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State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

L. P. Voigt
Secretary

July 24, 1970

BOX 450
MADISON, WISCONSIN 53701
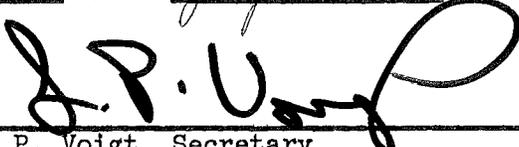
STATE OF WISCONSIN	)
	) ss.
DEPARTMENT OF NATURAL RESOURCES	)

TO ALL TO WHOM THESE PRESENTS SHALL COME, GREETINGS:

I, L. P. Voigt, Secretary of the Department of Natural Resources, and custodian of the official records of said department, do hereby certify that the annexed rules and regulations relating to the shoreland-floodplain management program were duly approved and adopted by this department on July 9, 1970.

I further certify that said copy has been compared by me with the original on file in this department and that the same is a true copy thereof, and of the whole of such original.

IN TESTIMONY WHEREOF, I have hereunto set my hand and affixed the official seal of the department at Pyare Square Building in the City of Madison, this _24th_ day of _July_ . , 1970.

_____
L. P. Voigt, Secretary

IN THE MATTER of repealing Chapters
RD 15 and RD 16, recreating, and re-
numbering them to be Chapters NR 115   :   M-3-70
and NR 116 of the Wisconsin Adminis-
trative Code, relating to shoreland
and floodplain management   :

ORDER OF THE STATE OF WISCONSIN NATURAL RESOURCES BOARD

ADOPTING, AMENDING AND REPEALING RULES

Pursuant to authority vested in the State of Wisconsin Natural Resources

Board by Section 144.26, Wisconsin Statutes, the State of Wisconsin Natural

Resources Board hereby repeals and adopts rules as follows:

SECTION 1. Chapter RD 15 of the Wisconsin Administrative Code is repealed,

renumbered to be Chapter NR 115, and recreated to read:

NR 115.01 INTRODUCTION. (1) The water resources act (chapter 614, laws

of 1965) requires counties to enact regulations for the protection of all shore-

lands in unincorporated areas by January 1, 1968. Shorelands as defined by the

law are lands within 1,000 feet of a navigable lake, pond or flowage and lands

within 300 feet of a river or navigable stream or to the landward side of the

floodplain, whichever distance is greater.

(2) The statute defines the purposes of regulations enacted for shoreland

protection: "to further the maintenance of safe and healthful conditions;

prevent and control water pollution; protect spawning grounds, fish and aquatic

life; control building sites, placement of structures and land uses and reserve

shore cover and natural beauty."

NR 115.02 NATURE OF THE PROGRAM. (1) The water resources act creates

section 59.971, Wis. Stats., which requires the zoning of shorelands in the

unincorporated areas of each county. Such zoning shall not require the approval

of the town boards. To assure that such zoning will be accomplished, s. 59.971 (6), Wis. Stats., states that if any county does not adopt an ordinance by January 1, 1968, or if the department of natural resources, after notice and hearing, determines that a county had adopted an ordinance which fails to meet reasonable minimum standards in accomplishing the shoreland protection objectives, the department shall adopt such an ordinance.

(2) To comply with the water resources act, it is necessary for a county to enact shoreland regulations, including zoning provisions, land division controls, sanitary regulations and administrative provisions ensuring enforcement of the regulations.

(3) It is the policy of the department, in the discharge of its responsibility under s. 144.26, to require adherence to certain specific standards and criteria. The standards and criteria are intended to define the objectives of the regulations.

NR 115.03 SHORELAND REGULATION STANDARDS AND CRITERIA. (1) Establishment of appropriate zoning districts. Shoreland area development can usually be controlled by regulations appropriate to wetlands (conservancy district), recreation-residential districts and general purpose districts. Where detailed land use planning has been accomplished, other types of districts may also be desirable.

(2) Establishment of land use zoning regulations. The zoning provisions adopted must provide sufficient control of the use of shorelands to afford the protection of water quality as specified in chapters RD 2 and 3 of the Wisconsin Administrative Code. The provisions shall include the following:

(a) Minimum lot sizes. All future lots in the shoreland area shall afford protection against danger to health and hazard of pollution of the adjacent body of water.

1. Lots served by public sewer shall have a minimum width of 65 feet and a minimum area of 10,000 square feet.

2. Lots not served by public sewer shall have a minimum average width of 100 feet and a minimum area of 20,000 square feet.

(b) Building setbacks. The permitted location of buildings and structures shall conform to health requirements, preserve natural beauty and reduce flood hazards.

1. Unless an existing development pattern exists, a setback of 75 feet from the normal high waterline shall be required.

2. No building shall be erected in the floodway of a stream (see NR 116, definitions).

3. Boathouses or similar structures which require a waterfront location shall not be used for habitation nor extend toward the water beyond the ordinary high waterline.

4. Buildings and structures shall be subject to any applicable floodplain zoning regulations.

(c) The cutting of trees and shrubbery shall be regulated to protect scenic beauty, control erosion and reduce the flow of effluents and nutrients from the shoreland. In the strip 35 feet inland from the normal high waterline, no more than 30 feet in any 100 feet shall be clear cut. In other areas, trees and shrub cutting shall be governed by consideration of the effect on water quality and should be in accord with accepted management practices.

(d) Filling, grading, lagooning and dredging may be permitted only in accord with state law and where protection against erosion, sedimentation and

impairment of fish and aquatic life has been assured.

(3) Establishment of sanitary regulations. The protection of health and the preservation and enhancement of water quality require sanitary regulations to be adopted by the county. (a) Where public water supply systems are not available, private well construction shall conform to the Wis. Admin. Code RD 12.

(b) Where a public waste collection and treatment system is not available, design and construction of private sewage disposal systems shall fully comply with the Wis. Admin. Code H62.20.

(4) Adoption of administrative and enforcement provisions. Each ordinance required by these regulations shall provide for:

(a) The appointment of an administrator and such additional staff as the work load may require.

(b) A planning agency (planning and zoning committee) and a board of adjustment as required by law.

(c) A system or permits for all new construction, reconstruction, structural alteration or moving of buildings and structures, including sanitary waste disposal and water supply facilities. A copy of all applications shall be filed in the office of the county administrator.

(d) Regular inspection of permitted work in progress to insure conformity of the finished structures with the terms of the ordinance.

(e) A variance procedure relating to the use, change of use or alteration of nonconforming lands and structures, and a special exception procedure for uses presenting special problems of pollution or flood hazard. The county shall keep a complete record of all proceedings before the board of adjustment and planning agency.

(f) Timely notice to the floodplain-shoreland management section of the department of natural resources of hearings on proposed variances, special exceptions and amendments and delivery to that section of copies of decisions on such variances, special exceptions and such amendments, when adopted.

(g) Mapped zoning districts and the recording, on an official copy of such map, of all district boundary changes.

(h) The prosecution of all violations of shoreland zoning ordinances.

(5) Establishment of land suitability review. The county shall review all land divisions which create three or more parcels or building sites of five acres each or less within a 5-year period. In such review the following factors should be considered:

(a) Hazards to the health, safety or welfare of future residents.

(b) Proper relationship to adjoining areas.

(c) Public access to navigable waters, as required by law.

(d) Adequate storm drainage facilities.

(e) Conformity to state law and administrative code provisions.

NR 115.04 THE ROLE OF THE DEPARTMENT OF NATURAL RESOURCES. (1) The department of natural resources is directed by the legislature to assist the counties in carrying out their responsibilities under the law and to review and evaluate the administration of the regulations. If necessary, the department may recommend to the natural resources board the adoption of an ordinance for a county, if the county failed to meet these standards and criteria.

(2) Compliance determined by evaluating county regulations with NR 115.03. (a) Compliance with the requirements of s. 59.971 will be determined by comparing the county shoreland regulations with the state minimum standards for shoreland protection as contained in NR 115.03. Counties that have enacted regulations that meet the minimum standards for shoreland protection will be considered as

complying with s. 59.971, Wis. Stats.

(b) Compliance status shall also be maintained by the county during subsequent reevaluation of the regulations to ascertain their effectiveness in maintaining the quality of Wisconsin water. A county shall keep its regulations current, effective and workable to retain its status of compliance. Failure to do so shall be deemed noncompliance.

(c) Compliance with NR 115 shall not affect a county's responsibility to comply with NR 116, floodplain management standards.

(d) The department shall issue a certificate of compliance when a county has, in the opinion of the department, complied with s. 59.971, Wis. Stats.

(3) Noncompliance. (a) Counties that have regulations that do not meet the minimum rules as contained in NR 115.03 shall be considered as not complying with the requirements of the water resources act pertaining to shoreland regulations. For these counties to achieve compliance status, they shall modify their regulations to meet the minimum standards within a time limit established by the department.

(b) Counties that have not drafted shoreland regulations shall be deemed noncomplying counties. They shall state to the department of natural resources their reasons, if any, for failure to comply with the water resources act. The department shall then require the county:

1. To proceed with regulation formation within a given time period, or;

2. a. To have the staff of the department of natural resources draft the regulations, or;

b. Contract with a consultant to draft the regulations. All costs for such actions by the department of natural resources shall be borne by the noncomplying county.

NR 115.05 ASSISTANCE TO COUNTIES. To the full extent of its resources, the department of natural resources will provide advice and assistance to the counties, seeking the highest practicable degree of uniformity consistent with the objectives of the shoreland regulation provisions of the water resources act.

SECTION 2. Chapter RD 16 of the Wisconsin Administrative Code is repealed, renumbered to be Chapter NR 116, and recreated to read:

NR 116.01 INTRODUCTION. (1) The Wisconsin legislature in enacting chapter 614, laws of 1965, recognized that floodplain zoning is a necessary tool to protect human life, health and to minimize property damages and economic losses. Counties, cities, and villages are required by s. 87.30, Wis. Stats., to adopt reasonable and effective floodplain zoning ordinances within their respective jurisdictions where serious flood damage may occur.

NR 116.02 DEFINITIONS. (1) Channel. A natural or artificial watercourse with definite bed and banks to confine and conduct the normal flow of water.

(2) Department. State of Wisconsin department of natural resources, division of environmental protection.

(3) Encroachment lines. Limits of obstruction to flood flows. These lines are on both sides of and generally parallel to the stream. The lines are established by assuming that the area landward (outside) of the encroachment lines will be ultimately developed in such a way that it will not be available to convey flood flows.

(4) Equal degree of encroachment. Established by considering the effect of encroachment on the hydraulic efficiency of the floodplain along both sides of a stream for a significant reach. Hydraulic efficiency depends on such factors as the relative orientation of the channel, natural and man-made characteristics of

the floodplain, relative ground level on both sides of the stream, the type of

vegetation on both sides of the stream and the resistance of such vegetation to flood

flows.

(5) Flood. A temporary rise in stream flow or stage that results in

inundation of the areas adjacent to the channel.

(6) Flood frequency. A means of expressing the probability of flood

occurrences as determined from a statistical analysis of representative stream

flow records. It is customary to estimate the frequency with which specific

flood stages or discharges may be equalled or exceeded, rather than the frequency

of an exact stage or discharge. Such estimates by strict definition are

designated "exceedence frequency", but in practice the term "frequency" is used.

The frequency of a particular stage of discharge is usually expressed as occurring

once in a specified number of years. Also see: Recurrence interval.

(7) Floodplain. The land adjacent to a body of water which has been or may

be hereafter covered by flood water including but not limited to the regional

flood.

(8) Floodplain management. The full range of public policy and action for

insuring wise use of floodplains. It includes everything from the collection and

dissemination of flood control information to actual acquisition of floodplain

lands; and the enactment and administration of codes, ordinances, and statutes

for floodplain land use.

(9) Flood profile. A graph showing the relationship of the water surface

elevation of a flood event to a location that generally is expressed as a distance

upstream from a designated point on a stream or river.

(10) Flood proofing. A combination of structural provisions, changes, or

adjustments to properties and structures subject to flooding primarily for the

reduction or elimination of flood damages to properties, water and sanitary

facilities, structures and contents of buildings in a flood hazard area.

(11) Floodway. The channel of a stream and those portions of the flood-plain adjoining the channel that are required to carry and discharge the flood water or flood flows of any river or stream including but not limited to flood flows associated with the regional flood.

(12) Freeboard. A factor of safety usually expressed in feet above a design flood level for flood protective or control works. Freeboard tends to compensate for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions such as wave action, bridge opening and floodway obstructions, and the hydrological effects of urbanization of the watershed.

(13) Maximum probable flood. The most severe flood with respect to flood peak that may be expected from a combination of the most critical meterological and hydrological conditions that are reasonably to be expected on the drainage basin.

(14) Reach. The longitudinal segments of a stream or river influenced by natural or man-made obstruction.

(15) Recurrence interval. The average interval of time, based on a statistical analysis of actual or representative stream flow records, which can be expected to elapse between floods equal to or greater than a specified stage or discharge. Recurrence interval is generally expressed in years. Also see: Flood frequency.

(16) Regional flood. A flood determined by the Department to be representative of large floods known to have generally occurred in Wisconsin and which may be expected to occur on a particular stream because of like physical characteristics. The regional flood generally has an average frequency of the one hundred (100) year recurrence interval flood.

(17) Rural areas. All areas that are not included in urban area, such as agricultural, forest and undeveloped lands.

(18) Standard project flood. A hypothetical flood, estimated by the Corps of Engineers, representing the critical flood runoff volume and peak discharge that may be expected from the most severe combination of meteorological and hydrologic conditions that are considered reasonably characteristic of the geographical region involved, excluding extremely rare combinations.

(19) Urban areas. For the purpose of floodplain management, urban areas shall be construed to include the following:

(a) The area within the present corporate limits plus the adjoining area that is or could be under the statutory extraterritorial zoning jurisdiction of any city, village or town;

(b) Any group of seasonal or permanent buildings which have a population density not characteristic of rural areas.

NR 116.03 GENERAL CRITERIA FOR FLOODPLAIN REGULATIONS. (1) Objectives. The objectives of these criteria are to provide a uniform basis for the preparation and implementation of sound floodplain regulations for Wisconsin rivers and streams to:

(a) Protect human life and health;

(b) Minimize expenditures of public monies for costly flood control projects;

(c) Minimize rescue and relief efforts, generally undertaken at the expense of the general public;

(d) Minimize business interruptions;

(e) Minimize damage to public facilities on the floodplains such as water mains, sewer lines, streets and bridges;

(f) Help maintain a stable tax base by the preservation or enhancement of property values for future floodplain development. In addition, development
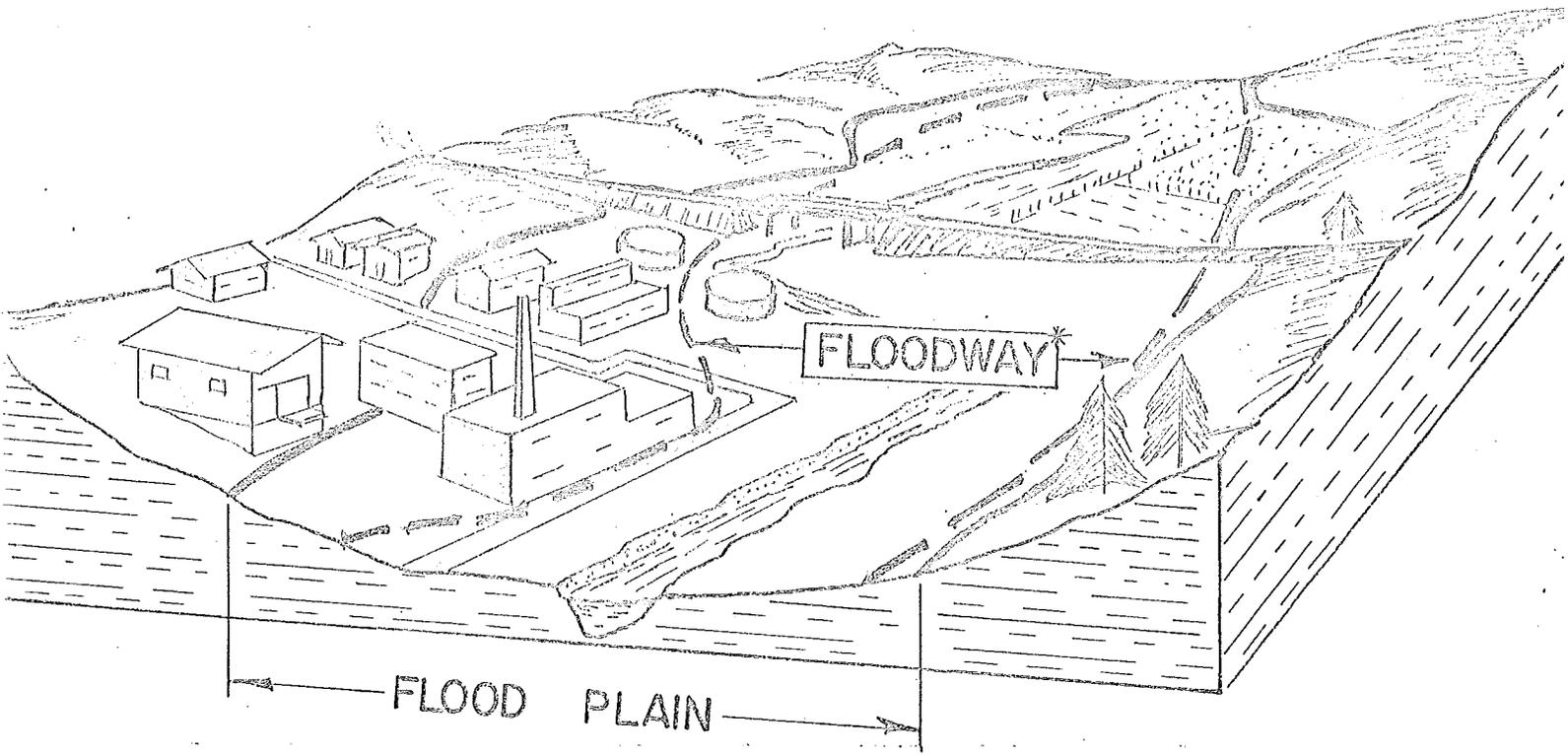
FLOOD PLAIN

*That portion of the flood plain required to carry and discharge
flood waters. The limits of the floodway are smooth lines that
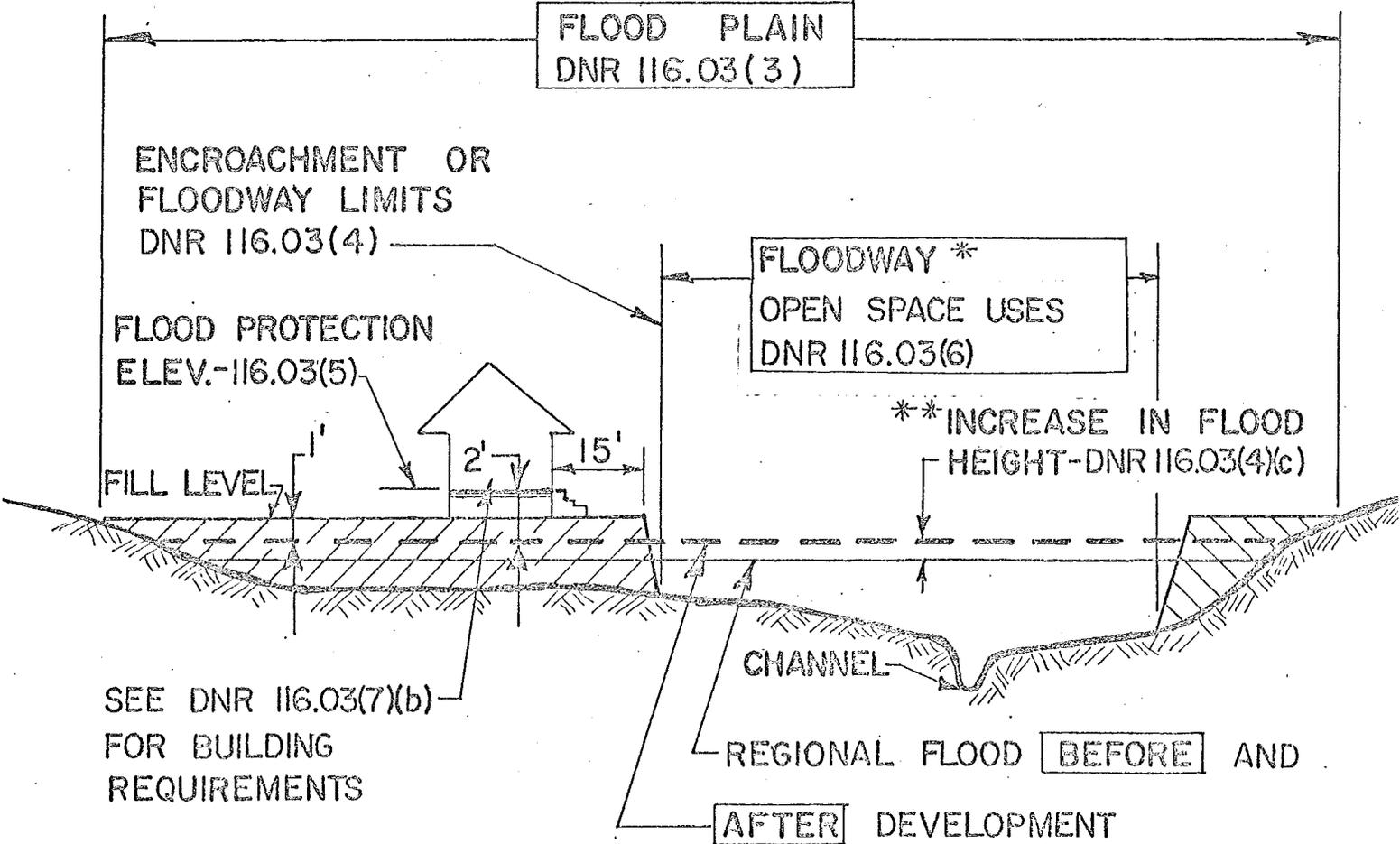exclude areas associated with stagnant flood waters, intensive
urban development and other areas not effective in conveying
flood waters.

FLOOD PLAIN
DNR 116.03(3)

ENCROACHMENT OR
FLOODWAY LIMITS
DNR 116.03(4)

FLOOD PROTECTION
ELEV.-116.03(5)

FLOODWAY *
OPEN SPACE USES
DNR 116.03(6)

**INCREASE IN FLOOD
HEIGHT-DNR 116.03(4)(c)

FILL LEVEL

1'

2'

15'

SEE DNR 116.03(7)(b)
FOR BUILDING
REQUIREMENTS

CHANNEL

REGIONAL FLOOD BEFORE AND
AFTER DEVELOPMENT

**Increases in flood heights result from filling and development on the flood plain.

VALLEY CROSS SECTIONS

of future flood blight areas on floodplains will be minimized and property

values and the tax base adjacent to the floodplains will be preserved;

(g) To discourage the victimization of unwary land and home buyers.

(2) Regional flood determination. The method of flood frequency

determinations for the regional flood generally will be based on the log-

Pearson type III distribution (with the log normal as a special case) as

described in the federal water resources council bulletin 15, "A Uniform

Technique for Determining Flood Frequency", December 1967. In special in-

stances the department may use or authorize the use of other acceptable hydro-

logic methods or techniques.

(3) Floodplain delineation. (a) The regional flood shall serve as a

basis for delineation of the minimum limits of the floodplains for regulatory

purposes;

(b) In absence of regional flood data, experienced flood maps, aerial

photos or detailed soil maps may initially serve as a basis for delineation

provided that:

1. The affected floodplains are generally undeveloped.

2. The associated text of the zoning ordinance provides for a special

exception procedure similar to NR 116.05(3)(c) to ascertain the effects of pro-

posed construction upon flood flows and the flood protection elevation.

3. The local unit of government has initiated a program to ultimately

obtain regional flood data in problem areas.

(c) Where technical information is available to ascertain the magnitude

of floods larger than the regional flood (such as the standard project flood or

the maximum probable flood), the floodplain limits of these large floods shall

be reflected on the official zoning district maps for public information

purposes;

(d) Accepted engineering principles and other techniques shall govern the delineation of the floodplain limits on the official zoning district map. Where a conflict exists between the floodplain limits illustrated on the map and actual field conditions, the elevations from the flood profile shall be the governing factor in locating the regulatory floodplain limits.

(4) Floodway delineation. (a) The delineation of the floodway shall be based on the channel of the river or stream and those portions of the adjoining floodplains which are reasonably required to carry and discharge the regional flood without any measurable increases in flood heights;

(b) The determination of the floodway limits shall be based on hydraulic and engineering studies;

(c) In areas having appreciable urban development on the floodplain, the floodway may be based on encroachment lines generally following the riverward limits of development provided that:

1. Encroachments on the floodway of any river or stream generally should not cause an appreciable increase in stage of the regional flood. Increased flood depths up to 0.5 foot in any one reach or for the cumulative effect of several reaches of a river or stream are generally acceptable. The department may authorize increases greater than 0.5 foot where:

a. The area affected by the increases is in open space use;

b. Local comprehensive plans and land use controls will assure the continuation of such open space use;

c. The increases do not affect adjoining communities; and

d. Appropriate legal arrangements have been made with the affected local unit of government and riparian landowners. If the increase in flood stage will materially increase the flood damage potential or affect adjoining communities, the department may require that such increase be less than 0.5 foot.

2. Floodway encroachments shall be:

a. Based on a uniform degree of encroachment for a significant reach on both sides of a river or stream;

b. Based on hydraulic and engineering studies; and

c. Compatible with local land use plans.

(5) Flood protection elevations. (a) The flood protection elevations shall correspond to a point not less than two feet above the water surface profile associated with the regional flood plus any increases in flood heights attributable to encroachments on the floodway established under s. NR 116.03(4)(c).

(b) The flood protection elevation shall be clearly lettered at identifiable positions on the official zoning district map consistent with the water surface profile of the regional flood, or the profile shall be attached to and made part of the official zoning district map.

(6) Areas within the floodway or between levees. (a) Permitted uses.

1. Open space uses having a relatively low flood damage potential such as those associated with agriculture, recreation, parking, storage yards, certain sand and gravel operations;

2. Certain structures accessory to permitted open space uses if the structures:

a. Are not designed for human habitation;

b. Have a low flood damage potential;

c. Are to be constructed and placed on the building site so as to offer the minimum obstruction to the flow of flood waters;

I. Whenever possible, structures will be constructed with the longitudinal axis parallel to the direction of flow of flood waters; and

II. So far as practicable, structures will be placed so their longitudinal

axes are approximately on the same line as those of adjoining structures.

d. Will be firmly anchored to prevent the structure or building from floating away and thus threatening to further restrict bridge openings and other restricted sections of the stream or river; and

e. Service facilities such as electrical and heating equipment will be at or above the flood protection elevation for the particular area.

3. Channel uses permitted by the department pursuant to c. 30, Wis. Stats.

(b) Prohibited uses. 1. Any fill, deposit, obstruction, excavation, storage of materials, or structure which acting alone or in combination with existing or future similar works will adversely affect the efficiency of the capacity of the floodway or adversely affect existing drainage courses or facilities.

2. Structures that are:

a. Designed for human habitation;

b. Associated with high flood damage potential; and

c. Not connected with permitted open space uses.

3. Storage of materials that are buoyant, flammable, explosive or injurious to human, animal or plant life; and

4. Uses that are not in harmony with and may be detrimental to the uses permitted in the adjoining district.

(7) Floodplain areas landward or outside of the floodway. (a) General. 1. All floodplain developments shall be compatible with a local comprehensive plan. In the absence of a formal plan, development shall be compatible with the uses permitted in the adjoining district;

2. Floodplain developments shall not adversely affect the efficiency of or unduly restrict the capacity of the channels or floodways of any tributaries to the main stream, drainage ditches, or any other drainage facilities or systems;

3. Floodplain developments shall not materially affect the storage capacity of the floodplains, based on an equal degree of encroachment, particularly in flood areas upstream from urban areas.

(b) Urban residential areas. 1. The finished surface of the first floor or basement floor of any building or structure to be erected, constructed, reconstructed, altered or moved on the floodplain shall be placed on fill at or above the flood protection elevation;

2. Fill elevation shall be not less than one foot above the regional flood elevation plus any increase in elevation due to floodway encroachment as described in NR 116.03(4)(c) and the fill shall extend at such elevation at least 15 feet beyond the limits of any structure or building erected thereon. Where existing streets are at elevations which make compliance with this provision impractical, the department may authorize use of other flood proofing measures or methods to the flood protection elevation in accordane with s. NR 116.03(8).

(c) Rural seasonal or permanent residences. 1. The finished surface of the first floor and any floor or a basement of a building or structure used for human habitation or associated with a high flood damage potential to be erected, constructed, reconstructed, altered or moved on the floodplain shall be at or above the flood protection elevation.

(d) Commercial areas. Commercial areas generally are to be constructed on fill with no first floor or basement floor below the flood protection elevation. Certain yards, parking lots and other auxiliary land uses may be at lower elevations. However, no such area in general use by the public shall be inundated to a depth greater than two feet or subjected to flood velocities greater than four feet per second upon the occurrence of the regional flood.

(e) Manufacturing and industrial areas. Protection methods utilizing fill, levees, floodwalls and flood proofing measures for buildings, structures and appurtenant works are to be provided to the flood protection elevation. Interference with normal plant operations is to be minimized, especially for streams

having protracted flood durations. A lesser degree of protection may be per-missible for storage yards, parking lots and other auxiliary uses compatible with these criteria.

(f) Public utilities, streets, and bridges. 1. When failure or inter-ruption of public facilities would result in danger to the public health or safety or where such facilities are essential to the orderly functioning of the area, protection to the flood protection elevation is to be provided;

2. Where failure or interruption of service would not endanger life or health, a lesser degree of protection may be provided for minor or auxiliary roads or utilities;

3. Public utilities, roads and bridges on the floodplain should be designed to minimize increases in flood elevations and should be compatible with the local comprehensive floodplain development plan.

(g) Storage of materials. Any storage of materials that are buoyant, flammable, explosive, or in times of flooding, could be injurious to human, animal or plant life, shall be at or above flood protection elevations.

(8) Flood proofing measures. When these criteria or variances in local ordinances permit flood proofing measures they shall be designed for flood velocities, depths, forces and other factors associated with the regional flood. A plan or document certified by a registered professional engineer or architect that the flood proofing measures are adequately designed shall be submitted to the local unit of government prior to any authorization. Some flood proofing measures are:

(a) Anchorage of structures to foundations.

(b) Installation of watertight doors, bulkheads and shutters.

(c) Reinforcement of walls to resist water pressures.

(d) Use of paints, membranes or mortars to reduce seepage of water through walls.

(e) Addition of mass or weight to structures to resist flotation.

(f) Installation of pumps to lower water levels in structures.

(g) Construction of water supply and waste treatment systems to prevent the entrance of flood waters.

(h) Pumping facilities for subsurface drainage systems for buildings to relieve external foundation wall and basement flood pressures.

(i) Cutoff valves on sewer lines or the elimination of gravity flow basement drains.

(j) Placing of essential utilities above flood protection elevations.

(9) Flood protective or control works for urban areas. (a) Levees or floodwalls.

1. Floodway encroachments described in section NR 116.03(4)(c) generally shall be applicable to levees or floodwalls;

2. The minimum height and design of any levee or floodwall shall be based on the flood profile of the regional flood confined between the levees or floodwalls, plus three feet of freeboard or the standard project flood confined between the levees or floodwalls, whichever provides the greater protection from floods;

3. Increases in flood stages resulting from any levee or floodwall in excess of the allowable increases due to floodway encroachments as described in NR 116.03(4)(c) shall be contained within the upstream extent of any levee or floodwall.

4. Floodplain developments landward of any levee or floodwall shall provide for interior drainage and designated ponding areas associated with any levee or floodwall;

5. The criteria for floodplain areas landward of or outside the floodway

in NR 116.03(7) shall apply for floodplain development until such time as the levees and floodwalls are constructed and operative.

(b) Agricultural levees. 1. Agricultural levees shall be designed so that the levees will overtop upon the occurrence of the 15-year recurrence interval flood.

2. Increase in flood heights in the area upstream from agricultural levees shall not exceed 0.5 foot for the 15-year recurrence interval flood based on an assumption of an equal degree of encroachment on both sides of a river or stream provided the consent of the affected property owners is obtained.

(c) Reservoirs and channel improvements. Flood protection elevations or floodplain and floodway limits based on any proposed reservoir or channel improvements shall not be effective until the reservoir or channel improvements are constructed and operative.

(11) Modifications or additions to existing structures. (a) Areas within floodway or between levees. No modifications or additions to any structure that are not in compliance with permitted floodway uses are permitted unless such modifications will decrease the flood damage potential of the structure or its degree of obstruction to flood flows.

(b) Areas landward or outside of floodway. 1. Any modifications or additions to any structure generally shall be in compliance with the general criteria for floodplain regulations.

2. Where compliance with applicable criteria results in undue hardship, the following shall apply:

a. Any modifications or additions to any structure for human habitation or with a high flood damage potential shall be protected to the flood protection elevation by flood proofing measures, in NR 116.03(8).

b. Modifications or additions to other structures may be permitted at elevations lower than the flood protection elevation if such modifications or additions will not be subjected to high flood depths or flood velocities and will not require the installation of public facilities.

c. Any modifications involving the internal use of an existing building not in compliance with these criteria may be permitted if such use will not endanger human lives, increase the flood damage potential by the occurrence of the regional flood, or require the installation of public facilities below the flood protection elevation.

3. Any modifications or additions to existing structures also shall comply with the statutory provisions for nonconforming uses.

(12) The removal of designated floodplain limits. The floodplain designation on zoning district maps shall not be removed from any area unless it can be shown that the area is filled above the flood protection elevation and is contiguous to other lands lying outside the floodplain.

(13) Certification of compliance. No vacant land in the floodplain shall be occupied or used and no building hereafter erected, altered or moved shall be occupied until the applicant submits to the local zoning administrator or building inspector a certification by a registered professional engineer or land surveyor that the finished fill and building floor elevations and other floodplain regulatory factors were accomplished in compliance with appropriate floodplain zoning provisions and other floodplain regulations.

(14) Public information. (a) Flood limits should be marked on the ground. Markers should also be set to show the depth of inundation at appropriate locations within the floodplain.

(b) All available information in the form of maps, engineering data and regulations should be freely and widely distributed.

(c) All legal descriptions of property transferred in the floodplain should include information relative to the zoning classification.

NR 116.04 DEPARTMENT DUTIES. (1) The establishment and upgrading of standards for local floodplain zoning ordinances and the review and evaluation of the administration and enforcement of local ordinances.

(2) Where counties, cities and villages fail to comply with s. 87.30, Wis. Stats., or section NR 116.05 herein, or where local ordinances have not been administered or enforced consistent with floodplain management criteria herein, the department shall recommend to the natural resources board the adoption and enforcement of an ordinance in accordance with the procedure in s. 87.30, Wis. Stats.

(3) The department shall issue a certificate of approval to a unit of government upon a finding that the adopted floodplain zoning ordinance meets the provisions of NR 116.03 and NR 116.05.

(4) The review of proposed, preliminary, final or enacted ordinances by the department will include the following:

(a) Determination if the most accurate maps were utilized in delineating the floodplains;

(b) Determination of the adequacy of the text of any ordinance;

(c) Determination of the compatibility of ordinances from adjoining communities on the same streams or rivers;

(d) Determination of the compatibility of floodplain ordinances with county shoreland regulations, existing zoning and any land use plan.

(5) The department with assistance from appropriate federal and state agencies will, upon request, assist local units of government or regional planning

commissions in evaluating flood hazards and floodplain delineation and relating these factors to floodplain zoning and enforcement practices. The primary contribution of the state and federal agencies toward this program will be to provide technical guidance and computer facilities for the necessary hydrologic, hydraulic and engineering studies. Local contributions to this program shall include, among other things, the necessary topographic and other base maps and field surveys.

(6) The department will coordinate floodplain management with programs of other state or federal agencies or institutions to assure that public works on the floodplains will not violate floodplain management criteria and local floodplain zoning ordinances.

NR 116.05 REGULATIONS APPLICABLE TO CITIES, VILLAGES AND COUNTIES. (1) Adoption of floodplain zoning ordinances. (a) Counties, cities and villages shall adopt and continue to administer and enforce reasonable and effective floodplain zoning ordinances that meet or exceed the criteria in s. NR 116.03 for all floodplains within their respective jurisdictions where serious damage may occur.

(b) Where necessary to assure the effectiveness of floodplain zoning ordinances, criteria in NR 116.03 shall be included in subdivision regulations, building and sanitary codes and flood insurance.

(c) Where the department finds that one or more of the following regulations or programs will accomplish the objectives and provisions of NR 116.03, these regulations or programs may be substituted in lieu of zoning ordinances:

1. Acquisition by easement or purchase of floodplain areas for open-space uses described in section NR 116.03(7).

2. Flood warning system.

3. Building codes.

4. Subdivision regulations.

5. Sanitary codes.

(d) Local units of government shall adopt or amend floodplain zoning ordinances to reflect adequate flood data within six months from the time such data are available. Local units of government shall also within six months incorporate any upgrading of floodplain management criteria or hydrologic data based on legal precedents and improved technical information and methods.

(2) Amendments. Any amendment to floodplain regulations shall be approved by the department before it becomes effective.

(3) Appeals, variances, exceptions. (a) Local decisions on floodplain zoning appeals, variances, special exceptions (conditional uses) shall not be contrary to the provisions of this code or other state regulations.

(b) Local units of government shall give mailed notice to the appropriate district and main office of the department of any public hearing on an application for a variance or special exception (conditional use). Such notice shall specify the time, place and subject matter of the public hearing.

(c) The local units of government may require the applicant to submit a map, plan and/or legal description which accurately locates or describes the proposal with respect to the floodplain districts and provides all pertinent information such as the nature of the proposal, fill limits and elevations and building floor elevations. The local unit of government may transmit this information to the department for a determination of flood protection levels and the evaluation of the effects upon flood heights, velocities and floodplain storage areas. The department may request additional information such as valley cross sections or other survey information to make its determination.

(d) The determination of these effects shall be based on the assumption that the floodplain or floodway encroachment resulting from any proposed fill, obstruction or structures will extend for a significant reach of the stream, together with any probable encroachment equal in degree on the opposite side of the stream.

(e) The department shall advise the local unit of government of its findings within 30 days of receiving notice of an application for a variance or special exception (conditional use) or 30 days after receiving all requested engineering information. Failure of the department to respond within 30 days may be construed to mean it has no comment.

(f) A copy of all decisions granting a variance or special exception (conditional use) relating to the floodplain or floodway areas, shall be mailed within 10 days to the district and main office of the department.

(4) Local enforcement procedures. Floodplain zoning ordinances enacted under s. 87.30, Wis. Stats., shall provide for the following, except that where a zoning administrator, planning agency and board of adjustment or appeals have already been appointed to administer a zoning ordinance adopted under ss. 59.97, 59.971 or 62.23(7), Wis. Stats., these officials shall also administer the floodplain zoning ordinance. (a) The appointment of an administrator and such additional staff as the work load may require;

(b) The establishment of a planning agency and a board of appeals or adjustment, as required by law;

(c) A system of permits for all new construction, reconstruction, structural alteration or moving of buildings and structures, including sanitary waste disposal and water supply facilities. A duplicate copy of all applications shall be filed in the office of the administrator;

(d) Regular inspection of permitted work in progress, to ensure conformity of the finished structures with the terms of the ordinance;

(e) Procedures for appeals, variances, special exceptions (conditional uses) in accordance with a variance procedure relating to the use, change of use or alteration of nonconforming lands and structures in s. NR 116.05(3).

There shall be a complete public record of all proceedings before the board of appeals or adjustment and the planning agency.

(f) Mapped zoning districts and the automatic recording, on an official copy of such map, of all district boundary changes;

(g) The firm prosecution of any and all violations of floodplain zoning regulations for which there is adequate evidence, unless such violations are voluntarily corrected in accordance with s. 87.30(2), Wis. Stats. .

The foregoing was approved by the State of Wisconsin Natural Resources Board on July 9, 1970.

The rules, amendments and repeals contained herein shall take effect on September 1, 1970.

DATED: *July 28, 1970*

STATE OF WISCONSIN .
DEPARTMENT OF NATURAL RESOURCES

/s/ *L. P. Voigt*
L. P. Voigt, Secretary

UNITED STATES

A UNIFORM TECHNIQUE

FOR DETERMINING FLOOD FLOW FREQUENCIES

DECEMBER 1967

WATER RESOURCES COUNCIL
WASHINGTON, D. C.

THE WATER RESOURCES COUNCIL

It is the function of the Council to effectuate the policy of the United States, as stated in the Water Resources Planning Act approved July 22, 1965, to encourage the conservation, development and use of water and related land resources of the United States. This is to be done on a comprehensive and coordinated basis by the Federal Government, States, localities and private enterprise with the cooperation of all affected Federal agencies, States, local governments, individuals, corporations, business enterprises and others concerned.

The officers and members of the Council are:

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1025 Vermont Avenue, N. W.
Suite 900
Washington, D. C. 20005

WATER RESOURCES COUNCIL

HYDROLOGY COMMITTEE

A UNIFORM TECHNIQUE

FOR DETERMINING FLOOD FLOW FREQUENCIES

DECEMBER 1967

BULLETIN NO. 15

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Water Resources Council, 1025 Vermont Avenue, N.W.
Washington, D.C. 20005

FOREWORD

Within the federalism that is a distinguishing characteristic of
the governmental structure of the United States, the responsibility
for managing the water and related land resources of the Nation's
river basins is shared among Federal, State, and local governments,
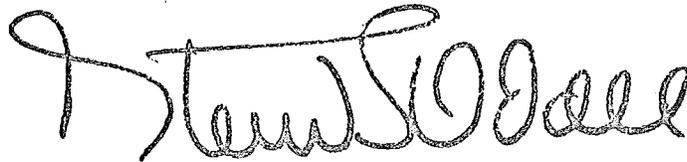and private enterprise.

In response to the practical problems that confront them, Federal
agencies are continually developing technical methods to improve the
performance of their assigned responsibilities. Where agencies have
different but related assignments, methodological differences in mak-
ing the same types of technical determinations tend to develop. The
determination of flood flow frequency is one of the technical methods
that has experienced separate agency evolution over the years, and
consequent differences in technique.

With the growing need for improved flood plain management,
desirability of a basic, uniform method of establishing flood frequen-
cies for general use throughout the Nation is manifest. A consistent
approach to estimation of the average annual value of flood losses--
a major analytical component in determination of the best measure,
or best combination of measures, in flood plain management--is de-
pendent upon equable analysis of flood frequencies whether determined
by Federal, State, local government or private engineers.

With this need in mind, the uniform technique for determining
flood flow frequencies set forth in this bulletin was adopted by the
Council's Hydrology Committee. It is hoped that this base method
will commend itself for use by State, local government and private
engineers, and that it will be looked upon as a desirable first step
in the development through further study, research, and experience
of a more precise and complete technique. The Water Resources
Council has adopted the uniform technique set forth in the bulletin

for use in all Federal planning involving water and related land resources. It has done this, however, with the understanding that efforts directed toward finding methodological improvements will be continued and adopted when deemed appropriate.

All who are interested in improving determinations of flood flow frequencies are encouraged to submit comments, criticisms, and proposals to the Water Resources Council for consideration by its Hydrology Committee.

Stewart L. Udall
Chairman, Water Resources Council

December 1967

TOWARD A UNIFORM TECHNIQUE
FOR DETERMINING FLOOD FLOW FREQUENCIES

In a letter of September 10, 1966, the Executive Director informed the Hydrology Committee that the Council had assigned it responsibility for developing a uniform technique for the determination of flood flow frequencies. The Hydrology Committee of the Council consists of technical staff members of the Federal departments represented in the Council and of the Tennessee Valley Authority. The Committee devotes its efforts to technical matters in hydrology and has published many hydrologic bulletins that are nationally used.

The Council's assignment was made in conformance with Recommendation 2 of the report by the Task Force on Federal Flood Control Policy, "A Unified National Program for Managing Flood Losses."[1] Recommendation 2 called for the establishment of a panel to examine methods of frequency analysis and to provide a set of techniques based on the best known hydrological and statistical procedures.

In a letter of October 20, 1967, the Chairman of the Hydrology Committee submitted the Committee's report to the Council. The letter and report contained (i) a resume of the Committee's activities in this field, (ii) recommendations regarding a technique of flood flow frequency analysis for gaged areas, (iii) an outline of the recommended base method of analysis, (iv) appropriate tables of constants for use with the base method, and (v) a discussion of further and immediate problems requiring the Committee's attention in this field. The Committee's letter and report were based on the report of the Work Group on Flood Flow Frequency Analysis, an ad hoc work group established by the Committee. Two professional statisticians were employed as technical advisors to the group. The group's main findings were that of six methods tested, three fitted the data well and showed no bias. The recommended base method is one of these three.

In its meeting of October 25, 1967, the Water Resources Council accepted the Committee's report and recommendations and agreed that they should be published.

1/ House Document No. 465, 89th Congress, 2nd Session.

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Recommendations

The recommendations of the Hydrology Committee are:

"1. The Hydrology Committee agreed that the state of the art with respect to flood flow frequency methods, as with most other hydrologic techniques, has not advanced to the point where complete standardization is feasible or appropriate. For that reason, the Committee recommends that a base method be adopted with provisions for using other methods where adequate justification is presented.

"2. On the basis of current use by Federal agencies, availability of detailed instructions and computer programs, and flexibility in application, the log-Pearson Type III distribution (with the log-normal as a special case) is recommended for adoption as a base method for flow frequencies. In those cases where information exists which indicates some other type of distribution or technique should be employed, such use should be acceptable provided appropriate justification is given. A concise summary of the log-Pearson Type III method is presented in Bulletin No. 13, April 1966, "Methods of Flow Frequency Analysis," prepared under the auspices of the Subcommittee on Hydrology, Inter-Agency Committee on Water Resources.[1]

"3. In view of the importance of flood flow frequency estimates in the expanding field of water resources development and related programs for managing flood losses, continuing efforts by the Hydrology Committee are needed to encourage and coordinate efforts of the member agencies in improving existing techniques and procedures in this field. In this connection, the Committee will establish appropriate ad hoc work groups when required for specific tasks; major emphasis, however, will be directed toward bringing such matters to the attention of the full Committee. Some immediate problems requiring attention are outlined in Attachment 4."[2]

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[1] Now the Hydrology Committee, Water Resources Council.
[2] The material in Attachment 4 is given later in this pamphlet under the title "Additional Considerations in Flood Flow Frequency Analysis."

The outline of work is as follows:

1. Transform the list of N annual flood magnitudes Y_1, Y_2, ... , Y_N to a list of corresponding logarithmic magnitudes X_1, X_2, ... , X_N.

2. Compute the mean of the logarithms:

$$M = \frac{\sum X}{N}$$

3. Compute the standard deviation of the logarithms:

$$S = \sqrt{\frac{\sum x^2}{N-1}}$$

$$= \sqrt{\frac{\sum X^2 - (\sum X)^2 / N}{N-1}}$$

4. Compute the coefficient of skewness:

$$g = \frac{N \sum x^3}{(N-1)(N-2)S^3}$$

$$= \frac{N^2 \sum x^3 - 3N \sum x \sum x^2 + 2(\sum x)^3}{N(N-1)(N-2)S^3}$$

5. Compute the logarithms of discharges at selected recurrence intervals or percent chance:

$$\log Q = M + K S$$

Take K from Table 1 or Table 2 for the computed value
of g and the selected recurrence interval or percent chance.
Log Q is the logarithm of a flood discharge having the same
recurrence interval or percent chance.

6. Find the antilog of log Q to get the flood discharge Q.$\underline{1/}$

Tables of K Values

Tables 1 and 2 were made from larger and more complete
tables prepared by H. Leon Harter (Mathematical Statistician,
Wright-Patterson Air Force Base) and the U.S. Soil
Conservation Service. Copies of those tables are available,
free of charge, from the Central Technical Unit, Soil
Conservation Service, 269 Federal Center Building,
Hyattsville, Md. 20782.

Computer Program Sources

Federal agencies such as the Bureau of Reclamation, Corps
of Engineers, Geological Survey, Soil Conservation Service,
Tennessee Valley Authority, and others, have prepared
computer programs for the log-Pearson Type III method.
These programs are in various computer languages and for
various types of computers. Inquiries regarding these pro-
grams should be addressed to those agencies.

References

(1) "Theoretical Frequency Curves," by H. A. Foster: American
Society of Civil Engineers, Transactions, v. 87, p. 142-203: 1924.

(2) "Methods of Flow Frequency Analysis," by the Subcommittee
on Hydrology, Inter-Agency Committee on Water Resources:
Notes on Hydrologic Activities, Bulletin 13, April 1966. For
sale by the Superintendent of Documents, Government Printing
Office, Washington, D.C. 20402. Price 35 cents.

1/ The frequency line can be shown by plotting each Q versus its
respective percent chance on lognormal probability paper and
drawing a continuous line through the plotted points.

Table 1 -- K values for positive skew coefficients

Recurrence Interval in Years

Skew Coefficient (g)	1.0101	1.0526	1.1111	1.2500	2	5	10	25	50	100	200
Percent Chance	99	95	90	80	50	20	10	4	2	1	0.5
3.0	-0.667	-0.665	-0.660	-0.636	-0.396	0.420	1.180	2.278	3.152	4.051	4.970
2.9	-0.690	-0.688	-0.681	-0.651	-0.390	0.440	1.195	2.277	3.134	4.013	4.909
2.8	-0.714	-0.711	-0.702	-0.666	-0.384	0.460	1.210	2.275	3.114	3.973	4.847
2.7	-0.740	-0.736	-0.724	-0.681	-0.376	0.479	1.224	2.272	3.093	3.932	4.783
2.6	-0.769	-0.762	-0.747	-0.696	-0.368	0.499	1.238	2.267	3.071	3.889	4.718
2.5	-0.799	-0.790	-0.771	-0.711	-0.360	0.518	1.250	2.262	3.048	3.845	4.652
2.4	-0.832	-0.819	-0.795	-0.725	-0.351	0.537	1.262	2.256	3.023	3.800	4.584
2.3	-0.867	-0.850	-0.819	-0.739	-0.341	0.555	1.274	2.248	2.997	3.753	4.515
2.2	-0.905	-0.882	-0.844	-0.752	-0.330	0.574	1.284	2.240	2.970	3.705	4.444
2.1	-0.946	-0.914	-0.869	-0.765	-0.319	0.592	1.294	2.230	2.942	3.656	4.372
2.0	-0.990	-0.949	-0.895	-0.777	-0.307	0.609	1.302	2.219	2.912	3.605	4.298
1.9	-1.037	-0.984	-0.920	-0.788	-0.294	0.627	1.310	2.207	2.881	3.553	4.223
1.8	-1.087	-1.020	-0.945	-0.799	-0.282	0.643	1.318	2.193	2.848	3.499	4.147
1.7	-1.140	-1.056	-0.970	-0.808	-0.268	0.660	1.324	2.179	2.815	3.444	4.069
1.6	-1.197	-1.093	-0.994	-0.817	-0.254	0.675	1.329	2.163	2.780	3.388	3.990
1.5	-1.256	-1.131	-1.018	-0.825	-0.240	0.690	1.333	2.146	2.743	3.330	3.910
1.4	-1.318	-1.168	-1.041	-0.832	-0.225	0.705	1.337	2.128	2.706	3.271	3.828
1.3	-1.383	-1.206	-1.064	-0.838	-0.210	0.719	1.339	2.108	2.666	3.211	3.745
1.2	-1.449	-1.243	-1.086	-0.844	-0.195	0.732	1.340	2.087	2.626	3.149	3.661
1.1	-1.518	-1.280	-1.107	-0.848	-0.180	0.745	1.341	2.066	2.585	3.087	3.575
1.0	-1.588	-1.317	-1.128	-0.852	-0.164	0.758	1.340	2.043	2.542	3.022	3.489
.9	-1.660	-1.353	-1.147	-0.854	-0.148	0.769	1.339	2.018	2.498	2.957	3.401
.8	-1.733	-1.388	-1.166	-0.856	-0.132	0.780	1.336	1.993	2.453	2.891	3.312
.7	-1.806	-1.423	-1.183	-0.857	-0.116	0.790	1.333	1.967	2.407	2.824	3.223
.6	-1.880	-1.458	-1.200	-0.857	-0.099	0.800	1.328	1.939	2.359	2.755	3.132
.5	-1.955	-1.491	-1.216	-0.856	-0.083	0.808	1.323	1.910	2.311	2.686	3.041
.4	-2.029	-1.524	-1.231	-0.855	-0.066	0.816	1.317	1.880	2.261	2.615	2.949
.3	-2.104	-1.555	-1.245	-0.853	-0.050	0.824	1.309	1.849	2.211	2.544	2.856
.2	-2.178	-1.586	-1.258	-0.850	-0.033	0.830	1.301	1.818	2.159	2.472	2.763
.1	-2.252	-1.616	-1.270	-0.846	-0.017	0.836	1.292	1.785	2.107	2.400	2.670
0	-2.326	-1.645	-1.282	-0.842	0	0.842	1.282	1.751	2.054	2.326	2.576

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Table 2.--K values for negative skew coefficients

Recurrence Interval in Years

Skew Coefficient (g)	1.0101	1.0526	1.1111	1.2500	2	5	10	25	50	100	200
						Percent Chance					
	99	95	90	80	50	20	10	4	2	1	0.5
0	-2.326	-1.645	-1.282	-0.842	0	0.842	1.282	1.751	2.054	2.326	2.576
- .1	-2.400	-1.673	-1.292	-0.836	0.017	0.846	1.270	1.716	2.000	2.252	2.482
- .2	-2.472	-1.700	-1.301	-0.830	0.033	0.850	1.258	1.680	1.945	2.178	2.388
- .3	-2.544	-1.726	-1.309	-0.824	0.050	0.853	1.245	1.643	1.890	2.104	2.294
- .4	-2.615	-1.750	-1.317	-0.816	0.066	0.855	1.231	1.606	1.834	2.029	2.201
- .5	-2.686	-1.774	-1.323	-0.808	0.083	0.856	1.216	1.567	1.777	1.955	2.108
- .6	-2.755	-1.797	-1.328	-0.800	0.099	0.857	1.200	1.528	1.720	1.880	2.016
- .7	-2.824	-1.819	-1.333	-0.790	0.116	0.857	1.183	1.488	1.663	1.806	1.926
- .8	-2.891	-1.839	-1.336	-0.780	0.132	0.856	1.166	1.448	1.606	1.733	1.837
- .9	-2.957	-1.858	-1.339	-0.769	0.148	0.854	1.147	1.407	1.549	1.660	1.749
-1.0	-3.022	-1.877	-1.340	-0.758	0.164	0.852	1.128	1.366	1.492	1.588	1.664
-1.1	-3.087	-1.894	-1.341	-0.745	0.180	0.848	1.107	1.324	1.435	1.518	1.581
-1.2	-3.149	-1.910	-1.340	-0.732	0.195	0.844	1.086	1.282	1.379	1.449	1.501
-1.3	-3.211	-1.925	-1.339	-0.719	0.210	0.838	1.064	1.240	1.324	1.383	1.424
-1.4	-3.271	-1.938	-1.337	-0.705	0.225	0.832	1.041	1.198	1.270	1.318	1.351
-1.5	-3.330	-1.951	-1.333	-0.690	0.240	0.825	1.018	1.157	1.217	1.256	1.282
-1.6	-3.388	-1.962	-1.329	-0.675	0.254	0.817	0.994	1.116	1.166	1.197	1.216
-1.7	-3.444	-1.972	-1.324	-0.660	0.268	0.808	0.970	1.075	1.116	1.140	1.155
-1.8	-3.499	-1.981	-1.318	-0.643	0.282	0.799	0.945	1.035	1.069	1.087	1.097
-1.9	-3.553	-1.989	-1.310	-0.627	0.294	0.788	0.920	0.996	1.023	1.037	1.044
-2.0	-3.605	-1.996	-1.302	-0.609	0.307	0.777	0.895	0.959	0.980	0.990	0.995
-2.1	-3.656	-2.001	-1.294	-0.592	0.319	0.765	0.869	0.923	0.939	0.946	0.949
-2.2	-3.705	-2.006	-1.284	-0.574	0.330	0.752	0.844	0.888	0.900	0.905	0.907
-2.3	-3.753	-2.009	-1.274	-0.555	0.341	0.739	0.819	0.855	0.864	0.867	0.869
-2.4	-3.800	-2.011	-1.262	-0.537	0.351	0.725	0.795	0.823	0.830	0.832	0.833
-2.5	-3.845	-2.012	-1.250	-0.518	0.360	0.711	0.771	0.793	0.798	0.799	0.800
-2.6	-3.889	-2.013	-1.238	-0.499	0.368	0.696	0.747	0.764	0.768	0.769	0.769
-2.7	-3.932	-2.012	-1.224	-0.479	0.376	0.681	0.724	0.738	0.740	0.740	0.741
-2.8	-3.973	-2.010	-1.210	-0.460	0.384	0.666	0.702	0.712	0.714	0.714	0.714
-2.9	-4.013	-2.007	-1.195	-0.440	0.390	0.651	0.681	0.683	0.689	0.690	0.690
-3.0	-4.051	-2.003	-1.180	-0.420	0.396	0.636	0.660	0.666	0.666	0.667	0.667

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ADDITIONAL CONSIDERATIONS IN FLOW-FREQUENCY ANALYSIS

There are important considerations in flow-frequency analysis beyond the type of distribution that may be used to fit the data. Some of these considerations are discussed below.

A short record of flood flows may contain large sampling errors because of chance geographical or temporal variations in rainfall during the period of record. Therefore a short record may be a poor indicator of the basic long-time distribution of floods at the site.

Flood flow frequencies often need to be determined for sites where there are no streamflow data. It is possible to examine the individual flood records within the region as a unit and to develop generalized relationships that apply anywhere in the region including ungaged sites. This approach often overcomes many of the uncertainties due to sampling error at individual sites. Several methods of regionalization have been developed to date; a study of such methods, and recommendations for their use, should be part of the continuing program of the Committee.

Another problem is the treatment of a record that contains one or more events of rare frequency--the so-called outlier problem. By using historical information at the site or at nearby sites it is often possible to assign a realistic recurrence interval to each outlier. This information is incorporated into the set of data to define the overall distribution. An alternative is to compute the frequency distribution omitting the rare events, plot the frequency line, and then to adjust the line to conform to the historical information. Where no historical information is available, an obviously very rare event may be excluded from the computations. The specific treatment that is used to handle outliers should become a matter of record.

Where streamflow data are lacking at the site or where a regional analysis is not justified, the use of hydrologic methods, such as rainfall-runoff relationships and unit hydrograph studies, may be the only feasible approach.

In the flood series for some streams in arid regions, it is not unusual for one or more of the flood values to be zero. This poses a difficulty when using a logarithmic transformation because the logarithm of zero is minus infinity. One way around the difficulty is to add a small constant to all the items of data. A second is to determine the frequency relation from only non-zero items and afterwards to adjust the relation to the full period of record. This

method does not retain the zeros. A third method is to consider a two-step or conditional probability. If Z is the percentage of zero items, the frequency relation is based on the nonzero items, and defines the probability in 100 - Z percent of all years; Z percent of future years are considered as having expected values of zero. Or, for any one year, the expected probability of a zero flood is Z/100, and the expected probability of any other size of flood, given that the flood is not zero, is that furnished by the developed frequency relation. This may be thought of as a separation into two frequency relations, both solvable, which are then recombined.

The skew coefficient has greater variability between samples than the mean and standard deviation, and it is therefore a less reliable estimator of a population statistic for a particular site. Use of a regionalized skew coefficient to replace that coefficient computed from the station data has been recommended at times. The standard error of estimate of a sample skew coefficient Sg, taken from a normal population having zero skew, is given by

$$Sg = \sqrt{\frac{6N(N-1)}{(N-2)(N+1)(N+3)}}$$

where N is the number of years of record. For a selected confidence level, this can be used to test whether or not a skew coefficient computed at a site is significantly different from zero. If a regional average skew coefficient is considered appropriate, the average of the Sg's, divided by $\sqrt{n}$, where n is the equivalent number of independent stations, should be used to test whether the regional value is significantly different from zero.

In the use of the log-normal and log-Pearson Type III distributions, an adjustment for length of record, referred to as "expected probability," has been applied to the probabilities. On the basis of comparative studies, it appears that the average fit of the log-Pearson is slightly improved by the use of this adjustment. However, the adjustment has been developed theoretically only for a normal (and log-normal) distribution, and its use for a log-Pearson Type III distribution is arbitrary. Simulation (Monte Carlo) techniques could be used to develop similar correction factors for the log-Pearson Type III distribution.

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