Appendix F
Generic Detailed Hydrologic Engineering Management Plan (HEMP) for a Water Supply Investigation

F-1. Sample Detailed HEMP

This sample detailed HEMP can be used as a guide for the hydrologic and hydraulic analysis needed for conducting a water conservation or a storage reallocation study. Examples might include: a water supply allocation plan for a new reservoir project; a drought operating plan for an existing reservoir project or system of projects; and a system-wide reevaluation of a master water control plan considering the potential of benefit reallocation. The analysis would typically employ a reservoir simulation model such as the Hydrologic Engineering Center (HEC)-5 or HEC- Prescriptive Reservoir Model (PRM). Flood control criteria might affect conservation purposes; therefore, flood routing studies may be required, and perhaps a rainfall-runoff model would be employed. The goal would be to evaluate nominated alternatives of storage quantities, firm water supply yields, seasonal rule curves, and instream flow goals by model simulation. The alternatives would be judged by comparing regulated flood frequency curves, low-flow frequency curves, reservoir elevation-duration curves, etc.

F-2. Preliminary Investigations

This is a preparatory phase that includes scoping the project, deciding upon and gathering data, coordinating with agencies affected by the study, etc. (Experience has shown that more than 50 percent of the study's budget can be consumed by data gathering and preparation.)

a. Initial preparation.

(1) Identify agencies/parties with which coordination is needed - for data, operational requirements.

(2) Identify problem, scope study objectives.

(3) Review existing documents.

(a) Design documents.

(b) Interagency agreements.

(c) Previous studies by Corps.

(d) Studies by other agencies.

b. Choice and application of models.

(1) Research, obtain consultation (HEC and others) on which models to employ and how they can be applied.

c. Obtain historic hydrologic/meteorological data.

(1) Project operating records; e.g., reservoir elevations, outflows.

(2) U.S. Geological Survey (USGS) streamflow records.

(3) National Weather Service (NWS) precipitation and temperature data.

(4) Evaporation records.

(5) Snow data.

(6) Irrigation withdrawals.

(7) Consumptive use (municipal and industrial) records.

d. Obtain project requirements and alternatives to be investigated.

(1) Municipal and industrial requirements.

(2) Instream flow requirements.

(3) Mandatory reservoir requirements.

(4) Alternative storage capacities.

(5) Future irrigation demands.

e. Scope major hydrologic activities; choose models.

f. Prepare detailed HEMP.

F-3. Develop Hydrologic Data for Analysis

a. Load raw data into study database (usually HEC-Data Storage System (HECDSS)).

(1) Develop naming conventions/database structure. Ascertain computer requirements. Consult with experts where necessary.

(2) Download data from various sources.

(3) Rough check data viability by display or screening processor.

b. Process hydrologic data for model input (streamflow data). This is a very important and potentially time-consuming step in which a uniform database of streamflow is derived, to be used as inflows in reservoir regulation models. Although monthly data are typically used, a shorter time period (daily or more frequent) may have to be developed if flood regulation analysis is involved. Take full advantage of HEC-DSS-linked programs (STATS, DSSMATH, etc.) to evaluate and process data.

(1) Perform cross-station checks such as double-mass plots to reveal record inconsistencies. Evaluate and correct as necessary.

(2) Decide on period of record to be used, considering data availability and incorporation of significant events.

(3) Estimate missing data.

(4) Compute storage changes at upstream reservoirs. Adjust historic records to remove effects of historic upstream reservoir regulation.

(a) Convert elevations to storage, if necessary, for each project.

(b) Calculate adjusted streamflow at downstream stream gages.

(c) Accumulate storage adjustments where more than one reservoir is involved.

(d) Produce tabulations, statistical summaries for checks.

(5) Process/estimate irrigation depletion data. Correct historic records for changes in irrigation diversions.

(a) Review irrigation records; determine magnitude of impact on study.

(b) Decide on scope of effort.

(c) Compute year-by-year historic diversions and return flows.

(d) Estimate future irrigation depletions.

(e) Compute changes in irrigation: future-historic.

(f) Prepare final computation of corrected flows.

(g) Produce display statistics of final irrigation quantities to be used.

(6) Prepare final computations; display and check data and formatting for model input.

(a) Perform checking computations to check data validity (e.g., compute locals).

(b) Prepare final production of statistical summaries, displays.

(c) Prepare final formatting for model input.

c. Derive synthetic (stochastic) monthly flow record (optional). In addition to the historic period of monthly flows, it may be desirable to employ a synthetic flow sequence, derived by stochastic techniques. This would be particularly important when multiple-year critical periods are being encountered.

(1) Consult with HEC and others on best available programs and techniques to derive a stochastic flow record, given the basin configuration and analysis requirements.

(2) Review technical publications; find examples of applications.

(3) Obtain computer programs, run on test data.

(4) Determine scope and cost of work and benefits of using stochastic record.

(5) Prepare input to stochastic flow generator as program requires.

(6) Analyze output to ascertain its statistical soundness. Revise input as needed.

d. Derive historic or synthetic flood flows. A water supply investigation or storage allocation study may require analysis of flood control criteria. If so, historic and/or synthetic flood hydrographs are needed. Examples of synthetic floods are design floods such as the Standard Project Flood; or, different spacial and temporal flood patterns that appear plausible but have not been observed historically. Derivation of such events would employ a runoff model. (See Appendix D for generic HEMP guidance.)

F-4. Preliminary Analysis

Prior to extensive analysis with hydrologic models (or in place of, for small-scale studies) it may be desirable to perform manual, short-cut water conservation analyses. These include procedures such as (1) mass-curve analysis for identifying critical periods and estimating firm yields; (2) limited scope sequential accounting using a spreadsheet or DSSMATH; and (3) low-flow frequency or flow-duration analysis.

a. Obtain references and consultation on use of methodology as necessary.

(1) Search literature as necessary.

(2) Consult with HEC and others.

(3) Decide on methodology to use.

b. Obtain or construct spreadsheet, computer programs, or other computational procedures.

(1) Obtain or develop computer code.

(2) Test program/spreadsheet.

(3) Develop display routines.

c. Prepare data input for analysis procedure. (See Paragraph F-3.)

d. Obtain project demands, requirements.

(1) Analyze requirements for validity.

(2) Prepare input for program being used.

e. Perform analysis with nominated alternatives to be considered.

(1) Verify technique on current data, if possible.

(2) Execute technique with each alternative.

f. Display results, document as necessary.

F-5. Develop Models for Detailed Study

This phase of the analysis involves the setting up, calibrating, and testing of computer models that are to be used in the analysis. An important part of this effort also is the processing of basic data that are needed for the model simulations. The following outline assumes that a reservoir simulation model with a monthly time-step (e.g., HEC-5) is to be employed, for analysis of seasonal or multi-year reservoir operations. An additional potential evaluation preliminary to HEC-5 is the use of HEC-PRM, a “prescriptive” network-flow model which is used to investigate relative values of alternative operating objectives and strategies in a reservoir system. Also, for flood control evaluations a precipitation-runoff model coupled with a short-term reservoir system and basin routing model might be needed. This might be HEC-1 and HEC-5, the North Pacific Division (NPD) SSARR Program (Streamflow Synthesis and Reservoir Regulation), or the Southwest Division (SWD) Reservoir Simulation and Routing Program.

a. Derivation of prescriptive model: HEC-PRM (optional). A prescriptive model can be used in multiple-purpose reservoir systems to help define the most desired operation, given relative economic values (or penalties) assigned to operating constraints and objectives.

(1) Consult with HEC and/or other users of this model.

(2) Obtain program; develop understanding of its application, requirements, end products.

(3) Decide on use of program and scope of effort.

(4) Formulate basic model structure to represent reservoir system. Decide upon location of reservoirs, nodes.

(5) Define penalty functions at nodes and reservoirs.

(a) Coordinate with economics personnel for penalty function derivation.

(b) Obtain indicators of economic impact versus flow or stage: flood damage, power values, recreation, instream flow (fishery, water quality), navigation, irrigation, and municipal and industrial.

(c) Plot penalty functions and input into model.

(6) Execute model with first estimate of current conditions and constraints.

(7) Check results (seasonal reservoir elevations) against real-world conditions. Modify penalty functions to obtain intuitively “calibrated” model. Repeat model adjusting as necessary.

(8) Perform production runs.

(a) Sensitivity analysis of economic functions.

(b) Potential future changes in operating constraints.

b. Develop descriptive model for monthly routing, e.g., HEC-5. A descriptive model performs a period-by-period simulation of reservoir operation following rule curves and other operating variables. The rule curves represent alternative possibilities of operation, reflecting both existing and nominated alternative conditions. Either may have emerged from the results of the prescriptive model simulation performed above.

(1) Consult as necessary on use and application of model. Obtain program and test.

(2) Formulate basic model structure to represent reservoir system. Decide upon location of reservoirs, control points.

(3) Prepare reservoir model characteristics.

(a) Reservoir elevation/area/storage capacity tables.

(b) Powerhouse characteristics.

(c) Tailwater ratings.

(d) Outlet constraints (maximum, minimum, rate-of-change, etc.).

(4) Prepare river system characteristics.

(a) Irrigation diversion relationships.

(b) Routing characteristics (for flood hydrograph routing).

(c) Natural lake characteristics - elevation/storage/outflow.

(d) Evaporation.

(5) Prepare reservoir rule curves (existing conditions if for an existing system).

(a) Seasonal flood control curves.

(b) Seasonal proportional draft curves.

(c) Other rule curves.

(6) Develop procedures for output display and summary.

(7) Execute model for initial test runs. Check results for reasonableness against known conditions.

(a) Historic regulated flows at control points.

(b) Historic reservoir elevations.

(c) Historic power generation.

(d) Low flow (7-, 10-day volumes, etc.) and flood frequency curves.

(8) Adjust model parameters to obtain a calibrated and tested model. Repeat above steps as necessary.

c. Develop daily (or shorter period) flow routing model.

(1) Determine basin configuration for model.

(a) Control/damage points.

(b) Routing reaches.

(c) Diversions.

(d) Lake characteristics.

(e) Backwater effects.

(2) Derive routing characteristics for individual reaches.

(a) Choose routing method and model.

(b) Obtain data to derive routing coefficients.

(c) Determine local inflows.

(d) Perform routings.

(e) Adjust model characteristics as necessary until calibration is achieved.

(3) Verify total basin model by simulating historic records and comparing with observed data.

F-6. Alternative Evaluations

This task is the “heart” of the water control management study, requiring repeated simulations with nominated alternatives of reservoir operating policies and procedures. It would be performed in close coordination with the interdisciplinary planning team. Alternatives may have been suggested by the prescriptive model, if used, or by the team’s agreed-upon formulations.

a. Define nominated alternative; prepare operating rule curve or other criteria accordingly.

b. Execute model; display and examine results.

(1) Seasonal reservoir elevations - number of refill failures, frequency curves, etc.

(2) Instream flow frequency, duration.

(3) Flood frequency curves.

(4) Power generation.

(a) Firm energy.

(b) Average energy.

(c) Capacity.

c. Repeat with alternatives; perform sensitivity tests as necessary.

d. Prepare model results for briefings, public meetings, etc., as necessary.

e. Document results.