

## CHAPTER 1

### INTRODUCTION

1-1 **PURPOSE.** This document establishes general concepts and procedures for the hydrologic design of surface and subsurface structures for the U.S. Army, Navy, Air Force, Marine Corps, and Federal Aviation Administration (FAA).

1-2 **SCOPE.** This UFC applies to all service elements and contractors preparing UFC.

1-3 **REFERENCES.** Appendix A contains a list of references used in this UFC.

1-4 **UNITS OF MEASUREMENT.** The unit of measurement system in this document is the International System of Units (SI). In some cases inch-pound (IP) measurements may be the governing critical values because of applicable codes, accepted standards, industry practices, or other considerations. Where the IP measurements govern, the IP values may be shown in parenthesis following a comparative SI value or the IP values may be shown without a corresponding SI value.

1-5 **APPLICABILITY.** This document covers a wide range of topics in the areas of surface and subsurface drainage and serves as the standard for several agencies responsible for hydrologic design for airfields and areas other than airfields. The intended use of the facility under design may differ between agencies and in some cases dictates the need for separate standards. In special cases where more than one standard is presented, or the standard does not apply to all agencies, special care has been given to clearly identify the relevant audience. Any user of this manual should pay close attention to the relevance of each topic to the intended agency.

1-6 **GENERAL INVESTIGATIONS.** An on-site investigation of the system site and tributary area is a prerequisite for study of drainage requirements. Information regarding capacity, elevations, and condition of existing drains will be obtained. Topography, size and shape of drainage area, and extent and type of development; profiles, cross sections, and roughness data on pertinent existing streams and watercourses; and location of possible ponding areas will be determined. Thorough knowledge of climatic conditions and precipitation characteristics is essential. Adequate information regarding soil conditions, including types, permeability or perviousness, vegetative cover, depth to and movement of subsurface water, and depth of frost will be secured. Outfall and downstream flow conditions, including high-water occurrences and frequencies, also must be determined. Effect of base drainage construction on local interests' facilities and local requirements that will affect the design of the drainage works will be evaluated. Where diversion of runoff is proposed, particular effort will be made to avoid resultant downstream conditions leading to unfavorable public relations, costly litigations, or damage claims. Any agreements needed to obtain drainage easements and/or avoid interference with water rights will be determined at the time of

design and consummated prior to initiation of construction. Possible adverse effects on water quality due to disposal of drainage in waterways involved in water-supply systems will be evaluated.

## 1-7 ENVIRONMENTAL CONSIDERATIONS

1-7.1 **National Environmental Policy.** The National Environmental Policy Act of 1969 (NEPA), approved 1 January 1970, sets forth the policy of the Federal Government, in cooperation with State and local governments and other concerned public and private organizations, to protect and restore environmental quality. The Act (Public Law 91-190) states, in part, that Federal agencies have a continuing responsibility to use all practicable means, consistent with other essential considerations of national policy, to create and maintain conditions under which man and nature can exist in productive harmony. Federal plans, functions and programs are to be improved and coordinated to (1) preserve the environment for future generations, (2) assure safe, healthful, productive, and aesthetically pleasing surroundings for all, (3) attain the widest beneficial uses of the environment without degradation, risk to health or safety or other undesirable consequences, ...and (4) enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources. All Federal agencies, in response to NEPA, must be concerned not just with the impact of their activities on technical and economic considerations but also on the environment.

1-7.2 **Executive Orders.** Executive Order 11514 of 5 March 1970 states that, "The Federal Government shall provide leadership in protecting and enhancing the quality of the Nation's environment to sustain and enrich human life. Federal agencies shall initiate measures to direct their policies, plans, and programs so as to meet national environmental goals." Executive Order 11752 of 17 December 1973 enunciates its purpose "to assure that the Federal Government in the design, construction, management, operation, and maintenance of its facilities shall provide leadership in the nationwide effort to protect and enhance the quality of our air, water, and land resources...."

1-7.3 **Environmental Considerations in DOD Actions.** DOD Directive 6050.1, 19 March 1964, establishes policy of the Department of Defense, as trustee of the environment, to demonstrate leadership and carry out its national security mission in a manner consistent with national environmental policies and host country environmental standards, laws, and policies. The directive requires that DOD components will:

"1. Assess at the earliest practical stage in the planning process and in all instances prior to the first significant point of decision, the environmental consequences of proposed actions.

"2. Review those continuing actions initiated prior to enactment of P.L. 91-190 for which the environmental consequences have not been assessed and ensure that any of the remaining actions are consistent with the provisions of the directive.

“3. Utilize a systematic interdisciplinary approach in planning and decision making.

“4. Prepare and process under the criteria contained in the directive a detailed environmental impact statement on every recommendation or report on proposals for legislation and other major defense actions which are expected to be environmentally controversial or could cause a significant effect on the quality of the human environment.

“5. Study, develop and describe appropriate alternatives to the recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources.”

1-7.4 **U.S. Army Environmental Quality Program.** AR 200-1, outlines the Army’s fundamental environmental policies, management of its programs, and its various types of activities, one of which, water resources management, includes minimizing soil erosion and attendant pollution caused by rapid runoff into streams and rivers. The overall goal is to “plan, initiate, and carry out all actions and programs in a manner that will minimize or avoid adverse effects on the quality of the human environment without impairment of the Army mission.” A primary objective is to eliminate the discharge of pollutants produced by Army activities. Provision of suitable surface drainage facilities is necessary in meeting this objective. Among the types of actions listed as requiring close environmental scrutiny because they may either affect the quality of the environment or may create environmental controversy are the following which pertain to surface drainage in the Arctic and Subarctic.

1-7.4.1 Real estate acquisition, disposal, and outleasing.

1-7.4.2 Proposed construction of utilities including drainage systems.

1-7.4.3 Constructing or installing open channels, ditches, culverts, or other barriers that might obstruct migration, passage or free movement of fish and wildlife.

1-7.4.4 Closing or limiting areas, such as roads or recreational areas, that were previously open to public use.

1-7.4.5 Proposed construction on flood plains or construction that may cause increased flooding, erosion or sedimentation activities.

1-7.4.6 Channelization of streams, diversions, or impoundment of water.

1-7.4.7 Proposed construction of pipelines and other drainage structures.

1-7.5 **U.S. Air Force Environmental Quality Program.** AFR 19-1 enunciates Air Force policy in compliance with above-stated NEPA executive orders and DOD directives. Procedures outlined are similar to those described for Army installations. AFR 19-2 establishes policies, assigns responsibilities, and provides guidance for

preparation of environmental assessments and statements for Air Force facilities. Sources and types of pollutants, pollution effects, and control measures are discussed.

1-7.6 **U.S. Navy Environmental Quality Program.** The Navy's Environmental Quality Initiative (EQI) is a comprehensive initiative focused on maximizing the use of pollution prevention to achieve and maintain compliance with environmental regulations. The EQI is a fundamental part of the Navy environmental strategy called AIMM to SCORE - Assess, Implement, Manage and Measure to achieve Sustained Compliance and Operational Readiness through Environmental Excellence.

1-7.7 **FAA Environmental Quality Program.** FAA Order 5050.4A, Airport Environmental Handbook, provides instructions and guidance for preparing and processing the environmental assessments, findings of no significant impact (FONSI), and environmental impact statements (EIS) for airport development proposals and other airport actions as required by various laws and regulations.

1-7.8 **Environmental Impact Analysis.** A comprehensive reference, "Handbook for Environmental Impact Analysis," was issued in September 1974. This document, prepared by the Corps of Engineers Construction Engineering Research Laboratory (CERL), presents recommended procedures for use by Army personnel in preparing and processing environmental impact assessments (EIA) and environmental impact statements (EIS). The procedures list step-by-step actions considered necessary to comply with requirements of NEPA and subsequent guidelines. These require that all Federal agencies use a systematic and disciplinary approach to incorporate environmental considerations into their decision making process. Eight major points to be covered by environmental impact statements are listed as follows:

1. A description of the proposed action, a statement of its purpose, and a description of the environmental setting of the project.
2. The relationship of the proposed action to land-use plans, policies, and controls for the affected area.
3. The probable impact of the proposed action on the environment
4. Alternatives to the proposed action, *including* those not within the existing authority of the responsible agency.
5. Any probable adverse environmental affects that cannot be avoided (summarizing the unavoidable parts Point 3 and, separately, how avoidable parts Point 3 will be mitigated).
6. The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity.
7. Any irreversible and irretrievable commitments of resources (including natural and cultural as well as labor and materials).

8. An indication of what other interests and considerations of Federal policy are thought to offset the adverse environmental effects identified.

1-7.9 **Environmental Effects of Surface Drainage Systems.** Such facilities in the Arctic or Subarctic could have either beneficial or adverse environmental impacts affecting water, land, ecology, and socioeconomic (human and economic) considerations. Despite low population density and minimal development, the fragile nature of the ecology in the Arctic and Subarctic has attracted the attention of environmental groups interested in protecting these unique assets. Effects on surrounding land and vegetation may cause changes in various conditions in the existing environment, such as surface water quantity and quality, groundwater levels and quality, drainage areas, animal and aquatic life, and land use. Proposed systems may also have social impacts on the community, requiring relocation of military and public activities, open space, recreational activities, community activities, and quality of life. Environmental attributes related to water could include such items as erosion, aquifer yield, flood potential, flow or temperature variations (the latter affecting permafrost levels and ice jams), biochemical oxygen demand, and content of dissolved oxygen, dissolved solids, nutrients and coliform organisms. These are among many possible attributes to be considered in evaluating environmental impacts, both beneficial and adverse, including effects on surface water and groundwater. Various methods are discussed for presenting and summing up the impact of these effects on the environment.

1-7.10 **Discharge Permits.** The Federal pollution abatement program requires regulatory permits for all discharges of pollutants from point sources (such as pipelines, channels or ditches) into navigable waters or their tributaries. This requirement does *not* extend to discharges from separate storm sewers except where the storm sewers receive industrial, municipal and agricultural wastes or runoff, or where the storm water discharge has been identified by the EPA Regional Administrator, the State water pollution control agency or an interstate agency as a significant contributor of pollution. Federal installations, while cooperating with and furnishing information to State agencies, do not apply for or secure State permits for discharges into navigable waters.

1-7.11 **Effects of Drainage Facilities on Fish.** Natural drainage channels in many locations are environmentally important to preservation of fish resources. Culverts, ditches, and other drainage structures constructed along or tributary to these fish streams must be designed to minimize adverse environmental effects. Culvert hazards to fish include high inverts, excessive velocities, undersized culverts, stream degradation, failed or damaged culverts creating obstructions, erosion and siltation at outlets, blockage by icing, and seasonal timing and methods of drainage construction. Consultation with Federal and State fish and wildlife agencies will provide guidance on probable effects and possible expedients to mitigate them. Special concern will be given to anticipated conditions during fish migration season. Certain conditions are discussed below.

1-7.11.1 **High inverts.** Fish passage is impossible when the culvert outlet is set too high, exceeding jumping ability of the fish and creating a spill velocity exceeding the swimming capability of the fish. Causes can be survey or design error, easier installation, or unexpected degradation of the downstream channel after culvert installation.

1-7.11.2 **High velocities in culverts.** These prevent fish from swimming upstream. Factors affecting velocity include the culvert's area, shape, slope, and internal roughness, and inlet and outlet conditions. Some increases in velocity result from the culvert alignment being straight in lieu of the natural stream's meander. Tailwater elevation, the water level in the downstream channel at the culvert outlet, should be about  $D/8$  where  $D$  is the pipe diameter or pipe arch rise, but not less than 2.5 in. This minimum should be set with due consideration to recommendations of local fishery biologists.

1-7.11.3 **Undersized or failed culverts.** These can cause overtopping and washout of an embankment and destroy a fish resource by release of large amounts of sediment and debris.

1-7.11.4 **Erosion along drainageways or at outlets.** Additional sediment from uncontrolled erosion can adversely affect fish. Causes can be high velocities, high inverts, undersized culverts, inadequate bank protection, and lack of suitable culvert endwalls.

1-7.11.5 **Channel filling.** Covering an extensive reach of stream bottom decreases the area most suitable for spawning, depleting renewal of stocks. Proper biological input in siting and designing drainageways will avoid this problem.

1-7.11.6 **Culvert installation.** Scheduling culvert excavation, channel diversion, and channel crossings by equipment should avoid times of the year which are critical to the fish cycle.

1-7.11.7 **Control of icing.** Thawing devices such as electrical cables or steam lines, essential to any design where there is ice buildup, should be in operation to assure freedom from ice blockages during the spring migration period.

## 1-8 DESIGN COMPUTER PROGRAMS

1-8.1 **Hydraulic Design Programs.** "CORPS" is a time-sharing system developed for the Corps of Engineers computer at the Waterways Experiment Station in Vicksburg, Mississippi, with a library of computer programs, principally in the field of hydraulics. Corps offices nationwide have telephone remote terminal access to "CORPS". Use of this computer system is fully explained in step-by-step procedures suited to engineering personnel communicating in discipline-oriented language. Among available hydraulic programs useful to drainage layers are the following.

- H6001 GEOMETRICAL ELEMENTS OF TRAP., TRIA., OR RECT. CHANNEL
- H6002 GEOMETRIC ELEMENTS OF CIRCULAR CONDUIT
- H6005 GEOMETRIC ELEMENTS OF A NATURAL CHANNEL
- H6110 NORMAL DEPTH-TRAP., TRIA., OR RECT. SECTION – MANNING FORMULA
- H6111 NORMAL DEPTH AND VELOCITY-CIRCULAR CONDUIT – MANNING FORMULA
- H6112 NORMAL DISCHARGE – MANNING FORMULA
- H6140 CRITICAL DEPTH AND VELOCITY FOR TRAP., TRIA., AND RECT. SECTION
- H6141 CRITICAL DEPTH AND VELOCITY FOR CIRCULAR CONDUIT
- H6201 FRICTION SLOPE – ANY FLOW SECT – MANNING, CHEZY OR COLEBROOK-WHITE
- H6208 FLOW PROFILE – CIRC. COND – MANNING, CHEZY, OR COLEBROOK-WHITE FORM
- H7220 EROSION AT CULVERT OUTLETS AND RIPRAP REQUIREMENTS

Details on these and other hydraulic design programs and their use are available from Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180.

1-8.2 **Storm Water Management Programs.** In developed areas, planners, designers and operators of storm water drainage systems are often required to determine quantities of storm water runoff and evaluate its quality as an important component in overall condition of an area or watershed. Two computer models, designed principally for urban areas, are available. These are “STORM”, developed by the Hydrologic Engineering Center of the Corps of Engineers, and “SWMM” (Storm Water Management Model), developed for the Environmental Protection Agency.

1-8.3 **DRIP (Drainage Requirement in Pavements).** DRIP is a Windows® computer program developed by the FHWA for pavement subsurface drainage design. A design example using this program is detailed in Appendix A.

1-8.4 **CANDE-89 (Culvert Analysis and Design).** CANDE-89 is a software program used for the structural analysis and design of buried culverts and other soil-structure systems. A variety of buried structures are considered, including corrugated steel and aluminum pipes, long span metal structures, reinforced concrete pipe, concrete box culverts and structural plastic pipes. The CANDE methodology

incorporates the soil mass with the structure into an incremental static, plane-strain boundary value problem. The program is available from the following website.

<http://www-mctrans.ce.ufl.edu>

1-8.5 **MODBERG.** ModBerg calculates the maximum depth of frost penetration for a given location. This program is available at the following address.

<http://www.pcase.com/>

1-8.6 **DDSOFT (Drainage Design Software).** Based on the Rational Formula and Manning Equation, DDSOFT determines the size and bed slope of drainage channel or storm sewer. The program works with channels of four different shapes (i.e., vertical curb, triangular, rectangular, and trapezoidal), and one sewer shape (i.e., circular). The program is available from the following website.

<http://www.ntu.edu.sg/home/cswong/software.htm>

1-8.7 **NDSOFT (Normal Depth Software).** Based on the Manning Equation, NDSOFT determines the normal depth in drainage channel. It works with channels of five different shapes (i.e., vertical curb, triangular, rectangular, trapezoidal, and circular). Further, the program can also determine the size of a circular sewer based on the normal depth under the full-flow condition. The program is available from the following website.

<http://www.ntu.edu.sg/home/cswong/software.htm>

1-8.8 **PIPECAR.** PIPECAR is a program for structural analysis and design of circular and horizontal reinforced concrete pipe. Load analysis includes pipe weight, soil weight, internal fluid load, live loads, and internal pressures up to 50 ft of head. The program is available for download from the following website.

<http://www.fhwa.dot.gov/bridge/hyddescr.htm>

1-8.9 **Visual Urban (HY-22) Urban Drainage Design Programs.** These programs perform tasks in drainage of highway pavements, open channel flow characteristics, critical depth calculations, development of stage-storage relationships, and reservoir routing. The software is available for download from the following website.

<http://www.fhwa.dot.gov/bridge/hyddescr.htm>