental impacts at the watershed and sub-watershed scales, as well as any adverse impacts of plans on current watershed uses as part of the acceptability screen.

[22] The issue paper on floodplains, flood risk management and public safety, which is included in Appendix A to this paper, outlines the reasons for formulating a Protection and Restoration Plan when the planning problem and opportunities include flood risk management.

[23] The explicit formulation of a Protection and Restoration Plan (PRP) contributes to creating a consistency between the way that compensatory environmental mitigation plans are developed for civil works planning, and the ways such compensation plans are expected to be developed for permitted dredge and fill projects under section 404 of the CWA. The matter of consistency between the compensatory mitigation planning in these two areas of Corps responsibility is a current focus of concern. However, unlike the 404 permitting context, the conceptual civil works planning framework presented here does **not** dictate selection of the PRP as the preferred alternative.

[24] Note that the purpose of formulating a plan that includes adaptive management elements is to address analytical uncertainty. An adaptive management plan is not one that calls for refining and modifying all elements of the plan over time, which is a process more appropriately called "evolutionary problem solving." More description of the minimum requirements for an adaptive management plan and explanation of the distinction made here between adaptive management and evolutionary problem solving would be provided in any further development of this framework.

[25] This characterization of NEE measurement recognizes that the same NEE effect can sometimes be evaluated in affected input markets (the economic value of water and related land resources) or alternatively, in affected output markets (the economic value of the national output of goods and services produced using water and related land resources). For assessing the benefits of flood damage reduction, however, restrictions on measuring NEE effects in input markets (using land market analysis) are needed because of myriad issues relating to the subjective perceptions of flood risk on the part of land market traders that make this approach conceptually problematic.

[26] The negative changes in the future, without-project condition relative to the reference condition must be the result of past Corps and non-Corps actions, and not be the result of future non-Corps actions. Otherwise, the plan would represent Corps-funded mitigation for non-Corps activities.

[27] For further discussion of NEQ metrics for evaluation, see Appendix B. Substantial additional development of the NEQ metrics discussion is possible and would be required in any further development of the framework.

[28] When applicable, these plan effects will serve as additional considerations in determining the set of plans that are offered for possible recommendation. For example, a GIS mapping with readily available data would allow the analysts to spatially display the risk reduction and residual risk levels (property damages and population at risk) in flood-prone areas, with and without a plan in place. The analyst could then overlay those results with the socio-economic descriptors of those groups located in flood prone areas and display (in map and/or tabular form) how the risk reduction benefits and residual risk to those groups are affected by alternative plans.

[29] This sentence is intended to provide general guidance on the application of monetization to ecological life support services. Further explanation can be found in the issue paper on evaluation included in Appendix B to this paper.

[30] The question of whether to discount NEQ effects in the same way as NEE effects is partly addressed by the requirement to display the time path of NEQ effects.

[31] This section addresses concerns relating to effects of public programs on the NEE calculations; for example, the use of agricultural prices that are significantly influenced by federal agricultural policies.

[32] For example, adverse effects on NEQ and OEQ should each be shown alongside a description of the conceptual compensation plan for these adverse effects as well as the estimated financial costs of implementing the compensation plan. Similarly, any evaluated adverse effects of a plan on existing watershed uses (e.g., recreation), should be shown alongside a description of any conceptual compensation plan for these effects as well as the estimated financial costs of implementing the compensation plan.

[33] The purpose of using the Protection and Restoration Plan as a point of reference for evaluating incremental NEE and NEQ effects is to be responsive to the often expressed criticism that Corps planning does not formulate and consider plans that address problems and opportunities while avoiding adverse impacts on the environment. In many (perhaps most) planning cases, opportunities for fully addressing problems and opportunities while avoiding adverse impacts on the environment may be limited or non-existent. For example, a Protection and Restoration Plan formulated to serve flood damage reduction (e.g., a plan involving permanent removal of structures in one area of a floodplain) may involve unacceptably high residual flood risks for adjacent properties. As another example, a Protection and Restoration Plan for improving deep draft navigation (e.g., a plan involving freight queuing or riding existing tidal changes) may not sufficiently address a defined problem of high harbor access costs for container ships. In such cases, the incremental analysis can help decision-makers to document limitations of the Protection and Restoration Plan for alleviating problems and realizing opportunities, while at the same time use that plan to systematically consider and balance the incremental NEE and NEQ effects of other plans in decision-making.

[34] While the Protection and Restoration Plan serves as a point of reference for Phase 2 plan comparison, and should be carried forward for selection consideration when it meets all formulation criteria, **there is no presumption that this plan should be selected as the preferred alternative**.

[35] Section 3.2.1 (e)(3) describes the different levels of engagement with others in planning. Aside from level 1 (inform), the other levels of consult, involve, collaborate and shared decision-making imply that decisions by the District Engineer on a recommendation of the preferred plan cannot be made in isolation from the preferences of other entities. Ideally, the District Engineer might lead a deliberative process to reach agreement on a preferred plan and organize that discussion around the plan display and comparison information.

[36] Examples of possible aggregate decision criteria include one or more of the following: net NEE, robustness, and NEQ incremental justification. Further identification and explanation of possible aggregation options can be prepared as part of any extension of this framework. In addition, the administration budget process might require certain aggregation results to be reported. However, if aggregation is used and reported in the justification narrative, the report should still include the plan display and comparison information and relate the creation of the aggregation criteria to that information.

Visiting Scholar Program

Maass-White Visiting Scholar Fellowship

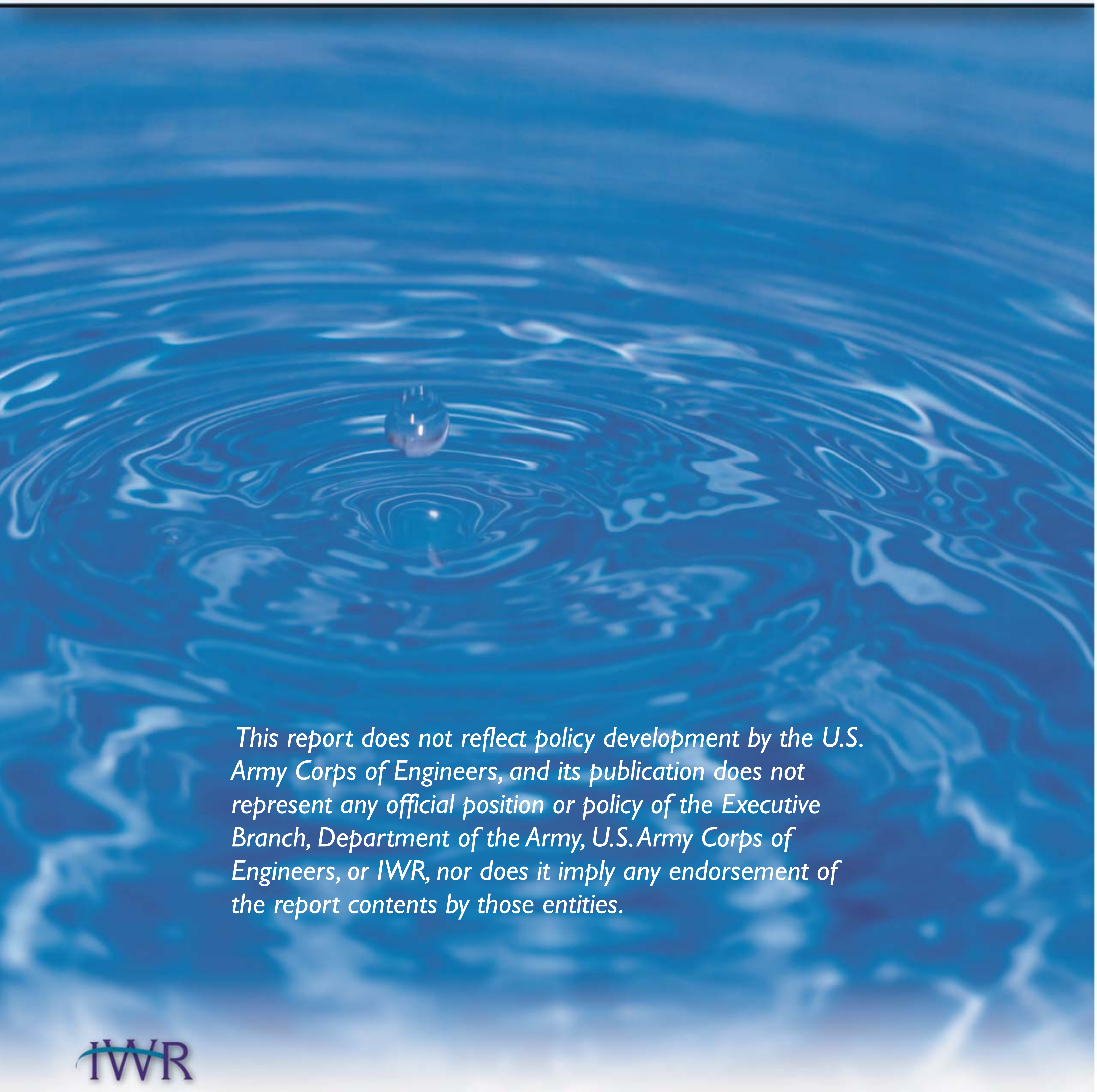
Dr. Leonard Shabman

Dr. Leonard Shabman served as the IWR Maass-White Visiting Scholar during 2004–2006 and since then as IWR Visiting Scholar, where he worked on a variety of activities connected with the overarching theme of water resources planning and policy analysis. Dr. Shabman's primary employment is as a Resident Scholar with Resources for the Future in Washington, DC. He joined Resources for the Future in 2002 after three decades on the faculty at Virginia Tech.

Dr. Shabman has served as a staff economist at the United States Water Resources Council and as Scientific Advisor to the Assistant Secretary of Army. At Resources for the Future his research and communications efforts are focused on programs for flood and coastal storm risk management, design of payment for ecosystem services programs, water quality management under the Clean Water Act, and development of evaluation protocols for ecosystem restoration and management projects, with special focus on the Everglades, Coastal Louisiana and Chesapeake Bay. He served for eight years on the National Research Council's Water Science and Technology Board and has been recognized as an Associate of the National Academy of Sciences.

About the Fellowship

The Maass-White Visiting Scholar Fellowship is designed to ensure that today's water resources challenges benefit from innovative thinking of the nation's top academics, and to promote a deeper understanding of real-world water resource problems by those in academia. The fellowship honors the late Arthur Maass and Gilbert F. White -- two scholars who had a revolutionary impact on the practice of water resources planning and management. Recognizing the importance of scholarship in water resources management, the Institute's Maass-White appointment is offered annually to a scholar whose works promote innovative, substantive reforms in water resources policy, research or analysis. The appointment enables a scholar to work on critical contemporary issues alongside the technical staff of the U.S. Army Corps of Engineer's Institute of Water Resources, either in the Washington DC area or at the Hydrologic Engineering Center in Davis, California.



This report does not reflect policy development by the U.S. Army Corps of Engineers, and its publication does not represent any official position or policy of the Executive Branch, Department of the Army, U.S. Army Corps of Engineers, or IWR, nor does it imply any endorsement of the report contents by those entities.

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2012-VSP-01

USGS Award No. G12AP20043 Modernizing the United States Army Corps of Engineers Planning and Regulatory Policies and Programs - Phase V

Basic Information

Title:	USGS Award No. G12AP20043 Modernizing the United States Army Corps of Engineers Planning and Regulatory Policies and Programs - Phase V
Project Number:	2012VA161S
Start Date:	2/1/2012
End Date:	10/31/2013
Funding Source:	Supplemental
Congressional District:	VA-9
Research Category:	Social Sciences
Focus Category:	Management and Planning, Law, Institutions, and Policy, None
Descriptors:	
Principal Investigators:	Stephen H. Schoenholtz, Leonard Shabman

Publications

There are no publications.

Modernizing USACE Planning and Regulatory Policies and Programs – Phase V

Dr. Shabman has prepared a background analysis for the Corps levee safety program on

1. the relationship of FEMA and Corps levee assessment procedures and
2. the role of benefit cost analysis is levee safety decision making. The content of both papers are under consideration in the program for possible use in the design of a levee safety engineer regulation.

No reports are currently available.

Information Transfer Program Introduction

The VWRRC supports timely dissemination of science-based information to policy- and decision-making bodies and to citizens. The VWRRC used its 104 funds to support expert personnel with responsibilities related to the VWRRC's outreach and collaborative programs. In FY 2011, the 104 funds supported:

(1) Preparation and electronic publication of the newsletter *Virginia Water Central*.

(2) Partial support for organizing the 2011 Virginia, West Virginia, Kentucky Water Research Symposium.

(3) Partial administrative support for the Virginia Water Monitoring Council.

4) Partial support for production and management of the VWRRC webpage, VWRRC Facebook, VWRRC Twitter, and Virginia Water Radio.

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2011VA150B
Start Date:	3/1/2011
End Date:	2/29/2012
Funding Source:	104B
Congressional District:	VA-9
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	Stephen H. Schoenholtz

Publications

1. Zimmer, M., S.W. Bailey, K.J. McGuire, and T.D. Bullen. 2012. Fine scale variations of surface water chemistry in an ephemeral to perennial drainage network. *Hydrological Processes.* DOI 10.1002/hyp.9449
2. Kruitbos, L.M., D. Tetzlaff, C. Soulsby, J. Buttle, S. Carey, H. Laudon, J. McDonnell, K. McGuire, J. Seibert, R. Cunjak, and J. Shanley. 2012. Implications of changing hydro-climatic controls for Plecoptera diversity in northern catchments. *Hydrobiologia.* DOI 10.1007/s10750-012-1085-1
3. Kelleher, C., T. Wagener, M. Gooseff, B. McGlynn, K. McGuire, and L. Marshall. 2012. Investigating controls on the thermal sensitivity of Pennsylvania streams. *Hydrological Processes.* 26(5): 771-785
4. Danehy, R.J., R.E. Bilby, R.B. Langshwa, D.M. Evans, T.R. Turner, W.C. Floyd, S.H. Schoenholtz, and S.D. Duke. 2012. Biological and water quality responses to hydrologic disturbances in third order forested streams. *Ecohydrology* 5(1):90-98
5. Devine, W.D.., T.B. Harrington, T.A. Terry, R.B. Harrison, R.A. Slesak, D.H. Peter, C.A. Harrington, C.J. Schilling, and S.H. Schoenholtz. 2011. Five-year vegetation control effects on aboveground biomass and nitrogen content and allocation in Douglas-fir plantations on three contrasting sites. *Forest Ecology and Management.* 262(12): 2187-2198/ DOI 10.1016/j.foreco.2011.08.010
6. Slesak, R.A., S.H. Schoenholtz, and T.B. Harrington. 2011. Soil carbon and nutrient pools in Douglas-fir plantations five years after manipulating biomass and competing vegetation in the Pacific Northwest. *Forest Ecology and Management.* 262(9): 1722-1728
7. Northington, R.M., E.F. Benfield, S.H. Schoenholtz, A.J. Timpano, J.R. Webster, and C.E. Zipper. 2011. An assessment of structural attributes and ecosystem function in restored Virginia coalfield streams. *Hydrobiologia* 671(1):51-63. DOI 10.1007/s10750-011-0703-7
8. Kelly, C.N., S.H. Schoenholtz, and M.B. Adams. 2011. Soil properties associated with net nitrification following watershed conversion from Appalachian hardwoods to Norway spruce. *Plant and Soil* 344(1):361-376. DOI 10.1007/s11104-011-0755-5
9. *Virginia Water Central,* July 2011 (No. 56), 38pp.
10. *Virginia Water Central,* January 2012 (No. 57), 36pp.

Information Transfer and Outreach

Newsletter *"Virginia Water Central"*

Email distribution to 680 recipients and announcement/availability on VWRRC Web site.

Notifications to Virginia Water Monitoring Council List Serves

The VWRRC provides administrative support to the Virginia Water Monitoring Council (VWMC). The VWMC was formed to promote and facilitate coordination of water monitoring programs throughout the Commonwealth of Virginia. Membership in the VWMC is open to any person or organization with responsibility for or interest in water monitoring in Virginia. Weekly water-related announcements via list serve are provided to 530 members (representing more than 250 different organizations) of the VWMC. Announcements include information about conferences, workshops, total maximum daily load (TMDL) public meetings in Virginia, job openings, newly published reports, information posted on Web sites, and other pertinent information.

1. Distributed 40 sets of general announcements as e-mail messages to the VWMC membership; each message contained at least a dozen informational announcements (545 announcements in total), including: calls for papers, conference announcements, job openings, training opportunities, recently published reports, etc. Distributed almost 290,000 general announcements (545 announcements x 530 members).
2. Developed 16 sets of special announcements and distributed these as e-mail messages to the VWMC membership for a total of 120 special announcements; these announcements pertained to VWMC-sponsored activities and information about beach-monitoring and water recreation as specified in grants from the

Virginia Department of Health (VDH). Distributed more than 63,000 special announcements (120 announcements x 530 members).

3. Weekly announcements are posted on the VWMC's website, www.vwrrc.vt.edu/vwmc

VWRRC Website (see www.vwrrc.vt.edu)

The VWRRC website is updated at least weekly and supports a Water News Grouper page, which is updated several times each week. The VWRRC website also serves as the portal for three other websites that the VWRRC manages:

1. Virginia Water Monitoring Council (http://www.vwrrc.vt.edu/vwmc/default.asp)

2. Virginia Department of Conservation and Recreation Stormwater BMP Clearinghouse (http://www.vwrrc.vt.edu/swc/)

3. Clinch-Powell Clean Rivers Initiative (http://www.vwrrc.vt.edu/cpcri/default.asp)

VWRRC is on

Twitter at http://twitter.com/VaWaterCenter and

Facebook (http://www.facebook.com/pages/Blacksburg-VA/Virginia-Water-Resources-Research-Center/186479556264?v=wall)

Virginia Water Radio (www.virginiawaterradio.org)

The VWRRC produces and hosts a weekly 5-minute radio show featuring summaries of recent water news, upcoming water events, and water-related sounds or music.

2011 Virginia, West Virginia, Kentucky Water Research Symposium

(http://vwrrc.vt.edu/symposium_coal2011.html)

The 2011 Virginia, West Virginia, Kentucky Water Research Symposium *"Coal and Water in Central Appalachia: The challenge to balance"* was co-sponsored by the institutes for water resources research in Virginia, West Virginia, and Kentucky and held on the campus of Virginia Tech November 15, 2011. Invited experts from the region provided contemporary insights into the policies and scientific information associated with water resources and coal mining in the central Appalachians. Representatives of federal and state agencies and the coal industry provided perspectives on water-protection policies that affect mining operations. Technical presentations by university scientists addressed the influences of coal mining practices on total dissolved solids, selenium, aquatic biota, and hydrology of rivers and streams in the region. Symposium participants had the opportunity to ask questions and participate in lively group discussions. A capacity audience of approximately 120 people attended the Symposium.

International Outreach Activities

1. Associate Director McGuire is invited member/co-leader of scientific steering group: Theme 2: Conceptualization of process heterogeneity, Predictions in Ungauged Basins (PUB) Initiative of the International Association of Hydrological Sciences (IAHS), 2008-present.

2. Associate Director McGuire is co-principal investigator of the Northern Watershed Ecosystem Response to Climate Change (NORTH-WATCH), which involves organization of annual international workshops, 2009-2011.

3. VWRRC Faculty serve as referees for numerous international journals.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	8	0	1	0	9
Masters	5	0	0	0	5
Ph.D.	5	0	0	0	5
Post-Doc.	1	0	0	0	1
Total	19	0	1	0	20

Notable Awards and Achievements